Modelling primary health care workforce needs towards health professions education and employment investment planning in Ghana

JA Asamani

orcid.org/0000-0003-0620-6010

A thesis accepted in fulfilment of the requirements for the degree of Doctor of Philosophy in Health Sciences with Health Professions Education at the North-West University

Promoter:	Dr CD Christmals
Co-promoter:	Prof GM Reitsma
Graduation:	November 2021
Student number:	37205722

PREFACE

THESIS FORMAT

The North-West University rules allow PhD theses to be submitted in article format. In line with the rules, this thesis, "Modelling primary healthcare workforce needs towards health professions education and employment investment planning in Ghana", is presented in the article format and comprises four articles (each as a chapter), an introductory chapter, and a concluding chapter. Three of the four articles have been accepted and published in scientific journals indexed in both Web of Science and Scopus, and the fourth article is under peer-review in PLOS One. The thesis, therefore, serves as the fulfilment of the requirements for the degree of Doctor of Philosophy in Health Sciences with Health Professions Education at the Potchefstroom Campus of the North-West University.

DECLARATION AND STUDENT CONTRIBUTION TO ARTICLES

I, James Avoka Asamani, student number 37205722, hereby declare that this thesis is my own work and that I contributed adequately towards the published articles by conducting the research and writing the manuscripts under the guidance and supervision of my promoters.

The study was undertaken under the guidance and supervision of Dr Christmal Dela Christmals (promoter) and Professor Gerda Marie Reitsma (co-promoter), both of the Centre for Health Professions Education (CHPE), Faculty of Health Sciences of the North-West University, Potchefstroom campus. This work has not been partly or fully submitted for any other degree, neither has it been submitted concurrently in candidature for any other degree.

James Avoka Asamani Signature: ……………….. Date: 2 September

(Candidate)

Dr Christmal Dela Christmals Signature: ……………….. Date: 2 September 2021

(Promoter)

Prof Gerda Reitsma

Digitally signed by Prof Gerda Reitsma
Date: 2021.09.02 12:52:52 +02'00'

Prof Gerda Marie Reitsma Signature: ……………….. Date: ……………

(Co-promoter)

AGREEMENT OF CO-AUTHORS

The co-authors of the four articles presented in this thesis, Dr Christmal Dela Christmals (promoter) and Professor Gerda Marie Reitsma (co-promoter), hereby give the candidate, James Avoka Asamani (student number 37205722), permission to include the four articles as part of his doctoral thesis. The student is the main author of all four articles and was responsible for the conceptualisation, data collection, and writing of the articles. All the research was conducted by the student. The contribution (advisory and supportive) of the co-authors was kept within reasonable limits, thereby enabling the candidate to submit this thesis for examination purposes.

Dr Christmal Dela Christmals Signature: ……………….. Date: 2 September 2021

(Promoter)

Prof Gerda Reitsma

Digitally signed by Prof Gerda Reitsma
Date: 2021.09.02 14:34:26 +02'00'

Prof Gerda Marie Reitsma Signature: ……………….. Date: ……………

(Co-promoter)

ACKNOWLEDGEMENTS

I wish to thank the almighty God for the grace and fortitude to pursue this PhD. Furthermore, I am highly indebted to all the staff and faculty of the Centre for Health Professions Education (CHPE) and the entire North-West University (NWU) for their tremendous support and encouragement throughout my study. I am particularly indebted to my promoters, who are the architects of my success, Dr Christmal Dela Christmals and Professor Gerda Marie Reitsma, for their meticulous guidance, supervision, and constructive feedback that were the source of my motivation throughout the study. Both Christmal and Gerda, on numerous occasions, had to sacrifice their comfort (sometimes on weekends) to work through my drafts and hold meetings with me to provide needed feedback and guidance. You are simply phenomenal, and I wish every PhD student everywhere had a piece of your kind! I cannot thank you enough for your overwhelming commitment.

Additionally, several friends, colleagues and mentors contributed in diverse ways that culminated in the successful completion of this study, and they deserve special thanks. In particular, Alhaji Hamza Ismaila (Executive Assistant to the Director-General, Ghana Health Service), Jerry Kwame Asamoah (Human Resource Manager, Ghana Health Service), Richmond Sowah (Statistician, Ghana Health Service), Fidelis Atibila (Lecturer, Valley View University), Isaac Hoesse (Ghana Health Service) and Akugri Abande Francis (Lecturer, University for Development Studies) are acknowledged for their excellent facilitation and support during the primary and secondary data collection. Dr Josephine Kyei (University of Ghana) supported and backstopped the data collection process as required by the GHS ethics committee, and I am much indebted to her.

Furthermore, I wish to extend my heartfelt appreciation to Dr Patrick Kuma Aboagye (Director-General of Ghana Health Service), who granted permission for the study within the Ghana Health Service. In the same vein, Dr Margaret Chebere (Director, Human Resources, Ghana Health Service), and the Regional Directors of Health Services for Upper East, Bono East and Greater Accra Regions are deeply appreciated for being gatekeepers for the study within the Ghana Health Service and for facilitating access to secondary data.

In addition, the initial proposal benefited from the constructive feedback of the following academics and subject matter experts, to whom I convey my gratitude: Dr Charles Adjei Ampong (University of Ghana), Dr Hilary Kipruto (World Health Organization), Selassi Amah D'Almeida (World Health Organization), Dr Yolande Heymans (CHPE, NWU), Prof. Juliet Nabyonga-Orem

(World Health Organization), and Samuel Alugsi (Bournemouth University, U.K.). Also, Frank Parimaa Yenuten (University of Ghana), Dr Mollent Okech (International Consultant on Health Workforce), and Teena Tunjamen (World Health Organization) reviewed early drafts of some of the manuscripts as the subject matter experts, and their contribution is highly appreciated. The administrative support of Mrs Paula Jardim (CHPE, NWU) has been awesome, and I remain thankful.

From a special place in my heart, I wish to thank Dr Margaret Chebere, Mr Francis Victor Ekey, Mme Jennifer Nyoni, Mr Selassi Amah D'Almeida and Prof Juliet Nabyonga-Orem for their mentorship, encouragement, and support in my career and also in my PhD pursuit. Without you, I would never have been here, and I would not have been the same!

Last but not least, I wish to show appreciation to my family for their patience and support, especially my loving wife, Mrs Bernice Immaculate Avoka Asamani, my children Robin, Delwin, Windin and Winpang, my mother, Queen Mother Ayaab Akuluak, and my siblings for the various sacrifices you had to make during my studies. I dedicate this work to you and the loving memory of my late father, Mr Akuluak Asamani.

God bless you all!

JA Asamani

SUMMARY

The health workforce is a critical part of developing responsive health systems that address routine population health needs and responding to health emergencies. However, defective planning has resulted in underinvestment and a looming shortage of about 18 million health workers globally. The empirical literature demonstrates substantial lacunae in existing health workforce planning models. Most models focus on one side of either supply or number needed, and even where there is an attempt to integrate them, the need component is often not linked to the population's need for health services. The need-based framework combines the population's health status, planned or otherwise necessary services, and professional standards of service delivery to estimate the health workers needed for a given population. Despite its intuitive appeal, several methodological gaps, and lack of open-access tools, have limited its use for planning in most countries, including Ghana. To address this gap and to contribute to knowledge in the field of health professions education, a need-based model for planning health professions education and employment in Ghana's primary healthcare context was developed and empirically applied. Leaning on the pragmatic research paradigm, this study adopted a sequential multi-method approach. In the first phase, this study conducted a systematic scoping review of empirical applications of the need-based health workforce planning approach to identify the key methodological gaps, from which six critical methodological considerations were synthesised. The second phase involved model development. Building on the synthesised evidence, a conceptual and empirical comprehensive need-based health workforce model was developed with an accompanying open-access Microsoft® Excel-based model. In the third phase, a cross-sectional survey was conducted amongst a nationally representative sample of health professionals to establish professional standards of service delivery (which is a proxy measure of productivity) that would be incorporated into the need-based analysis. In the final phase, data was triangulated from multiple sources to systematically apply the model to forecast the needs and supply of 11 health professionals in Ghana's primary health care context. The model application showed a significant gap between the needs of the population and that of the supply of health care professionals in Ghana. The need-based shortage was 73,203 health professionals across 11 professions, which could reach 161,502 health professionals by 2035. Regarding education and employment of health professionals for primary health care in Ghana, averting an existing 33% shortage would require, among others, increasing the intake of pharmacy technicians by 7.5-fold, general practitioners by 100%, and general nurses by 55%, whilst scaling down that of midwives by 15%. At least US$480.39 million investments from both the public and private sectors would be required in health professions education while planning for US$1.762 billion per annum (up to US$2.374 billion in 2035) in terms of the wage bill to maintain jobs and employ those to be trained. Linking the population's health needs to health professions education curricula and testing the economic feasibility of the need-based health workforce estimates are areas that may warrant further research.

Keywords: Health professions education planning, need-based modelling, primary health care, health workforce planning, human resources for health, health workforce investment, supply, need, workforce gap analysis, population health need, modelling.

OPERATIONAL DEFINITIONS OF TERMS USED

Several terms have been used throughout this thesis, for which this section provides definitions.

TERM	DEFINITION
Employment investment planning	The process of deciding the number of workers that need to be employed to meet the service delivery needs of an organisation and the resource implications of the employment (Bossert et al., 2007). In the context of this thesis, it refers to the funding required to train and employ the additional number of health professionals that are needed to deliver primary health care.
Health professional	A health worker who has a minimum of post-secondary education and is trained to provide direct health care treatment and advice to patients, families or communities (WHO, 2017a).
Health professions education	An approved and structured training given to people to qualify as health professionals (WHO, 2017a).
Health worker	Health workers are people whose job is primarily intended to enhance health. Such workers range from less-skilled professionals such as community health workers to highly skilled and specialised medical professionals. It also includes non-clinicians working in the health sector (WHO, 2006).
Health workforce	The aggregate health workers, in all their diversity of professions, skills and level of education or training, make up the health workforce (WHO, 2017a).
Need-based requirement	The number and mix of health professionals that is optimal to meet the health needs of a population irrespective of existing levels of access to health services or ability to pay (Lopes et al., 2015).
Primary health care	A system of the universal provision of essential health care to individuals and families in the community, including but not limited to vaccination; screenings; prevention, control and management of non-communicable and communicable diseases; care and services that promote, maintain and improve maternal, new-born, child and adolescent health; and mental, sexual and reproductive health (WHO & UNICEF, 2018).
Standard time/activity standard	The average amount of time it will take a well-trained health professional to accomplish a given service delivery task to an acceptable professional level (WHO, 2016).
Supply	The total number of health workers (disaggregated by profession) who are qualified and willing to find jobs in the health sector. It includes both the employed and the unemployed if they are actively seeking employment (Scheffler et al., 2016).
Universal health coverage	All persons having access to and making use of people-centred, high quality and effective promotive, preventive, curative, rehabilitative and palliative health services that they need, without suffering the risk of catastrophic financial hardship (or being pushed to poverty) (WHO, 2010).
General practitioner (ISCO-08 code 2211)	This category of health professionals is defined in ISCO-08 as generalist medical practitioners who apply the principles and procedures of modern medicine in the prevention, diagnosis, care, and treatment of diseases, illnesses, and injuries in humans and the maintenance of health in general. They can supervise the implementation of care and treatment plans and conduct medical education and research activities (ILO, 2008).
Nurse (ISCO-08 code 2221 and 3221)	This category of health professionals is defined in ISCO-08 as nursing professionals (ISCO-code 2221). They manage, plan, anticipate, and evaluate nursing services for people who require nursing care because of the effects of illness, injury, or other physical or mental disability or potential health risks. They work independently or in teams with physicians and other health care workers. They can oversee the implementation of nursing plans and conduct nursing education activities. They often work with and are supported by nursing associate professionals (ISCO-08 code 3221) in performing their tasks (ILO, 2008).
Midwife (ISCO-08 code 2222)	Midwifery professionals plan, manage, provide, and evaluate midwifery care services before, during, and after pregnancy and childbirth. They provide delivery care to help reduce health risks to women and new-born babies according to the practice and standards of modern midwifery and work autonomously or in teams with other health care providers.

TERM	DEFINITION
	They may conduct research on midwifery practices and procedures and implement midwifery education activities in clinical and community settings (ILO, 2008).
Physician assistant (ISCO-08 code 2240)	This category of health professionals is defined in ISCO-08 as paramedical practitioners and provide consultation, diagnosis, curative and preventive care services in a variety of settings. They work independently or with little supervision from physicians and apply clinical procedures for the treatment and prevention of diseases, injuries, and other physical or mental disabilities common to specific communities (ILO, 2008).
Production	Production implies the preparation of health care professionals through education and training to be ready for employment to contribute to health service delivery (Appiah-Denkyira & Herbst, 2013).
Biomedical scientist (ISCO-08 code 3212)	This category of health professional is defined in ISCO-08 2008 as medical and pathological laboratory technicians. They conduct clinical trials on samples of body fluids and tissues to obtain information about a patient's health or cause of death. Occupations in this category normally require training in biomedical sciences, medical technology, or a related field (ILO, 2008).
Pharmacist & pharmacy technician (ISCO-08 code 2262 and 3213)	Pharmacists store, preserve, compound, and dispense medicinal products. They counsel on the proper use and adverse effects of drugs and medicines following prescriptions issued by medical doctors and other health professionals. They contribute to researching, testing, preparing, prescribing, and monitoring medicinal therapies for optimising human health. Pharmacists are usually supported by pharmaceutical technicians (ISCO-08 code 3213) in the performance of their functions (ILO, 2008).
Nutritionist/dietician (ISCO-08 code 2265)	Defined in ISCO-08 as nutritionists and dieticians, these health professionals assess, plan, and implement programmes to enhance the impact of food and nutrition on human health. They may conduct research, assessments and education to improve nutritional levels among individuals and communities (ILO, 2008).

LIST OF ABBREVIATIONS

The following abbreviations and acronyms have been used in various parts of the thesis.

AWT	Available working time
CHIM	Centre for Health Information Management
CHN	Community health nurse
CHPS	Community-based health planning and services
GHS	Ghana Health Service
GSS	Ghana Statistical Service
HC	Health centre
HRIMS	Human resource information management system
MHA	Mental health authority
MOH	Ministry of Health
NHS	Needed health services
NWU	North-West University
ODK	Open data kit
PHC	Primary health care
PolyC	Polyclinic
PRISMA -ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analysis – extension for Scoping Reviews
RDHS	Regional Director of Health Services
SAR	Staff availability ratio
SDGs	Sustainable development goals
SME	Subject matter expert
TH	Teaching hospital
UHC	Universal health coverage
WHO	World Health Organization
WISN	Workload indicators of staffing need

TABLE OF CONTENTS

LIST OF TABLES

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Chapter 5

LIST OF FIGURES

CHAPTER 1:
ORIENTATION AND INTRODUCTION

1.1 INTRODUCTION

In 2015, the United Nations Member States adopted a set of 17 Sustainable Development Goals (SDGs) geared towards the realisation of a development agenda that leaves no one behind. Goal three of the SDGs are aimed at ensuring a healthy life and well-being for all ages and driving global health policy towards a progressive realisation of Universal Health Coverage (UHC) (WHO, 2016). The World Health Organization (WHO) defines UHC as all persons having access to and making the use of people-centred, high-quality and effective health services (promotive, preventive, curative, rehabilitative, and palliative) that they need, without suffering the risk of catastrophic financial hardship in using these services (WHO, 2010). Based on this definition, UHC is underpinned by three core principles, that is, equity in access, quality of services, and financial risk protection. Equity in access to health services can be attained by ensuring that everyone who needs health services should receive them regardless of their background, characteristics, or ability to pay (Morris et al., 2012). The health services must also be sufficient to improve the health of those receiving the services, and the cost of using health services should not be financially debilitating (WHO, 2015). Primary health care (PHC) is touted as the most efficient and cost-effective approach to catalysing the attainment of UHC by 2030 (WHO, 2019). Against this backdrop, the 2018 Astana Declaration on Primary Health Care calls on countries to scale up efforts towards UHC through a renewed focus on PHC (WHO & UNICEF, 2018).

PHC, which is defined as making "essential health care universally accessible to individuals and families in the community" (WHO, 1978, p. 2), forms an integral part both of a country's health system and the overall social and economic development. To this end, the scope of PHC is generally intended to address the promotive, preventive, curative, and rehabilitative health needs of communities. These needs may vary by country and community but include "…vaccination; screenings; prevention, control and management of noncommunicable and communicable diseases; care and services that promote, maintain and improve maternal, new-born, child and adolescent health; mental health and sexual and reproductive health" (WHO & UNICEF, 2018, para. V). Policymakers envision that UHC will be achieved when these services, which are of high quality, safe, comprehensive, integrated and affordable for everyone, are delivered to communities (WHO & UNICEF, 2018). Thus, the tenets of PHC are embodied in the cohesive definition of ensuring that people's health problems are addressed, systematically addressing the broader determinants of health, and empowering individuals, families, and communities to optimise their health (WHO, 2019).

In any health system, attaining UHC requires an adequate number of well-trained, motivated and committed multidisciplinary health professionals with an appropriate skills mix who are supported to perform (WHO and UNICEF, 2018; WHO, 2016). Before the emergence of the ongoing Coronavirus Disease 2019 (COVID-19) pandemic which strained health systems and health professionals, it was estimated that the price tag for SDG 3 by 2030 was US$3.9 trillion, of which more than 50% had to be invested in the education and employment of the health workforce (Stenberg et al., 2017).

Despite the acknowledgement that the health workforce is the cornerstone of responsive health systems, it is saddled with many challenges, especially in low- and middle-income countries. For instance, before COVID-19, the WHO estimated a potential shortage of more than 18 million health workers by 2030, which was likely to occur most in low- and middle-income countries (WHO, 2016). Amongst the 47 countries that make up the WHO Africa region, an anticipated shortfall of 6.1 million health workers was expected by 2030. Several reasons have been assigned to this looming shortage, including inadequate capacity on the part of health professions education institutions to produce sufficient and fit-for-purpose health workers, and high levels of voluntary and involuntary attrition of highly trained health professionals (Aiken et al., 2004; Connell et al., 2007; Dovlo, 2005; Scheffler et al., 2018a; WHO, 2016c). The aforesaid shortages are also within the context of slow economic growth and cost containment measures in which African countries are able to absorb just 2.4 million out of some 3.4 million health professionals who are likely to be available for employment by 2030 (Liu et al., 2016). Thus, nearly a third (~29%) of trained health professionals who will be 'needed' could be paradoxically unemployed across the Africa region (Asamani et al., 2019). Weak planning capacity in countries (Afriyie et al., 2019) have accentuated the aforesaid challenges whereby there is a substantial mismatch between the health needs of the population and the number and categories of health professionals being trained (Asamani et al., 2020; Birch et al., 2009). Although there are several tools for health workforce planning, most have been criticised for being overly reliant on demand factors rather than focusing on the population health needs and health system objectives (Murphy et al., 2016; Tomblin Murphy et al., 2009). Therefore, there is an urgent need to explore the use of health workforce planning tools and approaches that directly align production from health professions education institutions with the population's health needs.

1.2 BACKGROUND

1.2.1 The general approach to analysing and planning for health professionals

It has often been argued that health workforce planning is a part of and must be done within a broader context of health service and health system planning (Birch et al., 2007). From this perspective, understanding the broader need and policy direction of health systems, which include the set of institutional arrangements in and beyond the health sector, are critical for planning the health workforce. Thus, this perspective acknowledges that planning or implementing the health workforce may, in part, lie outside the remit of the health sector and thus require multi-sectoral and multi-stakeholder collaboration and coordination (Dieleman et al., 2011; Dussault & Dubois, 2003; WHO, 2017b).

Health system experts have argued that the health workforce planning component of health system planning involves a set of interrelated analyses that must be undertaken concurrently or sequentially and then coherently triangulated (Cometto et al., 2020; Dussault et al., 2010). These analyses include need-side analysis – determining the required health professionals; supply-side analysis – ascertaining the supply of health professionals; and gap analysis – comparing the need analysis with the supply analysis to determine gaps and resource implications for addressing the gaps (Roberfroid et al., 2009).

The need for health professionals refers to the optimal number and skills mix of health professionals required in a country (or geographical region) to address the health needs of a defined population – taking into account the demography, disease burden, models of health care, and productivity standards or norms (Kavya et al., 2014; MacKenzie et al., 2019). The supply-side deals with the pool of qualified health professionals who are willing to find jobs in the health sector. This depends on the inflow from domestic training pathways through immigration on the one hand, and on the other hand, outflows through voluntary exits (losses to other sectors, emigration) and involuntary exits such as retirement, ill health, and death (Lopes et al., 2015).

The gap analysis component involves a comparison of the need and the supply in both absolute and relative terms (Asamani et al., 2021). It has been argued that at the health system level, the aggregate absolute gaps are useful for determining the number of health professionals to train (and employ) while the relative gaps are useful for making prioritisation decisions based on the relative degree of shortage or surplus across categories of health workers (Asamani et al., 2018). Figure 1 illustrates the relationship between this trilogy of health workforce planning. In the subsequent sections, the components of Figure 1 on need and supply analyses are discussed in more detail.

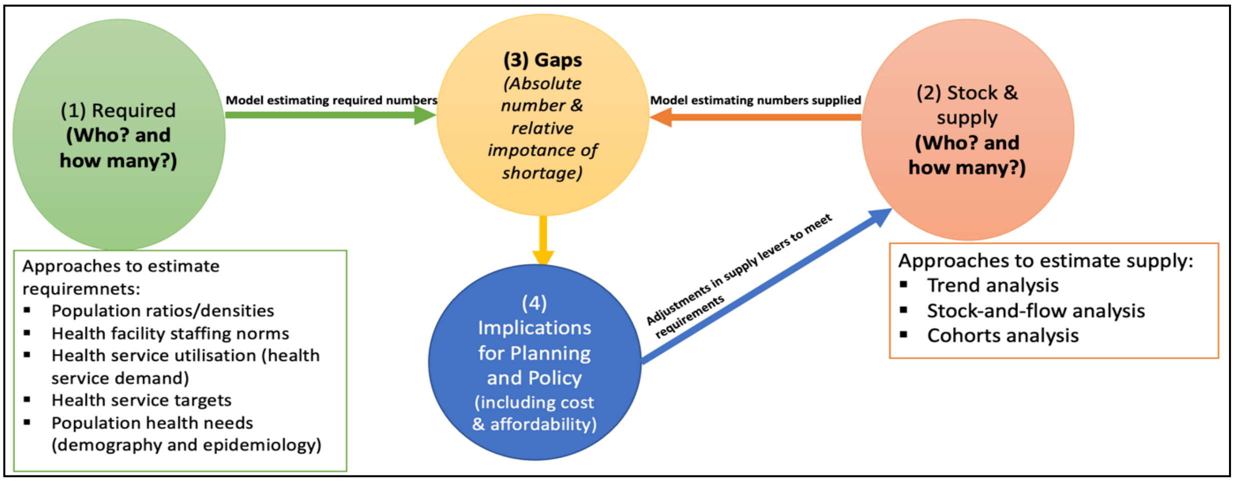

Figure 1: General approach to analysing and planning for health professionals

Source: Author's construction based on Roberfroid *et al.* (2009)

1.2.2 Estimating the required numbers of health professionals (need analysis)

One fundamental question policymakers and health systems scientists often face is: How many health workers are optimally needed in a country? Addressing this question has proven to be challenging, and no one answer fits all contexts across countries or even in the same country (Dussault et al., 2010). Therefore, over the years, researchers, planners, and policy practitioners have adopted different approaches to determining the number of health workers needed in a country. These have often been based on observed levels of health service utilisation; health services targets; number and size of health facilities (health facilities staffing norms); and health worker-to-population ratios – however, population health needs (or epidemiological approach) were seldom used. Table 1 provides a summary of the assumptions, strengths, and limitations of some conceptual approaches identified in the theoretical literature for estimating the required health professionals (Hall & Mejia, 1978; Kavya et al., 2014; Lopes et al., 2015; O'Brien-Pallas et al., 2001). The empirical application of these conceptual models is saddled with less standardisation, resulting in these models differing significantly in their levels of transparency, the required data and expertise, as well as outputs or conclusions (Kavya et al., 2014). As is evident from the summary provided in Table 1, the application of these approaches have limitations (Lopes et al., 2015; Van Greuningen et al., 2013) and needs to be tailored to country-specific needs and health system configurations (Murphy et al., 2016).

Table 1: Summary of approaches to modelling requirements for health professionals

Approach	Definition/Description	Main Strengths	Key Limitations
Health workforce per population	The approach is straightforward, as it estimates future health workforce needs by using an agreed staff-to-population ratio. It is founded on the assumptions that the population to be served is nearly homogeneous in terms of their health problems and needs, which will remain constant into the future (Lopes et al., 2015).	▪ The approach has minimal data requirements; hence, it is the quickest for computation and most easily understood, especially for those with limited statistical modelling skills. ▪ It is often used for comparative analyses across countries and over time (WHO, 2006; WHO, 2016).	▪ While it is the least data-demanding approach, it is less rigorous and tends to ignore other key variables of the population and workforce characteristics apart from only adjusting for population growth. ▪ It is often difficult to arrive at a consensus about the optimal ratio of health workers to the population. ▪ Obtaining reliable population data is a challenge in some countries, while preference for specific providers by the populations leads to distortions in service provision.
Facility-based or staffing norms	This approach recognises that health workforce requirements must be matched with the health infrastructure and technological capacity of the country; therefore, the focus must be on improving individual health facility capacity, mix by type and ownership (public, private), and their geographic distribution, taking into account future population expansion (Kavya et al., 2014). An agreed staffing norm is then applied to the number and mix of current and anticipated health facilities.	▪ Provides more detailed information on health facility types, distribution and mix. ▪ Different policy options can easily be explored in terms of the health facilities capacity and staffing norms than the health workforce to population ratio while remaining focused on the point of health services delivery (Kolehmainen-Aitken, 1993).	▪ The method ignores population demography and focuses on health facilities that may not geographically be optimally distributed and hence will inherently breed maldistribution of health workers. ▪ It does not accommodate information about the quality of health services to be delivered by health workers.
Health services utilisation (health services demand)	The approach is premised on observing current health service utilisation and making assumptions to apply a similar pattern to future populations (Kavya et al., 2014).	It is thought to yield estimates that tend to be economically realistic because it assumes no significant changes in health service utilisation rates in the future (O'Brien-Pallas et al., 2001).	▪ This approach is also relatively intensive in the data requirements on future population and current health service utilisation rates. ▪ Without adjusting for existing levels of underutilisation of health services, the method may produce a replica of current health needs for the future with very little or no adjustments, a challenge termed as producing "status quo" projections (Kavya et al., 2014).

Approach	Definition/Description	Main Strengths	Key Limitations
			▪ Future population characteristics are assumed to have similar health service utilisation rates as the base year without adjusting for current underutilisation.
Health service targets	This approach requires that the planner specifies targets for the productive utilisation of various types of health services and the institutions providing them based on a set of assumptions. The planner makes assumptions on how service utilisation will evolve in the future. The targets can then be translated into staffing requirements by using health workforce productivity norms and standards (Lopes et al., 2015; Roberfroid et al., 2009).	▪ Projections take into consideration realistic expectations of what is achievable and may complement other projection methods. ▪ The approach helps to identify critical health workforce skills needed and hence could guide future training initiatives. ▪ The approach tends to have a lower data demand and can be undertaken by persons with moderate planning capabilities. ▪ It is useful for programmatic planning where service coverage targets have been set.	▪ The approach may encourage extensively detailed planning processes, especially for components of health service demands which are mostly controlled by other variables that extend beyond health. ▪ It could also lead to potentially unrealistic or strong assumptions and targets made in the planning process. ▪ The approach has been viewed as mostly applicable to countries in which a strong public sector with tight control over manpower and health service delivery policy is held by the government (Kavya et al., 2014).
Population health needs	This approach, which is also known as the epidemiological approach, uses disease burden and population demographic profiles to estimate current and future health service needs (both met and unmet), which are then translated into staffing requirements by applying the standard time required for delivering the health services (Lopes et al., 2015).	▪ The approach is consistent with the tenets of UHC. It carries an instinctive appeal for including the plausible health needs of the entire population irrespective of their current level of access or ability to pay (Roberfroid et al., 2009). ▪ The approach requires an in-depth study of the productivity standards or the time required for service delivery by each health professional. ▪ Allows health planners and policy actors to gain insights into unmet population health needs and on improving health workforce efficiency in delivering health care services. ▪ It is very useful for the programmatic planning of health services.	▪ The concept of need is often defined differently by different people or by the same people from different perspectives (Culyer, 2006). Hence, defining what constitutes the "need for health services" which must be covered in the analysis often remains a challenge. ▪ Health workforce estimations based on the health needs approach is often criticised for being unrealistic (Basu & Pak, 2014) and ignores disparities in the current utilisation of health services. ▪ The method requires extensive data on disease burden, population structure, and productivity standards (Birch et al., 2007).

1.2.3 Diverging approaches to modelling health workforce needs: what is fit-for-purpose?

The health workforce literature is replete with models addressing health workforce requirements globally or for specific countries and/or sub-national levels. However, recent discourse in the field has centred on methodological (and/or ideological) debates as to whether the supply of health workforce should be aligned with need-based or utilisation-based (economic demand-based) planning (Basu & Pak, 2014; Birch et al., 2017; Scheffler et al., 2016; Scheffler & Arnold, 2019). It is argued that health workforce planning based on demand tends to reflect only the prevailing levels of service utilisation and inequity, thereby ignoring the population's health needs that are currently not being covered by current service provision, which is counterintuitive to the tenets of UHC (Birch et al., 2017). Therefore, advocates of need-based planning assert that estimating workforce requirements ought to account for even the unmet or anticipated needs of the population by paying attention to demography, health status, and disease epidemiology (Birch et al., 2017; Kapiriri et al., 2003; Kavya et al., 2014).

Basu and Park (2014) have, however, maintained that need-based planning tends to yield unrealistic and unaffordable estimates of health workforce requirements which, if used to inform training, would lead to an over-supply of health workers because it is independent of the country's economic capacity to employ, thereby resulting in unemployment and/or supplier-induced demand (Basu & Pak, 2014). Proponents of this notion believe that health workforce planning ought to be intricately linked to the health system's ability and willingness to absorb or employ to keep supply and demand at equilibrium.

Notwithstanding these debates, to progressively attain UHC, the 69th World Health Assembly (WHA) in 2016 adopted resolution WHA69.19, approving the global strategy on health workforce (WHO, 2016a). The strategy profoundly urged countries to make a paradigm shift in health workforce planning towards the use of population health needs as the basis for health workforce planning rather than the use of currently observed levels of health service utilisation, service targets, health facilities, or simple population ratios. In furtherance of this, the WHA called for health workforce investments to be based on a matching of "…the supply of health workers to population needs, now and in the future" (WHO, 2016 p.10). This paradigm shift has been deemed necessary to uphold the tenets of UHC in ensuring that all persons have access to the health worker they will require based on their health needs and not based on other characteristics. Thus, it has become critical for countries to devise effective policies that respond to population needs and effectively plan the future training of health professionals by quantifying the health workforce that is needed, based on the population health needs and their supply capacity from the evidence (WHO, 2016).

Consequently, recent developments in the health workforce planning have adopted a comprehensive approach to examining the dynamic interaction between the supply of health professionals on the one hand and their needs on the other, within the context of the health system capacity for training and employment (Scheffler et al., 2016; Sousa et al., 2013).

1.2.4 Challenges in population health need-based approach

Despite the intuitive support for population health needs-based workforce planning, there is a paucity of literature and a lack of consensus on the best way for its empirical application. For instance, reviews and syntheses mainly from high-income countries show that there has been no methodological consensus on an ideal population health needs-based model for planning the health workforce (Lopes et al., 2015; Murphy et al., 2016; Ono et al., 2013). Researchers are proposing many more new and divergent approaches, which are usually not readily adaptable to settings with weak planning and analytic capacity (Dreesch, 2005; Rees et al., 2018a, 2018b).

Only a few empirical studies, mostly from high-income countries, have explicitly explored the use of the burden of disease as the basis for modelling health workforce requirements (Ahern et al., 2019; Jansen et al., 2014; Murphy et al., 2017; Scheffler et al., 2018a). However, these did not take into account how much time is required of a trained health professional to deliver the services that address the various health needs of the population (Scheffler et al., 2018a). In contrast, one conceptual work (Birch et al., 2009) proposed the inclusion of the professional productivity standard or standard time it will take a health professional to deliver particular health services. Ahern et al. (2019) explored this further by imputing an expert-assumed standard service time. However, given that health professionals are at different levels in their career development and that contextual factors (such as resource constraints and cultural elements of service delivery) could influence the standard service time (Shipp, 1998), this inclusion proposed by Birch et al. and Ahern et al. remains a compelling area for exploration to elicit the standard service time from health professionals directly at their work settings. This inquiry may improve not only the validity and precision of the estimated health professionals needed but also the likelihood of the results' acceptability, its practical uptake in health workforce policies and plans, as well as the development of professional standards.

1.2.5 Health workforce supply-side modelling

On the supply side of health workforce planning, as shown in Figure 1, a review of physician supply models conducted by Van Greuningen et al. (2013) found that the models for projecting the anticipated supply tend to be straightforward. The researchers, however, found that the accuracy of supply models remains a challenge, as the mean absolute percentage errors varied between 2% and 15%. Models with a longer horizon tend to have more significant deviations – the further the prediction extends into the future, the higher the deviation. O'Brien-Pallas et al. (2007), therefore, contended that linear trend projections of health workforce supply rapidly lose their value if the projection is looking into several decades. Given that health workforce planning is inherently a long-term process, long-term projections are unavoidable, and a careful application of the stock-and-flow approach has shown promise in some supply-side projections (Hooker & Muchow, 2014).

1.2.6 Lingering gaps in health workforce planning

From the foregoing, the empirical literature shows significant gaps in health workforce planning in which existing models do not adequately link the number of health professionals that need to be produced from training institutions to the population health needs. Most models tend to focus on one side of either anticipated supply or number required, and even where there is an attempt to integrate them, the need component is not linked to the population need for health services (Scheffler et al., 2016).

Additionally, there is very limited or no contemporaneous literature that attempts to quantify the investments that are necessary for the education of health professionals to avert anticipated supply shortfalls. The work of Stenberg et al. (2017) provided a gross estimate of the global training investment needs within the context of UHC and SDG investment estimation. The model of Stenberg et al. (2017) used publicly available data to estimate that an additional 40-50% of an estimated US$3.9 trillion required to achieve SDG 3 must be invested in health workforce education and employment. However, this was founded on an assumed global normative threshold of 4.45 physicians, nurses and midwives per 1,000 population needed to achieve tracer indicators of SDG 3 (Scheffler et al., 2018b). Thus, the approach ignores the valuable contribution of other equally essential cadres of the health workforce addressing the population health service needs. Also, such macro-level models are challenging to reproduce with country-level data, thereby yielding a significant degree of deviations (McPake et al., 2014).

This gap has also resulted in health workforce strategic plans that often lack a sound investment case for health professions education and employment, hence attracting less than optimum investments, which in turn exacerbate the health workforce shortages.

1.3 PROBLEM STATEMENT

Despite widely acclaimed investments in social health insurance, health workforce and health system reforms over the years (Appiah-Denkyira & Herbst, 2013; Christmals & Aidam, 2020; Saleh, 2013; Schieber et al., 2012), coverage of essential health services continue to be suboptimal (Ministry of Health, 2016, 2018). For example, Ghana's UHC index of 47% in 2019 was just around the Africa region's average (WHO, 2019). Despite slight progress by two percentage points from the previous index of 45% in 2017, the 2019 score implies that up to 53% of Ghana's population health needs which are tracked by SDG tracer indicators are not being met by the existing health services. These coverage deficits are within a context of a challenged and deteriorating health financing mechanism (Akweongo et al., 2021), infrastructural deficits, shortages and inefficiencies in staffing (Asamani et al., 2021).

While facing the aforesaid chronic systemic challenges, the country is at the same time grappling with a double burden of communicable and non-communicable diseases (De Graft Aikins et al., 2012; Kushitor & Boatemaa, 2018). For instance, one systematic review and meta-analysis found that at least 43% of Ghanaians are either overweight or obese, which is a key risk factor for many chronic non-communicable diseases (NCDs) (Ofori-Asenso et al., 2016). Also, 30% of Ghanaian adults (19% of rural dwellers and 55% of urban dwellers) are estimated to have hypertension (Abariga et al., 2020; Addo et al., 2012). In addition, an estimated 6.5% of Ghanaian adults have diabetes (Asamoah-Boaheng et al., 2019) while an analysis of the nutritional status of Ghanaian children showed that 27.5% are stunted, 17.5% underweight and 7.7% wasted (Atsu et al., 2017).

At the same time, the prevalence of communicable and vector-borne diseases remains high. For example, the prevalence of malaria is conservatively estimated to be 14.1% in the population, accounting for 17.6% of all health facility attendance and 13.7% of hospital admissions (Anabire et al., 2019). Other important infectious diseases are HIV and tuberculosis, which affect 111 for every 100,000 Ghanaians (Bonsu et al., 2020), and hepatitis B, with an estimated prevalence rate of 12.3% (Ofori-Asenso & Agyeman, 2016). Despite a consistent decline over the years, the maternal mortality rate remains concerning (310 deaths per 100,000 live births), while the mortality rate of children below the age of five years is 52 deaths per 1,000 live births (Ghana

Statistical Service, 2018). Furthermore, the overall adult mortality rate is estimated to be 12 per 1,000 for the male population and eight per 1,000 for the female population (Ghana Statistical Service, 2018). While it can be said that the aforesaid and many other population health needs require investment across the different health system components, the critical alignment of the health workforce production with these population health needs is just as imperative.

Ghana adopted the PHC approach to health services in the 1970s based on which health sector reforms were undertaken, such as district health services that were enabled to focus on primary health care (Agyepong, 1999), community-based health planning and services (CHPS) that were introduced to bridge geographical barriers to PHC services (Ministry of Health, 2015a), and later, the National Health Insurance Scheme (NHIS) that was introduced to address financial barriers to health services (Nyonator et al., 2005). These initiatives expanded the coverage of health services and created a higher need and demand for health workers, especially mid-level professionals for community-based, close-to-client health interventions (Appiah-Denkyira & Herbst, 2013; Saleh, 2013).

To address severe health workforce shortages in the 1990s, Ghana expanded the public- and private-sector production of its health workforce, which increased the public sector health workforce by nearly three-folds between 2005 and 2019 (Appiah-Denkyira & Herbst, 2013; Ghana Health Service, 2020; Saleh, 2013). Ghana has been cited as one of the leading producers of physicians, nurses, and midwives in sub-Saharan Africa (Campbell et al., 2013). Nonetheless, analysis using the nationally agreed-upon facility-based staffing norms and standards (Ministry of Health, 2015b) revealed that Ghana still had at least a 42% shortage of health professionals to deliver service optimally, especially at PHC level (Asamani et al., 2018). However, further analysis indicated that on the one hand, the shortfall is more critical amongst highly trained health professionals, while on the other hand, some mid-level health workers appear to have been overproduced. This inequitable distribution has been further exasperated with health services favouring health facilities in large cities or that are highly specialised (Appiah-Denkyira & Herbst, 2013; Saleh, 2013). This has left significant staffing gaps at the PHC level where the majority of the population seek health care services, which has resulted in several persisting policy questions. These questions, amongst others, are: How many health professionals are needed at the PHC level based on the population health needs? and What level of investment in health professions training and employment will be needed to avert the shortages?

From a methodological perspective, Lopes et al. (2015) noted that although the literature on health workforce planning is generally available, there is "no consensus established on a definite methodology and technique, making it difficult for the analyst or policymaker to adopt the recent developments or for the academic researcher to improve the field" (p. 1). This observation signifies the critical conceptual and empirical gaps (and inconsistencies) in the existing knowledge and models for health workforce planning, especially for low- and middle-income countries like Ghana. Linking the time that it will take a health professional to accomplish different health service tasks (as a proxy measure of productivity standard) to meet the population's need for health services with informing decision making regarding the health professionals needed in a country remains a significant gap in the existing body of knowledge. These factors have concomitantly affected health workforce planning in some countries, particularly in Ghana, resulting in misalignments in the training of health professionals on the one hand and the health service needs of the population on the other hand (Asamani et al., 2020).

1.4 PURPOSE OF THE STUDY

Identifying the need-based gaps for health professionals is a sine qua non for planning the capacity and investment requirements for health professions education and employment (Birch et al., 2017, 2009; WHO, 2016). This study, therefore, sought to address the gaps discussed above by assessing the standard time for services delivered by health professionals at the PHC level to inform the development and application of an integrated planning model. This model incorporated population demographics, disease burden, and the health service delivery package to inform the future number of health professionals to be trained and the associated investments required for health professions education and employment over time. This study, therefore, bridged significant gaps in the empirical application of need-based planning models and have policy relevance for other low- and middle-income countries with a similar context, especially those in sub-Saharan Africa.

1.5 OBJECTIVES, RESEARCH QUESTION AND SUB-QUESTIONS

1.5.1 Research aim and objectives

The study sought to develop and apply a planning model (that considers population health needs) to assess the number of health professionals needed for primary health care in order to inform policy in Ghana. Furthermore, the model sought to determine the associated investment required in terms of health professions education and employment to fill anticipated gaps over 15 years.

The following specific research objectives were formulated:

Objective 1: To explore the extent to which need-based models have been used in health workforce planning in countries and synthesise the methodological considerations for need-based health workforce modelling through a systematic scoping review.

Objective 2: To develop a need-based health workforce planning model, based on the scoping review, that incorporates the population's level of health (disease burden), demographics, service package, and the standard time it takes health professionals to deliver the services.

Objective 3: To establish a standard time that health professionals spend in their main service delivery activities in PHC settings in Ghana.

Objective 4: To apply the need-based planning model to forecast the need and supply of health professionals to establish current and future gaps for primary health care in Ghana.

Objective 5: To estimate the health professions education investment required to fill the need-based gaps for PHC in Ghana.

Objective 6: To estimate the employment investment required to absorb the health professionals needed to be trained for PHC in Ghana.

1.5.2 Research question and sub-questions

To reach these objectives of the study, the main research question posed for this study was: What planning model can be developed and applied to assess the number of health professionals needed for PHC in order to inform policy in Ghana?

To achieve the main research question, the following sub-questions were formulated:

Question 1: To what extent have need-based models been used in health workforce planning in countries, and what are the main methodological considerations?

Question 2: Can a need-based health workforce planning model be developed to incorporate the population's level of health (disease burden), demographics, service package and the standard time it takes health professionals to deliver the services?

Question 3: How much time does it take health professionals to undertake their main service delivery tasks in PHC settings in Ghana?

Question 4: How many PHC professionals need to be trained in Ghana to optimally meet the population's health needs over the next 15 years?

Question 5: How much investment will be required in health professions education to meet the future need for PHC professionals in Ghana?

Question 6: What employment-related investments will be required to absorb the health professionals needed to be trained for PHC?

1.6 META-THEORETICAL ASSUMPTIONS AND RESEARCH PARADIGM

A pragmatic research philosophy underpins this study. This philosophical stand asserts that there are many ways of interpreting the world and undertaking research (Creswell, 2013). The pragmatism philosophy does not pin the researcher to the extremes of positivism or interpretivism, hence allowing for the integration of multiple research methods as appropriate to address the research objectives (Collis & Hussey, 2013).

This paradigm for the study was adopted in recognition that health workforce planning issues usually require a combination of methodological approaches, including desk reviews, surveys, modelling, and qualitative inquiry where appropriate (McPake et al., 2014).

1.7 RESEARCH DESIGN AND METHODOLOGY

Leaning on pragmatism, this study adopted a mixed-model design (Cameron, 2009), which allows for the use of various research methods in one study – each method based on a specific research objective (Mertens, 2014). This design may be executed in two forms, namely parallel or sequential. In the parallel form, different types of data are collected and analysed concurrently, whereas in the sequential form the analysis of one type of data provides a basis for the next (Cameron, 2009; Mertens, 2014). This study employed a sequential form of the mixed-model design. In applying this design, research is formulated in phases in which the results of one phase inform the type of data to collect for the next phase (Cameron, 2009; Creswell, 2014; McKim, 2015; Mertens, 2014). To meet the objectives of this study, a four-phase sequential design was adopted. Firstly, a scoping review to consolidate evidence (see Chapter 2) in support of the development of a needs-based planning model in the second phase (see Chapter 3). Following the model development, a desk review and a cross-sectional survey (see Chapter 4) were used to obtain the needed data for application (see Chapter 4) and the model was successfully applied in the context of PHC in Ghana (see Chapter 5). As indicated in Table 2, all research objectives were answered using the pragmatic sequential mixed-model approach employed in this study.

Table 2: Summary of the sequential multi-method approach employed in the study

Research method	Research objective addressed	Published/submitted article
Phase 1: Systematic scoping review	**Objective 1:** To explore the extent to which need-based models have been used in health workforce planning in countries and synthesise the methodological considerations for need-based health workforce modelling through a systematic scoping review.	Asamani, J. A., Christmals, C. D., & Reitsma, G. M. (2021). The needs-based health workforce planning method: a systematic scoping review of analytical applications. *Health Policy and Planning*. https://doi.org/10.1093/heapol/czab022
Phase 2: Model development	**Objective 2:** To develop a need-based health workforce planning model, based on the scoping review, that incorporates the population's level of health (disease burden), demographics, service package and the standard time it takes health professionals to deliver the services.	Asamani, J. A., Christmals, C. D., & Reitsma, G. M. (2021). advancing the population needs-based health workforce planning methodology: a simulation tool for country application. *Int. J. Environ. Res. Public Health*, 18, 2113. https://doi.org/10.3390/ijerph18042113
Phase 3: Cross-sectional survey	**Objective 3:** To establish a standard time that health professionals spend in their main service delivery activities in PHC settings in Ghana.	Asamani, J. A., Christmals, C. D., & Reitsma, G. M. (2021). Health service activity standards and standard workloads for primary healthcare in Ghana: a cross-sectional survey of health professionals. *Healthcare*, 9, 332. https://doi.org/10.3390/healthcare9030332
Phase 4: Model application	**Objective 4:** To apply the need-based planning model to forecast the need and supply of health professionals to establish current and future gaps for PHC in Ghana. **Objective 5:** To estimate the health professions education investment required to fill the need-based gaps for PHC in Ghana. **Objective 6:** To estimate the employment investment required to absorb the health professionals needed to be trained for PHC in Ghana.	Asamani, J. A., Christmals, C. D. and Reitsma, G. M. (2021). Modelling the supply and need for health professionals for primary health care in Ghana: implications for health professions education and employment planning. *PLOS One* (under review)

1.8 ETHICAL CONSIDERATIONS

Research studies are often confronted with moral and ethical issues such as the safety of participants during and after the study (physical or psychological harm); participants being fully informed about the aims, methods and benefits of the research; participants granting voluntary consent of participation while maintaining the right of withdrawal; and ensuring anonymity and confidentiality of participants' information (Babbie, 2015; Khan, 2012; Polit & Beck, 2013). To ensure conformance to ethical standards, the study was reviewed and approved by two research ethics committees and was subsequently classified as a minimal-risk study. Following approval by the Health Professions Education (HPEd) Scientific Committee, which is attached as Annexure A, the NWU Health Research Ethics Committee (NWU-HREC) reviewed and approved the study with number NWU-00416-20-A1, which is also attached as Annexure E. Additionally, the study was reviewed and approved by the Ghana Health Service Ethics Committee (GHS-EC) with number GHS-ERC017/07/20, which is attached as Annexure B. Following ethics approval from both institutions, permission was granted to commence with data collection (Annexure C). The Director-General of Ghana Health Service also sent an introductory letter to the Regional Directors of Health Services (attached as Annexure D). The ethical issues related to Phase 3 of the study, which involved a cross-sectional survey amongst health professionals working in PHC settings in Ghana, are described in detail in article 3 (Chapter 4).

1.9 STRUCTURE OF THE THESIS

This thesis follows the North-West University's 'article format'. The article format of presenting a thesis is different from the traditional format such that Chapters 2, 3, 4 and 5 are presented in the form of related but independent peer-reviewed articles published in international scientific journals. The articles were written to completely address the specific objectives of the PhD study, flowing from one to another. However, some overlapping occurred because the information presented was necessary to provide the readers of each article with complete information in terms of concepts and methodology. Each of the articles has sections detailing methodology and findings; hence, there are no separate chapters on methodology and findings included in the thesis. In addition to Chapter 1 (orientation and introduction), this thesis integrated the findings from the four standalone peer-reviewed articles (Chapters –2-5) in the final chapter (Chapter 6), where a summary, conclusion, limitations, and recommendations were provided. The scientific journals in which each of the four articles was published or submitted, were selected on the basis of the journal's scope, international impact, and readership. The formatting of each article has been aligned with the North-West University's standard, but the referencing style, tables, and figures have been preserved to be consistent with the requirements of the journals in which the papers were published. Weblinks with digital object identifiers (DOIs) of each of the published articles have been included in the relevant chapters along with "Information to authors", which details the requirements and style of each journal and which were also included as weblinks.

Chapter 1: Orientation and introduction: The chapter outlines the global health policy agenda with emphasis on the health workforce, gives an overview of various approaches to health workforce planning, and delineates the research problem addressed in the thesis as well as the objectives and research paradigm. The referencing style used in the chapter is consistent with the NWU 2020 guidelines for quoting sources. The reference list is presented at the end of the chapter.

Chapter 2: Article 1: The need-based health workforce planning method: a systematic scoping review of analytical applications. This article was published in the *Health Policy and Planning* journal, which has an impact factor of 3.344 based on the 2021 Journal Citation Report. The article addresses research objective 1 of the study. The chapter's formatting and referencing are according to the style of the journal, but modifications were made for the prescribed margins, font sizes and line-spacing to conform to the NWU guidelines and maintain uniformity with the rest of the thesis.

Chapter 3: Article 2: Advancing the population needs-based health workforce planning methodology: a simulation tool for country application: This article was published in the Global Health section of the *International Journal of Environmental Research and Public Health* (IJERPH), which has an impact factor of 3.390 based on 2021 Journal Citation report. The article addresses research objective 2 of the study. The chapter's formatting and referencing are presented according to the style of the journal, but modifications were made for the prescribed margins, font sizes, and line-spacing to conform to the NWU guidelines and maintain uniformity with the rest of the thesis.

Chapter 4: Article 3: Health service activity standards and standard workloads for primary health care in Ghana: a cross-sectional survey of health professionals. The article was published in the Health Policy section of *Healthcare*, a journal with an impact factor of 2.645 based on the 2021 Journals' Citation Report. The article addresses research objective 3. The chapter's formatting and referencing are presented according to the style of the journal, but modifications were made for the prescribed margins, font sizes, and line-spacing to conform to the NWU guidelines and maintain uniformity with the rest of the thesis.

Chapter 5: Article 4: Modelling the supply and need for health professionals for primary health care in Ghana: implications for health professions education and employment planning. This article was submitted to the *PLOS ONE* journal, which has an impact factor of 3.240 based on the 2021 Journals' Citation Report. The article addressed objectives 4, 5 and 6 of the study. The chapter's formatting and referencing are presented according to the style of the journal, but modifications were made for the prescribed margins, font sizes, and line-spacing to conform to the NWU guidelines and maintain uniformity with the rest of the thesis.

Chapter 6: Summary, conclusions, recommendations, and limitations. This chapter provides an overall summary and conclusions across all the chapters. Based on the conclusions drawn from various chapters, it also highlights the theoretical, methodological, and policy-related contribution of the study as well as recommendations for further research, policy, and planning. The referencing style used in the chapter is consistent with the NWU 2020 guidelines for quoting sources. The reference list is presented at the end of the chapter.

1.10 REFERENCES

Abariga, S. A., Kibria, G. M. A., & Albrecht, J. S. (2020). Impact of the 2017 American College of Cardiology/American Heart Association Guidelines on Prevalence of Hypertension in Ghana. *The American Journal of Tropical Medicine and Hygiene*, *102*(6), 1425–1431. https://doi.org/10.4269/ajtmh.19-0272

Addo, J., Agyemang, C., Smeeth, L., Aikins, A. D. G., Adusei, A. K., & Ogedegbe, O. (2012). A review of population-based studies on hypertension in Ghana. *Ghana Medical Journal*, *46*(2), 4–11. https://www.ajol.info/index.php/gmj/article/view/88761

Afriyie, D. O., Nyoni, J., & Ahmat, A. (2019). The state of strategic plans for the health workforce in Africa. *BMJ Global Health*, *4*(Suppl 9), e001115. https://doi.org/10.1136/bmjgh-2018-001115

Agyepong, I. A. (1999). Reforming health service delivery at district level in Ghana: The perspective of a district medical officer. *Health Policy and Planning*, *14*(1), 59–69.

Ahern, S., Woods, N., Kalmus, O., Birch, S., & Listl, S. (2019). Needs-based planning for the oral health workforce—Development and application of a simulation model. *Human Resources for Health*, *17*(1), 55. https://doi.org/10.1186/s12960-019-0394-0

Aiken, L. H., Buchan, J., Sochalski, J., Nichols, B., & Powell, M. (2004). Trends in international nurse migration. *Health Affairs*, *23*(3), 69–77.

Akweongo, P., Aikins, M., Wyss, K., Salari, P., & Tediosi, F. (2021). Insured clients out-of-pocket payments for health care under the national health insurance scheme in Ghana. *BMC Health Services Research*, *21*(1), 440. https://doi.org/10.1186/s12913-021-06401-8

Anabire, N. G., Aryee, P. A., Abdul-Karim, A., Abdulai, I. B., Quaye, O., Awandare, G. A., & Helegbe, G. K. (2019). Prevalence of malaria and hepatitis B among pregnant women in Northern Ghana: Comparing RDTs with PCR. *PLoS ONE*, *14*(2). https://doi.org/10.1371/journal.pone.0210365

Appiah-Denkyira, E., & Herbst, C. H. (2013). *Toward Evidence-Based Interventions for HRH*. http://elibrary.worldbank.org/doi/abs/10.1596/9780821396674_CH01

Asamani, J. A., Akogun, O. B., Nyoni, J., Ahmat, A., Nabyonga-Orem, J., & Tumusiime, P. (2019). Towards a regional strategy for resolving the human resources for health challenges in Africa. *BMJ Global Health*, *4*(Suppl 9). https://doi.org/10.1136/bmjgh-2019-001533

Asamani, J. A., Amertil, N. P., Ismaila, H., Akugri, F. A., & Nabyonga-Orem, J. (2020). The imperative of evidence-based health workforce planning and implementation: Lessons from nurses and midwives unemployment crisis in Ghana. *Human Resources for Health*, *18*(1), 16. https://doi.org/10.1186/s12960-020-0462-5

Asamani, J. A., Chebere, M. M., Barton, P. M., D'Almeida, S. A., Odame, E. A., & Oppong, R. (2018). Forecast of healthcare facilities and health workforce requirements for the public sector in Ghana, 2016–2026. *International Journal of Health Policy and Management*, *7*(11), 1040.

Asamani, J. A., Ismaila, H., Plange, A., Ekey, V. F., Ahmed, A.-M., Chebere, M., Awoonor-Williams, J. K., & Nabyonga-Orem, J. (2021). The cost of health workforce gaps and inequitable distribution in the Ghana Health Service: An analysis towards evidence-based health workforce planning and management. *Human Resources for Health*, *19*(1), 43. https://doi.org/10.1186/s12960-021-00590-3

Asamoah-Boaheng, M., Sarfo-Kantanka, O., Tuffour, A. B., Eghan, B., & Mbanya, J. C. (2019). Prevalence and risk factors for diabetes mellitus among adults in Ghana: A systematic review and meta-analysis. *International Health*, *11*(2), 83–92. https://doi.org/10.1093/inthealth/ihy067

Atsu, B. K., Guure, C., & Laar, A. K. (2017). Determinants of overweight with concurrent stunting among Ghanaian children. *BMC Pediatrics*, *17*(1), 177. https://doi.org/10.1186/s12887-017-0928-3

Babbie, E. R. (2015). *The practice of social research*. Nelson Education.

Basu, K., & Pak, M. (2014). Will the Needs-Based Planning of Health Human Resources Currently Undertaken in Several Countries Lead to Excess Supply and Inefficiency? *Health Economics*. https://doi.org/10.1002/hec.3125

Birch, S., Kephart, G., Murphy, G. T., O'Brien-Pallas, L., Alder, R., & MacKenzie, A. (2009). Health Human Resources Planning and the Production of Health: Development of an Extended Analytical Framework for Needs-Based Health Human Resources Planning. *Journal of Public*

Health Management and Practice, *15*(Supplement), S56–S61. https://doi.org/10.1097/PHH.0b013e3181b1ec0e

Birch, S., Kephart, G., Tomblin-Murphy, G., O'Brien-Pallas, L., Alder, R., & MacKenzie, A. (2007). Human Resources Planning and the Production of Health: A Needs-Based Analytical Framework. *Canadian Public Policy*, *33*(Supplement 1), S1–S16. https://doi.org/10.3138/9R62-Q0V1-L188-1406

Birch, S., Tomblin Murphy, G., MacKenzie, A., Whittaker, W., & Mason, T. (2017). Will the Need-Based Planning of Health Human Resources Currently Undertaken in Several Countries Lead to Excess Supply and Inefficiency? A Comment on Basu and Pak. *Health Economics*, *26*(6), 818–821. https://doi.org/10.1002/hec.3370

Bonsu, F., Addo, K. K., Alebachew, Z., Gyapong, J., Badu-Peprah, A., Gockah, R., Hanson-Nortey, N. N., Law, I., Tadolini, M., Onozaki, I., Sismanidis, C., & Owusu-Dabo, E. (2020). National population-based tuberculosis prevalence survey in Ghana, 2013. *The International Journal of Tuberculosis and Lung Disease*, *24*(3), 321–328. https://doi.org/10.5588/ijtld.19.0163

Bossert, T. J., Bärnighausen, T., Bowser, D., Mitchell, A., & Gedik, G. (Eds.). (2007). *Assessing financing, education, management, and policy context for strategic planning of human resources for health*. World Health Organization.

Cameron, R. (2009). A sequential mixed model research design: Design, analytical and display issues. *International Journal of Multiple Research Approaches*, *3*(2), 140–152. https://doi.org/10.5172/mra.3.2.140

Campbell, J., Buchan, J., Cometto, G., David, B., Dussault, G., Fogstad, H., Fronteira, I., Lozano, R., Nyonator, F., Pablos-Méndez, A., & others. (2013). Human resources for health and universal health coverage: Fostering equity and effective coverage. *Bulletin of the World Health Organization*, *91*(11), 853–863.

Christmals, C. D., & Aidam, K. (2020). Implementation of the National Health Insurance Scheme (NHIS) in Ghana: Lessons for South Africa and Low- and Middle-Income Countries. *Risk Management and Healthcare Policy*, *13*, 1879–1904. https://doi.org/10.2147/RMHP.S245615

Collis, J., & Hussey, R. (2013). Business research: A practical guide for undergraduate and postgraduate students. Macmillan International Higher Education.

Cometto, G., Buchan, J., & Dussault, G. (2020). Developing the health workforce for universal health coverage. *Bulletin of the World Health Organization*, *98*(2), 109.

Connell, J., Zurn, P., Stilwell, B., Awases, M., & Braichet, J.-M. (2007). Sub-Saharan Africa: Beyond the health worker migration crisis? *Social Science & Medicine*, *64*(9), 1876–1891.

Creswell, J. W. (2013). Research design: Qualitative, quantitative, and mixed methods approaches. Sage.

Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches (4th ed). SAGE Publications.

Culyer, A. J. (2006). Need: An Instrumental View. In R. E. A. of B. Ethics, A. D. S. L. in E. and Philosophy, H. R. in B. Ethics, & J. R. M. S. Lecturer (Eds.), *Principles of Health Care Ethics* (pp. 231–238). John Wiley & Sons, Ltd. http://onlinelibrary.wiley.com/doi/10.1002/9780470510544.ch30/summary

de Graft Aikins, A., Addo, J., Ofei, F., Bosu, W. K., & Agyemang, C. (2012). Ghana's burden of chronic non-communicable diseases: Future directions in research, practice and policy. *Ghana Medical Journal*, *46*(2), 1–3. https://www.ajol.info/index.php/gmj/article/viewFile/88731/78321

Dieleman, M., Shaw, D. M., & Zwanikken, P. (2011). Improving the implementation of health workforce policies through governance: A review of case studies. *Human Resources for Health*, *9*(1), 10. https://doi.org/10.1186/1478-4491-9-10

Dovlo, D. (2005). Wastage in the health workforce: Some perspectives from African countries. *Human Resources for Health*, *3*(1), 6. http://www.biomedcentral.com/1478-4491/3/6

Dreesch, N. (2005). An approach to estimating human resource requirements to achieve the Millennium Development Goals. *Health Policy and Planning*, *20*(5), 267–276. https://doi.org/10.1093/heapol/czi036

Dussault, G., Buchan, J., Sermeus, W., & Padaiga, Z. (2010). *Assessing future health workforce needs*. World Health Organization Copenhagen.

Dussault, G., & Dubois, C.-A. (2003). Human resources for health policies: A critical component in health policies. *Human Resources for Health*, *1*(1), 1. https://doi.org/10.1186/1478-4491-1-1

Ghana Health Service. (2020). *Human Resource Annual Report—2019*. Ghana Health Service.

Ghana Statistical Service. (2018). *Ghana Maternal Health Survey 2017*. Ghana Statistical Service. https://www.dhsprogram.com/publications/publication-fr340-other-final-reports.cfm

Hall, T. L., & Mejia, A. (1978). *Health manpower planning: Principles, method, and issue.* World Health Organization.

Hooker, R. S., & Muchow, A. N. (2014). Supply of physician assistants: 2013-2026. *Journal of the American Academy of PAs*, *27*(3), 39–45.

ILO. (2008). Options for the Classification of Health Occupations in the Updated International Standard Classification of Occupations (ISCO-08) (ISCO-08). International Labour Organisation.

Jansen, C., Codjia, L., Cometto, G., Yansané, M. L., & Dieleman, M. (2014, November 20). Realizing universal health coverage for maternal health services in the Republic of Guinea: The use of workforce projections to design health labor market interventions. Risk Management and Healthcare Policy. https://doi.org/10.2147/RMHP.S46418

Kapiriri, L., Norheim, O. F., & Heggenhougen, K. (2003). Using burden of disease information for health planning in developing countries: The experience from Uganda. *Social Science & Medicine*, *56*(12), 2433–2441. https://doi.org/10.1016/S0277-9536(02)00246-0

Kavya, S., Sanjay, P. Z., Abhay, G., & Syed, Z. Q. (2014). Methodological issues in estimating and forecasting health manpower requirement. *Journal of Public Administration and Policy Research*, *6*(2), 25–33. https://doi.org/10.5897/JPAPR2011.067

Khan, J. A. (2012). *Research methodology*. APH Publishing Corporation.

Kolehmainen-Aitken, R.-L. (1993). *Human resources planning: Issues and methods*. Data for Decision Making Project, Department of Population and International Health, Harvard School of Public Health. http://www.harvardschoolofpublichealth.com/ihsg/publications/pdf/No-1.PDF

Kushitor, M. K., & Boatemaa, S. (2018). The double burden of disease and the challenge of health access: Evidence from Access, Bottlenecks, Cost and Equity facility survey in Ghana. *PLOS ONE*, *13*(3), e0194677. https://doi.org/10.1371/journal.pone.0194677

Liu, J. X., Goryakin, Y., Maeda, A., Bruckner, T., & Scheffler, R. (2016). *Global Health Workforce Labor Market Projections for 2030*. http://documents.worldbank.org/curated/en/546161470834083341/pdf/WPS7790.pdf

Lopes, M. A., Almeida, Á. S., & Almada-Lobo, B. (2015). Handling healthcare workforce planning with care: Where do we stand? *Human Resources for Health*, *13*(1). https://doi.org/10.1186/s12960-015-0028-0

MacKenzie, A., Tomblin Murphy, G., & Audas, R. (2019). A dynamic, multi-professional, needs-based simulation model to inform human resources for health planning. *Human Resources for Health*, *17*(1), 42. https://doi.org/10.1186/s12960-019-0376-2

McKim, C. A. (2015). The Value of Mixed Methods Research: A Mixed Methods Study. *Journal of Mixed Methods Research*. https://doi.org/10.1177/1558689815607096

McPake, B., Scott, A., & Edoka, I. (2014). *Analyzing Markets for Health Workers: Insights from Labor and Health Economics*. The World Bank. http://elibrary.worldbank.org/doi/book/10.1596/978-1-4648-0224-9

Mertens, D. M. (2014). Research and evaluation in education and psychology: Integrating diversity with quantitative, qualitative, and mixed methods. Sage publications.

Ministry of Health. (2015a). National Community-Based Health Planning and Services (CHPS) Policy: Accelerating attainment of Universal Health Coverage and bridging the access inequity gap. Ministry of Health, Ghana.

Ministry of Health. (2015b). *Staffing Norms for the Health Sector of Ghana (Volume 1)*. Ministry of Health, Ghana.

Ministry of Health. (2016). *Holistic Assessment of the Health Sector Programme of Work 2015*. Ministry of Health, Ghana. www.moh.gov.gh

Ministry of Health. (2018). Health Sector Holistic Assessment of the Health Sector Performance—2017. Ministry of Health, Ghana.

Morris, S., Devlin, N., Parkin, D., & Spencer, A. (2012). *Economic analysis in health care* (2nd ed.). John Wiley & Sons.

Murphy, G. T., Birch, S., MacKenzie, A., Bradish, S., & Rose, A. E. (2016). A synthesis of recent analyses of human resources for health requirements and labour market dynamics in high-income OECD countries. *Human Resources for Health*, *14*(1), 59. http://files/3788/s12960-016-0155-2.html

Murphy, G. T., Birch, S., Mackenzie, A., Rigby, J., & Langley, J. (2017). An integrated needs-based approach to health service and health workforce planning: Applications for pandemic influenza. *Healthcare Policy*, *13*(1), 28.

Nyonator, F. K., Awoonor-Williams, J. K., Phillips, J. F., Jones, T. C., & Miller, R. A. (2005). The Ghana community-based health planning and services initiative for scaling up service delivery innovation. *Health Policy and Planning*, *20*(1), 25–34.

O'Brien-Pallas, L., Baumann, A., Donner, G., Murphy, G. T., Lochhaas-Gerlach, J., & Luba, M. (2001). Forecasting models for human resources in health care. *Journal of Advanced Nursing*, *33*(1), 120–129. https://doi.org/10.1046/j.1365-2648.2001.01645.x

O'Brien-Pallas, L.-L. & others. (2007). *Health human resources modelling: Challenging the past, creating the future*. Canadian Health Services Research Foundation Ottawa. https://www.researchgate.net/profile/Raquel_Meyer/publication/252260023_Health_Human_Resources_Modelling_Challenging_the_Past_Creating_the_Future/links/00b4953b3db66cd0a1000000.pdf

Ofori-Asenso, R., & Agyeman, A. A. (2016). Hepatitis B in Ghana: A systematic review & meta-analysis of prevalence studies (1995-2015). *BMC Infectious Diseases*, *16*(1), 130. https://doi.org/10.1186/s12879-016-1467-5

Ofori-Asenso, R., Agyeman, A. A., Laar, A., & Boateng, D. (2016). Overweight and obesity epidemic in Ghana—A systematic review and meta-analysis. *BMC Public Health*, *16*(1), 1239. https://doi.org/10.1186/s12889-016-3901-4

Ono, T., Lafortune, G., & Schoenstein, M. (2013). Health Workforce Planning in OECD Countries: A Review of 26 Projection Models from 18 Countries. https://doi.org/10.1787/5k44t787zcwb-en

Polit, D. F., & Beck, C. T. (2013). Essentials of nursing research: Appraising evidence for nursing practice. Wolters Kluwer Health.

Rees, G. H., Crampton, P., Gauld, R., & MacDonell, S. (2018a). Rethinking health workforce planning: Capturing health system social and power interactions through actor analysis. *Futures*, *99*, 16–27.

Rees, G. H., Crampton, P., Gauld, R., & MacDonell, S. (2018b). The promise of complementarity: Using the methods of foresight for health workforce planning. *Health Services Management Research*, *31*(2), 97–105.

Roberfroid, D., Leonard, C., & Stordeur, S. (2009a). Physician supply forecast: Better than peering in a crystal ball? *Human Resources for Health*, *7*, 1–13. https://doi.org/10.1186/1478-4491-7-10

Roberfroid, D., Leonard, C., & Stordeur, S. (2009b). Physician supply forecast: Better than peering in a crystal ball. *Hum Resour Health*, *7*(10), 1–13. http://www.biomedcentral.com/content/pdf/1478-4491-7-10.pdf

Saleh, K. (2013). The Health Sector in Ghana: A Comprehensive Assessment. World Bank Publications.

Scheffler, R. M., & Arnold, D. R. (2019). Response to Stephen Birch. *Health Economics, Policy and Law*, *14*(2), 295–297. https://doi.org/10.1017/S1744133118000348

Scheffler, R. M., Campbell, J., Cometto, G., Maeda, A., Liu, J., Bruckner, T. A., Arnold, D. R., & Evans, T. (2018a). Forecasting imbalances in the global health labor market and devising policy responses. *Human Resources for Health*, *16*(1), 5.

Scheffler, R. M., Campbell, J., Cometto, G., Maeda, A., Liu, J., Bruckner, T. A., Arnold, D. R., & Evans, T. (2018b). Forecasting imbalances in the global health labor market and devising policy responses. *Human Resources for Health*, *16*(1), 5. https://doi.org/10.1186/s12960-017-0264-6

Scheffler, R. M., Herbst, C. H., Lemiere, C., & Campbell, J. (Eds.). (2016). *Health Labor Market Analyses in Low- and Middle-Income Countries: An Evidence-Based Approach*. The World Bank. https://doi.org/10.1596/978-1-4648-0931-6

Schieber, G., Cashin, C., Saleh, K., & Lavado, R. (2012). *Health Financing in Ghana*. The World Bank. https://doi.org/10.1596/978-0-8213-9566-0

Shipp, P. J. (1998). Workload indicators of staffing need (WISN): A manual for implementation. Geneva: World Health Organization.

Sousa, A., Scheffler, R. M., Nyoni, J., & Boerma, T. (2013). A comprehensive health labour market framework for universal health coverage. *Bulletin of the World Health Organization*, *91*, 892–894. https://doi.org/10.2471/BLT.13.118927

Stenberg, K., Hanssen, O., Edejer, T. T.-T., Bertram, M., Brindley, C., Meshreky, A., Rosen, J. E., Stover, J., Verboom, P., Sanders, R., & Soucat, A. (2017). Financing transformative health systems towards achievement of the health Sustainable Development Goals: A model for projected resource needs in 67 low-income and middle-income countries. *The Lancet Global Health*, *5*(9), e875–e887. https://doi.org/10.1016/S2214-109X(17)30263-2

Tomblin Murphy, G., Kephart, G., Lethbridge, L., O'Brien-Pallas, L., & Birch, S. (2009). Planning for what? Challenging the assumptions of health human resources planning. *Health Policy*, *92*(2–3), 225–233. https://doi.org/10.1016/j.healthpol.2009.04.001

Van Greuningen, M., Batenburg, R. S., & Van der Velden, L. F. (2013). The accuracy of general practitioner workforce projections. *Human Resources for Health*, *11*(1), 31. https://doi.org/10.1186/1478-4491-11-31

WHO. (1978). *Primary health care: A joint report*. World Health Organization.

WHO. (2006). *The world health report: 2006: working together for health*. http://apps.who.int/iris/handle/10665/43432

WHO (Ed.). (2010). *Health systems financing: The path to universal coverage*. World Health Organization, Geneva, Switzerland.

WHO (Ed.). (2015). Health in 2015: From MDGs, Millennium Development Goals to SDGs, Sustainable Development Goals. World Health Organization.

WHO. (2016a). Global strategy on human resources for health: Workforce 2030. *World Health Organisation*. https://www.who.int/hrh/resources/globstrathrh-2030/en/.

WHO. (2016b). Workload Indicators of Staffing Need (WISN): Selected Country Implementation Experiences. *Human Resources for Health Observer Series*, *15*. http://apps.who.int/iris/bitstream/10665/205943/1/9789241510059_eng.pdf

WHO. (2016c, December). *Equitable Access to Functional Health Workforce and Community Health Workers in the Africa Region*. WHO Regional Forum on Strengthening Health Systems for the SDGs and UHC, Windhoek, Namibia. http://www.afro.who.int/index

WHO. (2017a). National health workforce accounts: A handbook. World Health Organization.

WHO. (2017b). National Health Workforce Accounts—Implementation Guide. World Health Organization.

WHO. (2019, January 24). *Universal health coverage (UHC)*. World Health Organisation. https://www.who.int/news-room/fact-sheets/detail/universal-health-coverage-(uhc)

WHO, & UNICEF. (2018). *Declaration of Astana: From Alma-Ata towards universal health coverage and the Sustainable Development Goals* [Declaration]. World Health Organization (WHO) and United Nations Children's Fund (UNICEF).

CHAPTER 2:
ARTICLE 1: THE NEEDS-BASED HEALTH WORKFORCE PLANNING METHOD: A SYSTEMATIC SCOPING REVIEW OF ANALYTICAL APPLICATIONS

James Avoka Asamani [1,2], Christmal Dela Christmals[1,*] and Gerda Marie Reitsma[1]

[1]Centre for Health Professions Education, Faculty of Health Sciences, North-West University, Potchefstroom Campus, Building PC-G16, Office 101,11 Hoffman St, Potchefstroom, 2520, North West Province, South Africa

[2]World Health Organisation, Regional Office for Africa. Universal Health Coverage – Life Course Cluster Intercountry Support Team for Eastern and Southern Africa 82 – 86 Cnr Enterprise/Glenara Roads Highlands, Harare, Zimbabwe

*Corresponding author. Centre for Health Professions Education, Faculty of Health Sciences, North-West University, Potchefstroom, South Africa. E-mail: christmal.christmals@nwu.ac.za

Accepted on 9 February 2021

Keywords: Population health needs, needs-based health workforce, health workforce planning, health service planning, human resources for health, workforce modelling

This article was published in the Health Planning and Policy journal (link to the publication: https://doi.org/10.1093/heapol/czab022). Based on the 2021 Journals' Citation Report, the journal's impact factor is 3.344. The article included is presented in accordance with the specific guidelines for the journal (journal's author guidelines: https://academic.oup.com/heapol/pages/General_Instructions), but with exceptions for prescribed margins, line-spacing, fonts and also presented in one column per page instead of two columns per page by the journal. These modifications were to adhere to the NWU guidelines and to maintain uniformity of the thesis. Tables 1 and 2 are reformatted in line with NWU guidelines to facilitate easier reading and comprehension.

2.1 ABSTRACT

Although the theoretical underpinnings and analytical framework for needs-based health workforce planning are well developed and tested, its uptake in national planning processes is still limited. Towards the development of an open-access needs-based planning model for national workforce planning, we conducted a scoping review of analytical applications of needs-based health workforce models. Guided by the Preferred Reporting Items for Systematic reviews and Meta-Analyses - extension for Scoping Reviews (PRISMA-ScR) checklist, a systematic scoping review was conducted. A systematic search of peer-reviewed literature published in English was undertaken across several databases. Papers retrieved were assessed against predefined inclusion criteria, critically appraised, extracted and narratively synthesised. Twenty-five papers were included, which showed increased uptake of the needs-based health workforce modelling, with 84% of the studies published within the last decade (2010 – 2020). Three countries (Canada, Australia, and England) accounted for 48% of the publications included whilst four studies (16%) were based on low-and-middle-income countries. Only three of the studies were conducted in sub-Saharan Africa. Most of the studies (36%) reported analytical applications for specific disease areas/programs at sub-national levels; 20% focused on the health system need for particular categories of health workers, and only two (8%) reported the analytical application of the needs-based health workforce approach at the level of a national health system across several disease areas/programs. Amongst the studies that conducted long-term projections, the time horizon of the projection was an average of 17 years, ranging from 3 to 33 years. Most of these studies had a minimum time horizon of ten years. Across the studies, we synthesised six typical methodological considerations for advancing needs-based health workforce modelling.

Conclusion: As countries aspire to align health workforce investments with population health needs, the need for some level of methodological harmonisation, open-access needs-based models and guidelines for policy-oriented country-level use is not only imperative but urgent.

Key Messages

- Needs-based health workforce planning framework is increasingly considered as the conceptually appropriate framework for Universal Health Coverage and is increasingly (but slowly) being tried for planning in countries.

- The uptake of the needs-based approach to health workforce planning has more than doubled since 2010 but riddled with methodological diversity, lack of standardization and lack of open-access model for use.

- Across peer-reviewed analytical applications of the needs-based health workforce planning framework, we synthesized six broad methodological and process considerations that were typical, albeit variations in how they were implemented across individual models. Future models should aim to incorporate all these methodological considerations as we strive towards standardization of need-based modelling in health workforce planning.

- Open-access models on the needs-based health workforce planning framework are needed now than ever for policy-driven applications as countries (especially in low-and-middle-income settings) push towards universal health coverage which must be underpinned by universal access to the skilled and functional health workforce.

2.2 INTRODUCTION

Health workforce planning is an essential element of health service planning and in building responsive and efficient health care systems. Notwithstanding its significance, health workforce planning is often delinked from and remains one of the weakest links to health services planning in many countries (Andalón and Fields, 2011; Araujo *et al.*, 2016; Birch *et al.*, 2020). Unsurprisingly, a systematic review demonstrated that more than 50% of all workforce models were applied in the health sectortrft6 (Safarishahrbijari, 2018), albeit a lack of methodological consensus (Ono *et al.*, 2013; Lopes *et al.*, 2015; Tomblin Murphy *et al.*, 2016), and amid new and divergent approaches being proposed (Dreesch *et al.*, 2005; Rees *et al.*, 2018a, 2018b). These are further being fuelled by growing concerns among researchers, health planners and development practitioners that many health workforce challenges are rooted in poor planning which is culminating in insufficient investments in health workforce education, employment and retention (Cometto and Campbell, 2016; Asamani *et al.*, 2020).

The health workforce planning literature is replete with estimates of shortages of health workers in nearly all countries, a testament that countries have made estimates of the supply of health workers on the one hand, and on the other hand, estimates of the 'required' calibre and number of health workers to meet its health system objectives. The supply-side analysis has been relatively a straightforward accounting process involving health worker headcounts and adjustments for future inflows, attrition and labour participation (Dal Poz *et al.*, 2010; Kavya *et al.*, 2014; Birch *et al.*, 2020).

However, the conceptual basis for the estimation of the required number of health workers has been varied and evolving. Over the years, many estimates of health workforce requirements have either been based on a simple ratio of health workers to population or some variants of demand-based approaches. The population-based ratios are founded on the assumptions that the population to be served is nearly homogeneous in terms of their health status and needs, which will remain constant into the future (Lopes *et al.*, 2015) – hence the task of the planner is to determine a size of the population that one health worker (of a particular type) will be capable of delivering services. Besides the health worker-to-population ratio approach, others have used a demand-based approach to estimate health workforce requirements. For example, applying currently observed or target levels of health service utilisation (demand for services) to future population – by size, gender and age cohorts to determine health workforce requirements (Stuckless *et al.*, 2012; Kavya *et al.*, 2014; Lopes *et al.*, 2015). Another variant of the demand-based approach is establishing a statistical relationship between health worker density per unit of population (e.g., per 10,000 population) and the level of health expenditure or some measure of economic capacity (e.g., gross domestic product, or gross national income). The observed relationship is then extrapolated into the future to estimate the health workforce requirements that reflect a country's ability and willingness to employ health workers (Scheffler *et al.*, 2008), an approach termed as economic demand (Liu *et al.*, 2017). It has been argued by Birch *et al.*, (2013) that the service demand or economic demand approach tends to reflect only the existing levels of service utilisation and could perpetuate the existing inequities into the future. It ignores the population's health needs that are currently not being covered by current levels of service provision, which is counterintuitive to the tenets of universal health coverage (UHC) (Murphy *et al.*, 2016).

The demand for health services is not entirely independent of the level of supply of the health workforce. On the one hand, a limited supply of health workers could lead to reduced service utilisation but an excess supply of health workers on the other hand, as was seen in the United States and the United Kingdom, can induce higher service utilisation perpetuated by the health workers with the view of sustaining their income/employments, a phenomenon termed as supplier-induced demand (Birch, 1988; Birch *et al.*, 2013). Therefore, Segal and Leach (2011) argued that the health sector market conditions are inappropriate for using "demand as a basis for health workforce planning [which] is also inconsistent with the adoption of equity as a health system objective" (p. 2).

Given the foregoing limitations, a needs-based approach that makes an "… explicit consideration of population health needs, direct measures of levels of health that give rise to need for care – and the planned number and type of services to be provided to address those needs" have been proposed (Tomblin Murphy *et al.*, 2012, p.193). In the needs-based framework, the required health workforce becomes a function of four primary measures:

(a) **Demographic characteristics**: The size, gender, and age distribution population in a defined geographical area.

(b) **Level of health**: Disease burden and health risk factors affecting the age and gender-specific groups of the population (epidemiology).

(c) **Level of service**: The types and frequency of health services to be delivered that are necessary to address disease burden and risk factors of the population to promote healthy growth and development.

(d) **Productivity or service delivery standard**: The type of health worker(s) and the rate at which the services can be provided to acceptable professional standards.

In 2016, the World Health Assembly (WHA) adopted resolution WHA69.19, approving the global strategy on health workforce (World Health Organization, 2016) which profoundly urged countries to make a paradigm shift in health workforce planning towards the use of population health needs as the basis for health workforce planning, rather than the use of currently observed levels of health service utilisation, service targets, health facilities or simple population ratios. In furtherance of this, it called for health workforce investments to be based on a matching of "…the supply of health workers to population needs, now and in the future" (World Health Organization, 2016). This paradigm shift has been deemed necessary to uphold the tenets of UHC in ensuring that all persons have access to the health worker they will require based on their health needs and not based on other characteristics. Thus, it has become critical for countries to devise effective policies that respond to population needs and to effectively plan the future training of health professionals by quantifying the needed health workforce based on the population health needs and their supply capacity based on the evidence (World Health Organization, 2016).

The theoretical underpinnings and analytical framework for needs-based health workforce planning are reasonably well developed and tested in many contexts (O'Brien-Pallas *et al.*, 2001; Birch *et al.*, 2007; O'Brien-Pallas *et al*, 2007; Murphy *et al.*, 2013; Segal *et al.*, 2013, 2018; Ahern *et al.*, 2019; MacKenzie *et al.*, 2019). As the concept is intrinsically aligned with the tenets of universal health coverage (UHC), its use for country-level health workforce planning is becoming appealing, especially in low-and-middle-income countries (LMICs). Nevertheless, there have been limited guidelines and tools to support the real-life application of the needs-based planning concept to inform health workforce policies and strategies in countries, especially in contexts where there are weak planning and analytical capacity. Even across developed countries, only 14% (18 out of 130) of national planning documents have been based on the needs-based approach (Murphy *et al.*, 2016). As part of efforts geared towards the development of guidelines and open-access needs-based planning tools for policy-driven application in countries, we conducted a scoping review of analytical applications of needs-based health workforce modelling. This review sought to answer the following questions: (1) to what extent have needs-based health workforce modelling been analytically applied in countries? (2) what methodological and practical considerations have informed the analytical applications of the needs-based health workforce planning approach?

2.3 METHODOLOGY

2.3.1 Study design and rationale

The conduct of the review was guided by the Arksey and O'Malley (2005) framework for systematic scoping reviews which outlines five main steps of (1) identifying the research question; (2) identifying relevant studies; (3) study selection; (4) charting the data; and (5) collating, summarising and reporting the results. The reporting of this study was also guided by the Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) checklist (Tricco *et al.*, 2018) and methodological guide for publishing scoping reviews (Lockwood and Tricco, 2020). According to Tricco *et al.* (2018), systematic scoping reviews are appropriate to "examine the extent (that is, size), range (variety), and nature (characteristics) … summarise findings from a body of knowledge that is heterogeneous in methods [to] … identify gaps [for further work]" (p.267). The needs-based health workforce planning conceptual framework has been well-grounded, but its analytical models are emerging with substantial methodological heterogeneity. Thus, a systematic scoping review was deemed most appropriate to assess the volume, variety, nature, methodological gaps, and considerations with the view of further advancing the analytical models in needs-based modelling of health workforce requirements.

2.3.2 Identifying the research question

An initial general search of the literature via Google Scholar and PubMed was conducted in February 2020 which found a systematic review of general workforce models across different sectors (Safarishahrbijari, 2018) and useful syntheses of health workforce planning methods including needs-based approaches (Ono *et al.*, 2013a; Lopes *et al.*, 2015; Tomblin Murphy *et al.*, 2016). There was, however, no systematic synthesis of how the needs-based models have been analytically applied in countries – a critical piece needed to understand their main strengths and limitations. The papers found through this initial search were used to shape the review questions.

2.3.3 Identifying relevant studies: Strategy for systematic search

A systematic search strategy was developed, guided by the PRISMA-ScR Checklist (Tricco *et al.*, 2018; Peters *et al.*, 2020). The databases searched were PubMed, Scopus, Web of Science, EBSCOHost and Google scholar. A sample of the search strategy used for the PubMed database is shown in box 1, which was modified as appropriate for other databases. To ensure that relevant papers were not unduly excluded or missed, there was no restriction on year of publication or country of origin, but there was a restriction to papers published in only the English language. Also, forward, and backward citation search of highly cited papers were manually conducted. The search was last updated on 22 August 2020.

Box 1: Example of search terms and strategy for PUBMED

1. ((((human resources for health) OR (health work*)) OR (health professional*)) OR (doctors)) OR (physician*)) OR (nurs*) OR (midwi*) OR (pharmacist*) OR (laboratory scientist) OR (nutritionist) OR (dietician)
2. (((((need*) OR (planning)) OR (projection)) OR (model*)) OR (forecast*)) OR (prediction)
3. #1 AND #2

2.3.4 Screening and selection of studies

After removing duplicate items, the process of screening was conducted in two stages. In the first stage, titles and abstracts of the paper were screened for relevance and suitability to be retained considering the review objective. Papers with titles and abstracts that provided insufficient information to decide at this stage were retained for the next stage. In the second stage, the full texts of the retained papers from the first stage of screening were downloaded and evaluated against the inclusion criteria. All selected articles from this stage were saved in a separate folder for quality assessment and synthesis. Papers that were excluded based on the full-text assessment against the inclusion and exclusion criteria were justified with the reasons. The entire screening and selection process was undertaken independently by two authors who later compared notes, and where there were discrepancies, a third author's independent view was used for an amicable resolution.

2.3.5 Inclusion and exclusion criteria

Papers were included if they: a) reported the use of health workforce planning models that link population health needs, disease burden and population demography to health workforce requirements; b) employed methods and reported on findings of an analytical application of needs-based health workforce requirement; c) were published in the English language, and d) the full article of the publication was accessible. Those that only described the conceptual approach to needs-based health workforce modelling without analytical application were excluded.

2.3.6 Data extraction, charting and synthesis

Relevant data were extracted from each of the included studies using a data extraction matrix adapted from the CHARMS checklist (Moons *et al.*, 2014) and the Joana Briggs Institute Reviewer's Manual for Scoping Reviews (Peters *et al.*, 2020) of which the results are presented in Table 1. Descriptive analysis and narrative synthesis (Centre for Reviews and Dissemination, 2009) of the findings were conducted and presented, taking into account the volume and quality of studies as well as the critical modelling considerations made in the analytical application of the needs-based approach to health workforce planning. Particular attention was paid to the key considerations in the model and analysis, their scope, main strengths, and weaknesses, as well as the differences and similarities between modelling approaches.

2.3.7 Quality assessment of included studies

We could not find specific quality appraisal tools for assessing the quality of needs-based health workforce planning models. Therefore, we adapted the Critical Appraisal and Data Extraction for Systematic Reviews of Prediction Modelling Studies (CHARMS Checklist) (Moons *et al.*, 2014a); the Phillips checklist for health economic models (Philips *et al.*, 2006); Segal's key needs-based health workforce questions (Segal *et al.*, 2018); and criteria for fit-for-purpose health workforce planning tools (Murphy *et al.*, 2016) into a quality assessment checklist for the purpose of this study. The checklist has 27 items which were assigned an unweighted point for each item (Table 2). The checklist was applied across all the included studies to appraise the quality, comprehensiveness, and transparency of the analytical applications of the needs-based health workforce planning models. Studies that scored 80% or more were considered to be ‘very comprehensive and of high quality’; between 70% and 79% were considered to be ‘quite comprehensive and of good quality’ whilst those that scored between 50% and 69% were considered to of moderate comprehensiveness and quality. Scores below 50% were considered not comprehensive and of low quality.

2.4 FINDINGS

2.4.1 Characteristics of included studies

Out of four hundred and thirty-six (436) papers identified, only twenty-five (25), which reported analytical applications of needs-based health workforce modelling, satisfied the inclusion criteria, and were included. The 436 titles were screened, excluding 368. The full articles of 68 papers that were retained after the initial screening were read after which 43 (63.2%) were excluded with reasons: 38 (88.4%) were not needs-based models; 7 (16.3%) were only theoretical descriptions of the needs-based approach whilst for five (11.6%), the full text of the publications could not be obtained. The remaining 25 papers were included after a critical appraisal and reading of the full articles. No study was excluded based on its quality. Figure 1 provides a flowchart of the search and inclusion process.

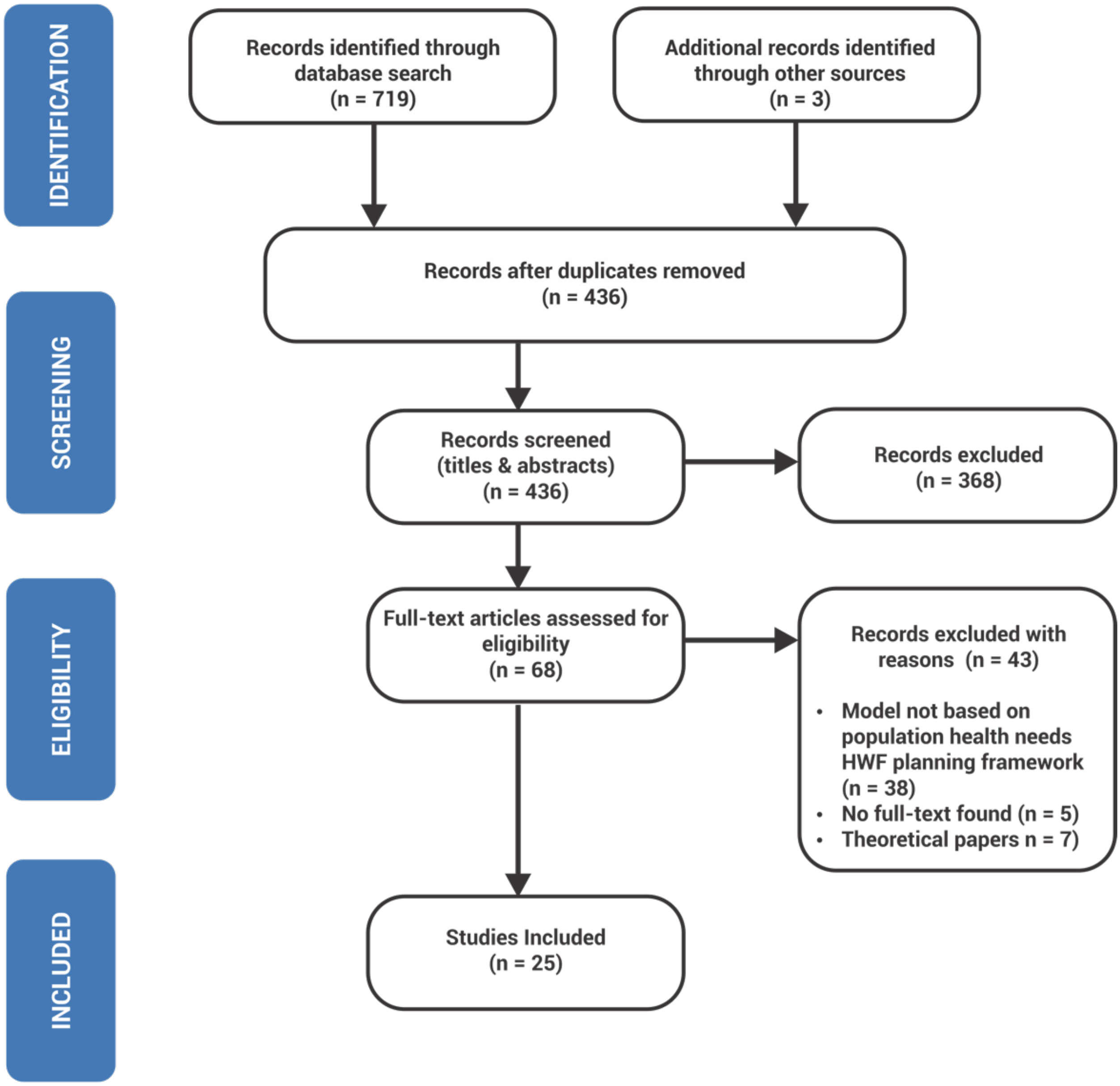

Figure 1: Flowchart of search and inclusion process

Adapted from: The PRISMA Statement. PLoS Med 6(6): e1000097.

Table 1: Data extraction matrix

No	Author (country)	The horizon of the projection	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
1	Ahern et al., 2019 (Ireland)	2017 - 2050	Microsimulation	Program: Oral health Health workers: Dentists	Demography: age cohorts, gender, population size Health status: number of natural teeth, type of dental problem Level of Service: level, frequency and type of service	Special Eurobarometer 330 Oral Health Survey dataset; National Statistics; Professional register	One-way sensitivity analysis by changing the treatment time (standard time), hours worked and both. The model results showed it was sensitives to each of these variables.	Not stated	Followed a typical need-based HWF framework and used data from a large survey to estimate population variables for dental care.	The standard time used to provide oral services was not collected, so an assumption of 20 minutes per case was made. It was assumed that the dentist spends 90% of the time providing services but no records review or prior studies were used to back the assumption.
2	Ansah et al., 2015 (Singapore)	2015 - 2040	Macrosimulation	Program: Eyecare Health workers: Ophthalmic nurses and allied health professionals	Demography: age cohorts, gender, population size Health status: prevalence of diseases	Singapore Epidemiology of Eye Diseases study and National population statistics.	Scenario analysis based on three policy options and with ranges of projection estimated from the 95% confidence intervals of the input variables.	Two critical tests (behaviour and structure validation test) were selected to demonstrate their fit and quality. Behaviour test was done by comparing the	Extensive use of data and stakeholder engagement during all stages of the modelling. The future prevalence of disease was projected and then translated into demand.	The need for services (as defined by population variables) is used interchangeably as demand for services. No explicit assumption of how much time ophthalmologists spend in treating a disease during each patient visit - the

No	Author (country)	The horizon of the projection	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
								model output for historical years to available data. The structure validation was done by presenting the structural assumptions to stakeholders for validation.		staff time was proportionally distributed to clinical, research other duties.
3	Ansah et al., 2019 (Singapore)	2015 - 2040	Macrosimulation	Program: Eyecare Health workers: Ophthalmologists	Demography: age cohorts, gender, population size Health status: prevalence of diseases	Singapore Epidemiology of Eye Diseases study and National population statistics.	Scenario analysis based on three policy options and with ranges of projection estimated from the 95% confidence intervals of the input variables.	Two critical tests (behaviour and structure validation test) were selected to demonstrate their fit and quality. Behaviour test was done by comparing the model output for historical years to available data. The structure	Extensive use of data and stakeholder engagement during all stages of the modelling. The future prevalence of disease was projected and then translated into demand.	The need for services (as defined by population variables) is used interchangeably as demand for services. No explicit assumption of how much time ophthalmologists spend in treating a disease during each patient visit - the staff time was proportionally distributed to

No	Author (country)	The horizon of the projection	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
								validation was done by presenting the structural assumptions to stakeholders for validation.		clinical, research other duties.
4	Birch et al., 2020 (Multiple (Europe))	Not stated	Macrosimulation	Disease-specific application (breast cancer, acute myocardial infarction and type 2 diabetes) based on data from the Czech Republic, England, Germany, Italy, Netherlands, Norway, Poland, Scotland and Turkey Health workers: Doctors and nurses	Demography: age cohorts, gender, population size Health status: prevalence of diseases Provider: productivity, practice differences and pay (3Ps)	project-based survey and routine data	The sensitivity of the estimates to different levels of exposure to each profession was tested by separately assuming that physicians see 100% of patients, while advanced and specialist nurses see 60% of patients in the care pathway	The specific process to validate the model is not stated.	Provides an explicit need-based framework with transparent formulae. Estimated provider productivity directly from the health workers.	Empirical limitations related to the use of a self-reported survey of health workers in selected health facilities which may not be generalisable. Data limitations constrained application to only three disease areas
5	Birch et al., 2013 (England)	Not applicable	Macrosimulation	National	Demography: age cohorts, gender, population size Health status:	General Household Survey for	Not conducted	The specific process to validate the	Arguing from the angle of supplier-induced demand, the paper	Albeit empirical analysis to illustrate the need-based framework, the

No	Author (country)	The horizon of the projecti on	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
					prevalence of diseases Provider: productivity	England, 1985 - 2006		model is not stated.	illustrates the advantage of need-based HWF planning over utilisation/demand -based models using data from England	papers do not apply the model to project the needed HWF.
6	Bruckner et al., 2011 (Multiple (Low-and-middle income countries))	One-off	Macrosimulation	Program: Mental Health Multi-country Health workers: psychiatr ists, nurses and psychosocial care providers	Demography: Population size Health status: Disease prevalence Provider: productivity (assumed)	Publicly available data - international databases and survey for disease burden	Not conducted	Not stated	The paper used a global instrument for assessing disease burden and hence need	HWF productivity as assumed (not elicited) and applied in a constant manner for all professionals
7	Burke et al., 2013 (United States)	2010 (one-off)	Macrosimulation	Program: mental health Health workers: psychiatr ists, psychologists, licensed clinical social workers, psychiatric social workers, psychiatric nurse practitioners, family therapists	Prevalence rates, insurance coverages	2010 National Survey on Drug Use and Health; Insurance coverage data	Not conducted	The specific process to validate the model is not stated.	Used administrative data and publicly available data to estimate ate need for services which was translated into staffing requirements.	The formula is not described hence it is difficult to assess it.

No	Author (country)	The horizon of the projection	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
8	Elisha et al., 2004 (Israel)	2000 (one-off)	Macrosimulation	Program: mental health Health workers: Psychiatrists, Nurses, Psychologists and Social Workers	demographic variables, workers' productivity, anticipated demand, and standards on annual visits per client distributed among the core mental health professions.	Expert opinion and administrative data	Not stated	The specific process to validate the model is not stated.	Clear linkage of population-based variables and disease prevalence to need, translating the need to demand and then staff requirements.	Used standards based on both expert consensus and existing staffing patterns while they note the need for more rigorously derived and empirically-based standards.
9	Gallagher et al., 2010 (England)	2005 - 2028	Macrosimulation	Program: Oral health Health workers: Dentists	combined demography (65-99 years), rates of edentulousness, patterns of dental attendance and treatment rates for older people, along with GDS treatment times	Administrative and survey data: Dental Practice Board directly and via their website and from The Information Centre, The Government Actuary's Department and the most recent UK Adult Dental Health Survey, together with other	Monte-Calo simulation using plausible ranges of input parameters	Not stated	Clear linkage of population-based variables and disease prevalence to need, translating the need to demand and then staff requirements.	Assumed only aged population would be in need. Used the need to derive demand for services based on treatment rates; hence the estimated HWF needs are in a practical sense a demand-based requirement rather than a need-based requirement.

No	Author (country)	The horizon of the projecti on	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
						relevant data such as treatment times from the BDA and registrations of dental professionals with the General Dental Council.				
10	Gallagher et al., 2013 (England)	2013 (one-off)	Microsimulation	Program: Oral health at Regional level Health workers: Dental therapist	population, attendance, oral health trends and the proportion of treatments in each 'band of care' received by the different age groups (0–19, 20–64, 65+)	Dental Workforce Survey from a locality with similar context; expert opinion.	Monte-Calo simulation using plausible ranges of input parameters	Not stated	Clear linkage of population-based variables and disease prevalence to need, translating the need to demand and then staff requirements.	Assumed only aged population would be in need. Used the need to derive demand for services based on treatment rates; hence the estimated HWF needs are in a practical sense a demand-based requirement rather than a need-based requirement.
11	Jansen et al., 2014 (Guinea)	2018 - 2024	Macrosimulation	Program: Maternal and Newborn Health Health workers: Doctors, Nurses and Midwives	Demographic variables, a national package of MNH service to address health needs	Administrative, surveys and prior facility, expert opinion, an assessment report	Not stated	The methodology, parameters, and input data for the baseline scenario were	One of the first attempts to explicitly link the essential package of services to need-based HWF	The paper expressed difficulties encountered in translating detailed health service package into need-based plans: The

No	Author (country)	The horizon of the projecti on	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
								discussed and determined with a group of international and national experts, including a demographer, public health experts, HRH experts, and (para)medical professionals.	planning assumptions.	model presented for the calculation of the population HRH needs departs from a clearly defined package of MNH services that are to be offered to a clearly defined population (pregnant women) within a delineated period (10 months)
12	Konrad et al., 2009 (United States)	2006 (one-off)	Macrosimulation	Program: National Mental Health Health workers: Mental health professionals	Demography: Population size, age, sex Health need: disease prevalence, functional limitation Level of service: mental health utilisation Provider: productivity	Administrative data, data from surveys and publicly available information	Not stated	Not stated		
13	Laurence et al., 2016 (Australia)	2004 - 2011	Macrosimulation	Regional health system Health workers:	Population: Age cohorts, gender, population size	Administrative data, burden of disease data,	Scenario analysis - observed	Supply model validated with observed data	Provided explicit and transparent steps in the	While the need sub-model accounted for differences in the

No	Author (country)	The horizon of the projecti on	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
				General practitioners	Health status: prevalence of diseases Provider: productivity	surveys and expert opinion	utilisation and need-based approaches	but validation measures for the need-based model not stated	application of the need-based model.	number and duration of consultations, by age and sex, it was not possible to determine different consultation lengths for different conditions
14	Laurence et al., 2018 (Australia)	2012 - 2033	Macrosimulation	Regional health system Health workers: General practitioners	Population: Age, gender, rural, urban Health status: age- and sex-specific prevalence and incidence of disease categories	Administrative data; Bettering Evaluation and Care of Health (BEACH)	Scenario analysis based on policy options and 95% confidence intervals of the projections.	Not stated	Used constant prevalence rates but built in the impact of policy scenarios; separated rural model from an urban model.	How the productivity or activity standards of GPs were estimated to translate health needs to workforce requirements not stated. Data quality is acknowledged as a critical challenge in the modelling process.
15	MacKenzie et al., 2019 (Canada)	2018 - 2032	Macrosimulation	Regional - Paediatric mental health Health workers: General Practitioners, Nurse Practitioners, Paediatricians,	Population: Age cohorts, gender, population size Health status: prevalence of diseases Provider: productivity, work	Administrative and publicly available data	Scenarios analysis using work divisions amongst health professionals; and clinical focus of the health professionals	Not stated	The provided explicit and transparent methods, including all formulae and how they were derived. It also explicitly allows for the	How the productivity or activity standards of GPs were estimated to translate health needs to workforce requirements not stated. Supplemented with estimates of

No	Author (country)	The horizon of the projection	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
				Psychiatrists, Psychologists, Registered Nurses and Social Workers	division and clinical focus				division of labour; and clinical focus amongst health workers	clinician panels and assumed estimates for illustration
16	Murphy et al., 2017 (Canada)	1918 vs 2009	Microsimulation	Regional - Influenza Health workers: Doctors, nurses, pharmacists, others	Population - Age, size Health status: Disease prevalence Provider: productivity and competence	Administrative, publicly available and assumptions made by a clinical panel	Scenario analysis from the supply of health workers.	Validated through stakeholder consultation which included members of a steering committee made up of clinicians	Provides explicit and transparent steps in the application of the need-based model.	An attempt was made to estimate the final two parameters of the analytical framework – competency prevalence and productivity – using survey methods similar to those described in the pilot study. Because of a low (10%) response rate, alternative methods of estimating these parameters were developed.
17	Murphy et al., 2014 (Jamaica)	15 years (specific dates not stated)	Macrosimulation	Regional health system Health workers: Pharmacists	Population: size, age, sex Health need: disease burden Level of service Provider: productivity	Administrative databases and key informants	Scenario analysis from the supply of health workers.	Findings were validated with the Steering Committee.	Provides explicit and transparent steps in the application of the need-based model and involved local	Data limitations.

No	Author (country)	The horizon of the projecti on	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
									stakeholders for ownership.	
18	Roos et al., 1999 (Canada)	1993/1994	Macrosimulation	Regional health system Health workers: General practitioners	Population: size, age, sex Disease burden: Premature mortality rate (death younger than 75 years) Level of service: Population - physician contact rate Provider: Workload	Administrative and publicly available data	Not stated	Stakeholder validation (committee and Medical Association)	One of the seminal works on need-based analysis.	The paper used the observed workload of physicians as a benchmark for translating 'need for utilisation' into the number of required physicians - There was a wide variation on the observed workload that was not tested in a sensitivity analysis.
19	Roos et al., 1997 (Canada)	1993/1994	Macrosimulation	Regional health system Health workers: Physicians	Population: size, age, sex Disease burden: Premature mortality rate Level of service: Population - physician contact rate Provider: Workload	Administrative and publicly available data	Not stated	Stakeholder validation (committee and Medical Association)	One of the seminal works on need-based analysis.	The paper used the observed workload of physicians as a benchmark for translating 'need for utilisation' into the number of required physicians - There was a wide variation on the observed workload that was not tested in a sensitivity analysis.

No	Author (country)	The horizon of the projecti on	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
20	Segal et al., 2018 (Australia)	2016 (one-off)	Microsimulation	Regional program: mental health care for distressed infants, children, and adolescents Health workers: psychology, nursing, social work, counselling, and teaching	Population: Age cohorts (within 0 - 17 years), gender, population size, family characteristics Health status: risk factors (adversities) for mental illness in the defined population. Provider: time needed (on average per patient) for each of the defined roles along a care pathway	Administrative data, data from separate longitudinal surveys.	Not stated	Two expert advisory groups were established to provide feedback and test findings across the project. Estimates of time needed to deliver services were critically reviewed—via a survey of clinicians and modified if a discrepancy emerged.	Strong theoretical and clinical foundation, linking models of care, clinical competencies with disease burden. Provides a step-by-step process of need-based analysis for the HWF	Whereas the theoretical and clinical basis of the analysis was clearly stated, formalising the analytical part (formula) was not clear. The model is, however, in excel is accompanied as an appendix
21	Segal et al., 2013 (Australia)	2011 (one-off)	Microsimulation	Regional program: mental health care for distressed infants, children and adolescents Health workers: Dietitian, District nurse, Diabetes educator, Practice	Population: size, age, socioeconomic background Health status: diabetes prevalence and complications Provider: Competencies	Administrative and publicly available data; international literature on the prevalence of specific diabetes attributes	Not stated	Three (3) clinical panels were consulted to validate the process and results at each stage	In-depth analysis of the clinical pathways of the different patient attributes of diabetes and translating into the evidence-based need for consultations and	Whereas the theoretical and clinical basis of the analysis was clearly stated, formalising the analytical part (formula) was not clear. The model is, however, in excel is accompanied as an

No	Author (country)	The horizon of the projecti on	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
				nurse, Exercise physiologist, Psychologist, General practitioner, Social worker, Podiatrist, Pharmacist, Ethnic/migrant health worker, Optometrist, Dentist, Occupational therapist, Orthotist, Aboriginal health worker and Community midwife	required to address needs for different patient attributes				then HWF requirements.	appendix An acknowledged limitation is that the model "reflects a population and its health status and other attributes at a particular point of time (most inputs were from 2006) and best-practice care as described in 2011 by clinical experts, also drawing on earlier published guidelines".
22	Sukeri et al., 2015 (South Africa)	One-off (Year not stated)	Macrosimulation	Program: mental health care in a region Health workers: Psychiatrists, Psychologist, Medical Officer, Nurses, Occupational therapists, social workers,	Population: Size of the adult population (18 years and above) Health Status: Prevalence of the three diseases and desired service coverage level of 80% Provider: professional	Administrative, publicly available data and scientific publications for prevalence rates	Not stated	Not stated	Demonstrated the analytical framework (formulae) for analysis and provided a step-by-step explanation of the analysis	No form of validation was indicated. The use of norms explicitly stated by the norm itself is not provided or discussed.

No	Author (country)	The horizon of the projecti on	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
				community health workers	norms for caseloads					
23	Tomblin et al., 2012 (Canada)	2007–2022.	Macrosimulation	National health system Health workers: Nurses	Demography: Population size, age, sex Health need: disease burden Level of service Provider: productivity	Administrative and publicly available data	Scenario analysis based on six policy options: increasing productivity of nurses, increasing RN retention, reducing RN absenteeism, reducing in-migration, reducing training attrition, increasing training enrolments	Not stated	Explored the impact of different factors affecting need and supply in the model.	Not clear how productivity was estimated.
24	Tomblin et al., 2016 (Multiple (OECD countries))	2015 - 2030	Macrosimulation	Multi-country Health workers: midwives, nurses, and physicians	Demography: Population size, age, sex Health need: disease burden Level of service Provider: productivity, participation	Publicly available data - international databases and national websites	Scenario analysis: Multiple scenarios were used to demonstrate the sensitivity of the simulations to different	No stakeholder or statistical validation is described.	The first attempt to apply the need-based framework in a multi-country context.	Used self-reported measures of health as a marker of health status (no prevalence or disease burden data was used from objective measures) The productivity of health workers was

No	Author (country)	The horizon of the projection	Type of model/modelling approach	Scope of application (dx, region, program, national health system)	Input parameters and data source	Data sources	Sensitivity analysis	Model validation process	Main strengths	Limitations
							assumed future values of model parameters			assumed from previous work. No direct elicitation was done.
25	Vedanthan et al., 2019 (Kenya)	Three years (dates not stated)	Microsimulation	Disease: Hypertension in a region Health workers: Physicians, Clinical Officer, Nurses, Pharmacist and Triage Staff/Technicians	Demographics: Assumed number of patient enrolments, 26 “patient states” or attributes of patients Health status: Degree of control of hypertension Level of service: number of follow-ups needed provider: Activity standards elicited through time-motion study	Administrative data, patient records and primary data collection.	Two scenarios of need (ramp-up and steady-state) modelled to explore their impact on HWF need	Clinical teams validation and feedback	Used Focus Group Discussions and Delphi technique alongside clinical protocols to identify patient treatment pathways; used the time-motion study to estimate the time required to deliver services (activity standards)	The empirical model made no direct linkage with population growth, age cohorts, gender and prevalence of the disease in the population.

2.4.1.1 Year of publication and country of origin

Twenty-one (84%) of the included studies were published within the last decade (2010–2020). Only three (12%) of the included studies were published before 2005 (see Figure 2).

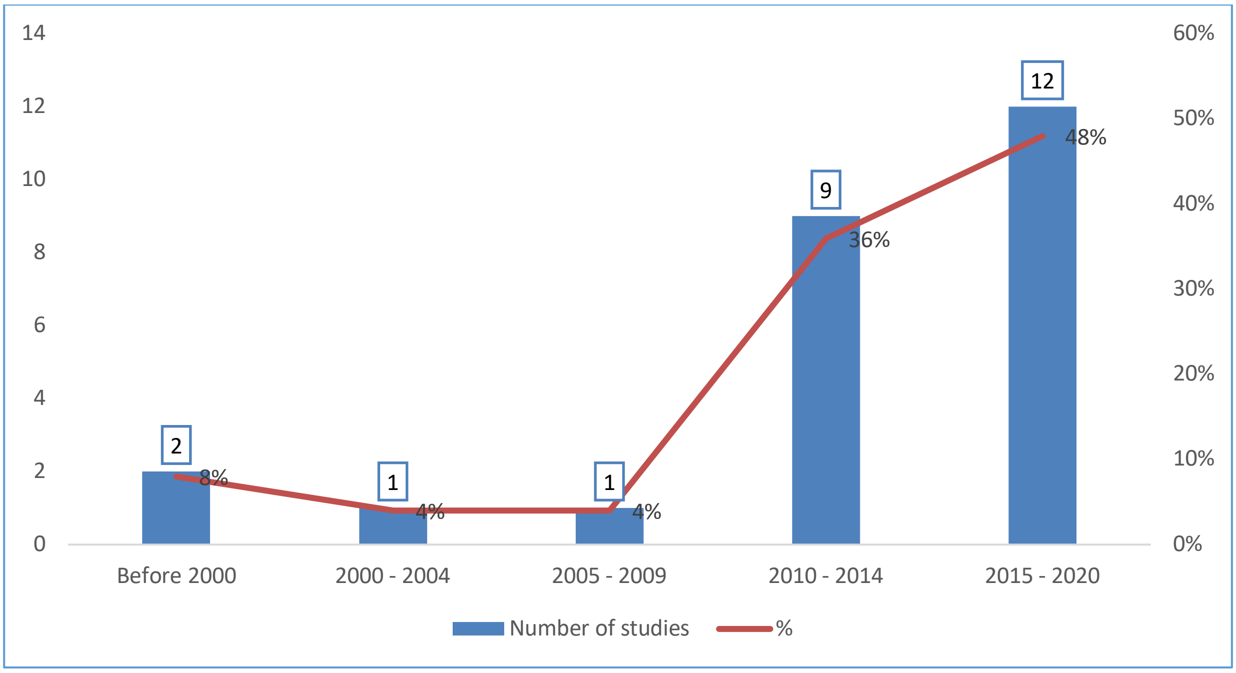

Figure 2: Year of publication of included studies

2.4.1.2 Country of origin of the included studies

As shown in Table 1, twenty-two of the included studies (88%) were from 11 countries (Australia, Canada, England, Guinea, Ireland, Israel, Jamaica, Kenya, Singapore, South Africa, and the United States). Three (12%) of the papers reported multi-country analysis (Bruckner *et al.*, 2011; Tomblin Murphy *et al.*, 2016; Birch *et al.*, 2020) whilst five (20%) were based on the context of Canada (Roos *et al.*, 1997, 1999; Tomblin Murphy *et al.*, 2012b; Murphy *et al.*, 2017; MacKenzie *et al.*, 2019b). Analysis based on Australia's context was reported by four of the included papers which represent 16% (Segal *et al.*, 2013, 2018; Laurence and Karnon, 2016; Laurence *et al.*, 2018). Also, three of the publications originated from and were based on the context of England, which represents 12% of the included papers (Gallagher *et al.*, 2010, 2013; Birch *et al.*, 2013). The context of the United States and Singapore each contributed two publications to the included studies, and the rest of the countries had one publication each. Three countries (Canada, Australia, and England) accounted for 48% of the publications included. Only four of the included papers (16%) were based on the context of low-and-middle-income countries (Jansen *et al.*, 2014;

Murphy *et al.*, 2014; Sukeri *et al.*, 2015; Vedanthan *et al.*, 2019), of which three were from sub-Saharan Africa (Kenya, South Africa and Guinea).

2.4.2 Quality of the studies included

The overall scores of the assessment revealed substantial variations in the considerations made in the model development and application (or at least how they were reported). The papers included met between 57.7% and 88.5% of the adopted criteria with an average of 72% (95% CI: 69.5% - 75.9%). Only five (20%) of the studies (Ansah *et al.*, 2015, 2019; Laurence and Karnon, 2016; Murphy *et al.*, 2017; Segal *et al.*, 2018) measured up to 80% or more of the adopted criteria which were considered to be 'very comprehensive and of high quality'. Another set of seven (28%) of the studies (Roos *et al.*, 1997; Gallagher *et al.*, 2013; Segal *et al.*, 2013; Murphy *et al.*, 2014; Ahern *et al.*, 2019; MacKenzie *et al.*, 2019; Birch *et al.*, 2020) scored between 70% and 79% and were considered to be 'quite comprehensive and of good quality'. The rest (scores between 50% and 69%) were considered to be moderate in terms of comprehensiveness and quality. No included study scored below 50% to be categorised as not comprehensive and of poor quality. Figure 3 provides a summary of the assessment scores, and Table 2 provides the detailed items of the assessment criteria with the individual papers scores.

The main areas of weaknesses across the studies were that they did not: a) explicitly report some key assumptions, b) undertake validation of the analysis, c) conduct sensitivity analysis and in most instances, d) account for the cost implications of the estimated needs-based requirements.

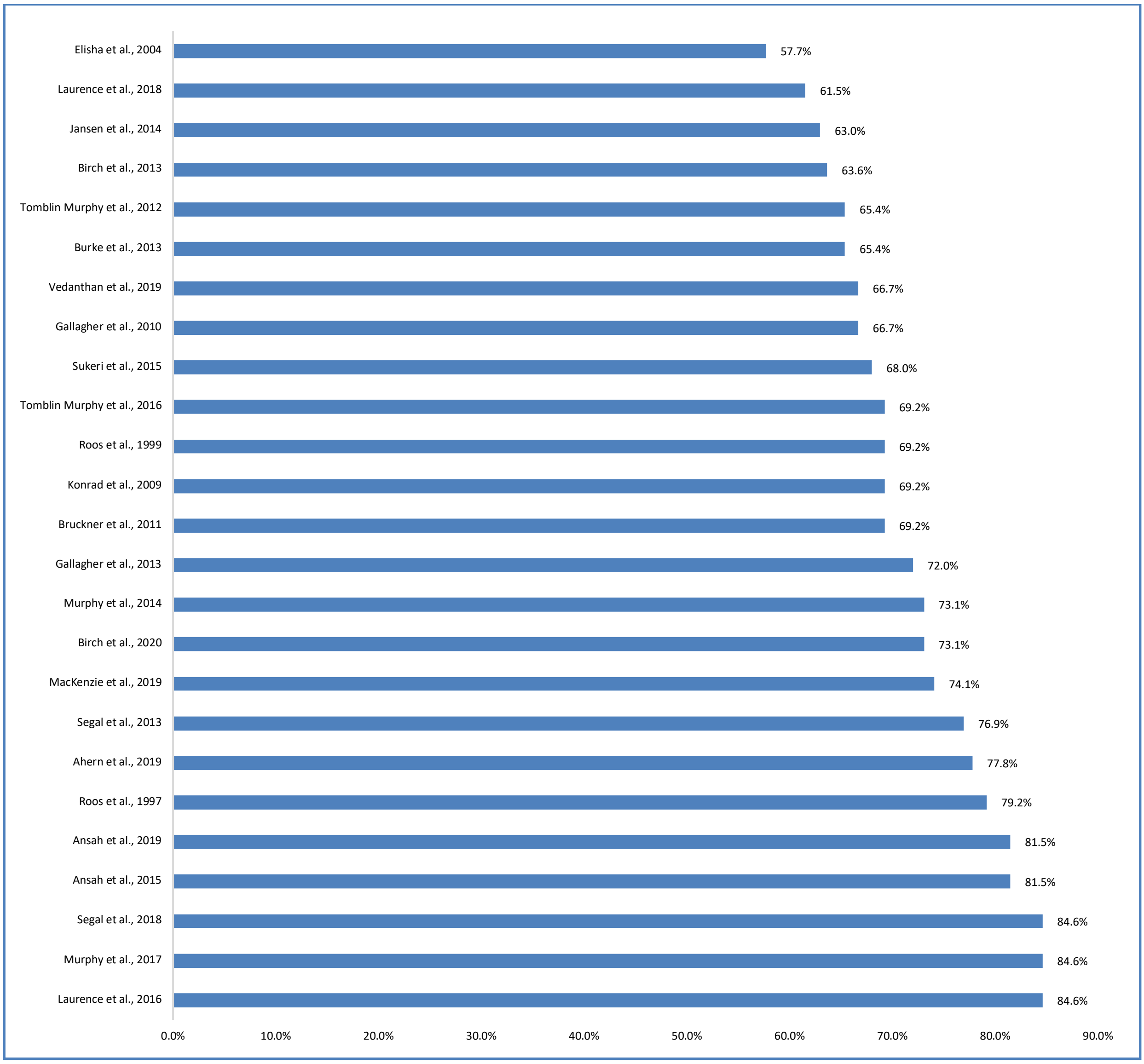

Figure 3: Summary of comprehensiveness and quality of studies included

Table 2: Quality assessment matrix

DOMAIN	CRITERIA	Ahern et al., 2019	Ansah et al., 2015	Ansah et al., 2019	Birch et al., 2020	Birch et al., 2013	Bruckner et al., 2011	Burke et al., 2013	Elisha et al., 2004	Gallagher et al., 2010	Gallagher et al., 2013	Jansen et al., 2014	Konrad et al., 2009	Laurence et al., 2016	Laurence et al., 2018	MacKenzie et al., 2019	Murphy et al., 2017	Murphy et al., 2014	Roos et al., 1999	Roos et al., 1997	Segal et al., 2018	Segal et al., 2013	Sukeri et al., 2015	Tomblin Murphy et al.,	Tomblin Murphy et al.,	Vedanthan et al., 2019
1. Health policy alignment	1. Is there a clear statement of the health policy objective/problem?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2. Scope of modelling	2. Is the geographical area or jurisdiction defined?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	3. Is/are the categories of health workers being modelled defined?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	4 Is the horizon (timeframe) of projection defined?	Y	Y	Y	NS	N/A	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NS	Y	Y	Y
3. Source of data and assumptions	5. Are sources of all input data clearly stated and referenced?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N/A	Y
	6. Are all structural assumptions of the model stated and consistent with the modelling objective?	Y	Y	Y	Y	N/A	NS	Y	NS	Y	Y	NS	Y	Y	Y	Y	Y	Y	NS	NS	Y	Y	Y	Y	Y	Y
4. Identificati on of	7. Is the population to be served clearly defined by size, age	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

DOMAIN	CRITERIA	Ahern et al., 2019	Ansah et al., 2015	Ansah et al., 2019	Birch et al., 2020	Birch et al., 2013	Bruckner et al., 2011	Burke et al., 2013	Elisha et al., 2004	Gallagher et al., 2010	Gallagher et al., 2013	Jansen et al., 2014	Konrad et al., 2009	Laurence et al., 2016	Laurence et al., 2018	MacKenzie et al., 2019	Murphy et al., 2017	Murphy et al., 2014	Roos et al., 1999	Roos et al., 1997	Segal et al., 2018	Segal et al., 2013	Sukeri et al., 2015	Tomblin Murphy et al.,	Tomblin Murphy et al.,	Vedanthan et al., 2019
population health needs	cohorts, gender or other relevant demographic/socioeconomic variables?																									
	8. Is the population need for health services directly derived from disease burden (prevalence, mortality or risk factors) or other priority health issues?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	9. Is the statistical procedure or formulae for deriving the need for services clearly stated or referenced?	Y	Y	Y	Y	Y	Y	Y	NS	NS	Y	NS	Y	Y	NS	Y	Y	NS	Y	Y	Y	Y	Y	NS	NS	Y
	10. Are assumptions of how future changes in need are taken into account in the model stated?	NS	Y	Y	N/A	N/A	N/A	N/A	N/A	NS	N/A	NS	N/A	NS	NS	NS	N/A	NS	N/A	N/A	N/A	N/A	N/A	Y	NS	Y
5. Estimation of staffing requirements	11. Does the model explicitly consider the role and	Y	Y	Y	Y	Y	Y	Y	Y	Y	NS	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NS	Y	NS	NS

DOMAIN	CRITERIA	Ahern et al., 2019	Ansah et al., 2015	Ansah et al., 2019	Birch et al., 2020	Birch et al., 2013	Bruckner et al., 2011	Burke et al., 2013	Elisha et al., 2004	Gallagher et al., 2010	Gallagher et al., 2013	Jansen et al., 2014	Konrad et al., 2009	Laurence et al., 2016	Laurence et al., 2018	MacKenzie et al., 2019	Murphy et al., 2017	Murphy et al., 2014	Roos et al., 1999	Roos et al., 1997	Segal et al., 2018	Segal et al., 2013	Sukeri et al., 2015	Tomblin Murphy et al.,	Tomblin Murphy et al.,	Vedanthan et al., 2019
	determinants of productivity (i.e., units of service per hour of work) or activity standard (time required to deliver a unit of service)?																									
	12. Is the approach to eliciting health worker productivity clearly described (primary studies, secondary sources, panel discussion, assumptions, etc.)?	Y	Y	Y	Y	NS	Y	NS	Y	NS	NS	Y	Y	Y	NS	Y	Y	Y	NS	N/A	Y	Y	Y	NS	Y	NS
	13. Are assumptions of the division of work among different cadres or role assignment of different professional groups stated?	Y	NS	NS	Y	N/A	Y	NS	NS	Y	N/A	Y	NS	N/A	N/A	Y	Y	N/A	NS	N/A	Y	Y	Y	N/A	Y	Y
	14. Are the statistical formulae for translating population health needs for services	Y	Y	Y	Y	Y	Y	Y	NS	NS	NS	NS	Y	Y	NS	Y	Y	Y	Y	Y	Y	Y	Y	NS	Y	Y

DOMAIN	CRITERIA	Ahern et al., 2019	Ansah et al., 2015	Ansah et al., 2019	Birch et al., 2020	Birch et al., 2013	Bruckner et al., 2011	Burke et al., 2013	Elisha et al., 2004	Gallagher et al., 2010	Gallagher et al., 2013	Jansen et al., 2014	Konrad et al., 2009	Laurence et al., 2016	Laurence et al., 2018	MacKenzie et al., 2019	Murphy et al., 2017	Murphy et al., 2014	Roos et al., 1999	Roos et al., 1997	Segal et al., 2018	Segal et al., 2013	Sukeri et al., 2015	Tomblin Murphy et al.,	Tomblin Murphy et al.,	Vedanthan et al., 2019
	into health workforce requirements stated or referenced?																									
6. Model validation	15. Are statistical procedures for checking the model validity described?	NS	Y	Y	NS	NS	NS	NS	NS	NS	NS	NS	NS	Y	Y	NS	NS	NS	NS	NS	Y	Y	NS	NS	NS	Y
	16. Are procedures for model/results validation with policymakers, peers or stakeholders described?	NS	Y	Y	NS	NS	NS	NS	NS	NS	NS	Y	NS	Y	NS	NS	Y	Y	Y	Y	Y	Y	NS	NS	NS	NS
7. Results	17. Do the results presented adequately address the objective of the modelling?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	18. Do the results include estimates of the population need for health services?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NS	Y	Y	NS	NS	Y	NS	Y	Y	Y	Y	Y	Y	Y	Y
	19. Do the results include estimates of HWF requirements to meet the population's need for health services?	Y	Y	Y	Y	NS	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

DOMAIN	CRITERIA	Ahern et al., 2019	Ansah et al., 2015	Ansah et al., 2019	Birch et al., 2020	Birch et al., 2013	Bruckner et al., 2011	Burke et al., 2013	Elisha et al., 2004	Gallagher et al., 2010	Gallagher et al., 2013	Jansen et al., 2014	Konrad et al., 2009	Laurence et al., 2016	Laurence et al., 2018	MacKenzie et al., 2019	Murphy et al., 2017	Murphy et al., 2014	Roos et al., 1999	Roos et al., 1997	Segal et al., 2018	Segal et al., 2013	Sukeri et al., 2015	Tomblin Murphy et al.,	Tomblin Murphy et al.,	Vedanthan et al., 2019
	20. Is HWF gaps analysis (comparison with current/future supply) presented?	Y	NS	NS	NS	NS	Y	NS	NS	Y	Y	Y	NS	Y	Y	Y	Y	Y	NS	NS	Y	NS	N/A	Y	Y	NS
	21. Is the cost of providing the modelled care or HWF requirement explored and presented/stated/referenced?	NS	NS	NS	Y	N/A	NS	NS	NS	NS	Y	NS	NS	NS	NS	NS	NS	NS	NS	Y	Y	Y	Y	NS	NS	NS
8. Sensitivity analysis	22. Was the potential impact of alternative parameter data or explored and presented?	NS	NS	NS	NS	NS	NS	NS	NS	Y	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Y	NS
	23. Was the potential impact of alternative policy scenarios and assumptions explored and presented?	Y	Y	Y	NS	NS	NS	NS	NS	Y	Y	Y	NS	Y	Y	Y	Y	Y	NS	NS	NS	NS	NS	Y	Y	NS
10. Interpretation and discussion	24. Is the model results interpreted in the context of the data and applicable population?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

DOMAIN	CRITERIA	Ahern et al., 2019	Ansah et al., 2015	Ansah et al., 2019	Birch et al., 2020	Birch et al., 2013	Bruckner et al., 2011	Burke et al., 2013	Elisha et al., 2004	Gallagher et al., 2010	Gallagher et al., 2013	Jansen et al., 2014	Konrad et al., 2009	Laurence et al., 2016	Laurence et al., 2018	MacKenzie et al., 2019	Murphy et al., 2017	Murphy et al., 2014	Roos et al., 1999	Roos et al., 1997	Segal et al., 2018	Segal et al., 2013	Sukeri et al., 2015	Tomblin Murphy et al.,	Tomblin Murphy et al.,	Vedanthan et al., 2019
	25. Is there is a discussion comparing the model with current knowledge of HWF issues in the jurisdiction or with other studies?	Y	Y	Y	Y	Y	NS	Y	Y	NS	Y	NS	Y	Y	Y	Y	Y	Y	Y	Y	Y	NS	NS	NS	NS	NS
	26. Is there a discussion on the generalizability, strengths and limitations of the model?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
11. Public access to model	27. Does the publication include the model in an unprotected spreadsheet(s) or source codes for software (or links to them)?	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	Y	NS	NS	NS	NS	Y	Y	NS	NS	NS	NS	NS	Y
Total Scores (Yes)		21	22	22	19	14	18	17	15	18	18	17	18	23	16	20	22	19	18	19	22	20	17	17	18	18
Not Stated		6	5	5	7	8	8	9	11	9	7	10	8	3	10	7	4	7	8	5	4	6	8	9	8	9
Not Applicable (N/A)		0	0	0	1	5	1	1	1	0	2	0	1	1	1	0	1	1	1	3	1	1	2	1	1	0

Notes: Y = Yes, NS = Not Stated, N/A = Not applicable for the nature of the analysis.

2.4.3 Scope and Typology of Needs-Based Modelling Applications

2.4.3.1 The time horizon of modelling

Twelve (12) out of the 25 (48%) studies included in the review made projections of future health workforce requirements (for the jurisdictions in which they were based) while 13 studies (52%) focused on one-time point analysis of the health workforce requirements (Figure 4). Amongst the studies that focused on long-term projections, the duration or time horizon of the projection ranged from 3 to 33 years, with an average of 17 years. However, 75% (n = 9) of these studies made the projections for a time horizon of ten years or more.

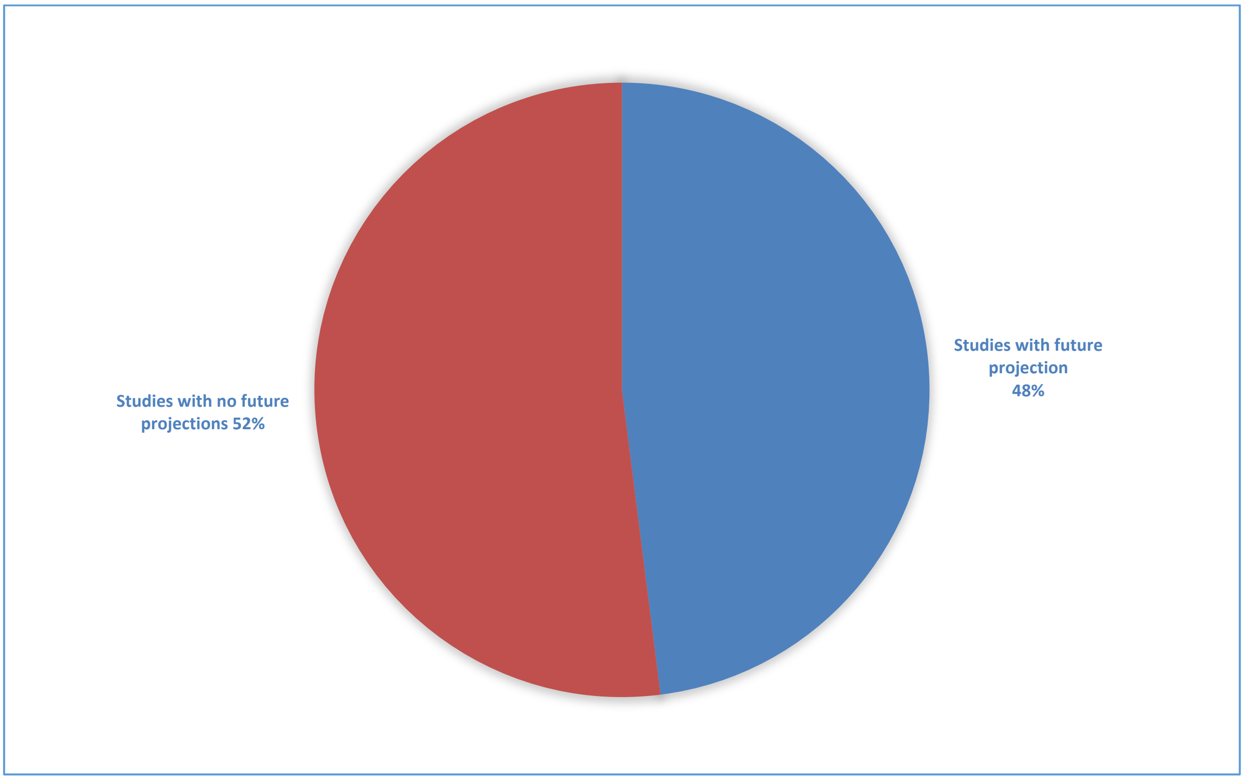

Figure 4: One-time point analysis versus long-term projections

2.4.3.2 Scope of application of need-based health workforce planning models

Besides the three papers that employed multi-country applications of the need-based health workforce modelling (Bruckner *et al.*, 2011; Tomblin Murphy *et al.*, 2016; Birch *et al.*, 2020) – two of which covered multiple disease areas, only other two papers (Tomblin Murphy *et al.*, 2012b; Birch *et al.*, 2013b) reported the application of needs-based health workforce models at the level of a national health system across several disease areas or programs. Most of the studies (n = 9, 36%) reported applications in specific disease areas or programs within the scope of a defined sub-national level. In five (20%) of the studies, the focus was on the health system need for particular categories of health workers within a sub-national or regional context (Roos *et al.*, 1997, 1999; Murphy *et al.*, 2014; Laurence and Karnon, 2016; Laurence *et al.*, 2018). Also, the health workforce categories covered in the applications ranged from single cadres such as nurses, general practitioners, pharmacists to multiple health workers (Table 3).

Table 3: Distribution of studies by scope and area of population health needs focused

Jurisdictional scope	The focus of population health needs	No. of studies	Percent
Multi-country	Mental health	1	4%
	Multiple diseases	1	4%
	Non-communicable diseases (cancer, diabetes and myocadiac infarction)	1	4%
Multi-country Total		3	12%
National health system	Multiple diseases	2	8%
National health system Total		2	8%
National program area	Eyecare	2	8%
	Maternal and newborn health	1	4%
	Mental health	4	16%
	Oral health	2	8%
National program area Total		9	36%
Sub-national health system	Influenza	1	4%
	Multiple diseases	5	20%
Sub-national health system Total		6	24%
Sub-national program area	Hypertension	1	4%
	Mental health	3	12%
	Oral health	1	4%
Sub-national program area Total		5	20%
Overall		25	100%

2.4.3.3 Typology of Needs-Based Model Applications

The nature of models developed and applied primarily depended on the practical feasibility given the focus and scope of the analysis rather than the issue of methodological rigour. Some studies employed micro-level simulation techniques whilst others adopted macro-model techniques. A distinction is also noticeable in what seems to be needs-informed demand analysis versus complete needs-based analysis.

2.4.3.3.1 Needs-based macro-simulation models

Studies that adopted macro-level modelling techniques used aggregate population-based evidence on the level of health which included prevalence rates, mortality rates and risk factors alongside aggregate demographic data (population size, gender, age, etc.) to estimate the population need for health services, and then translated into health workforce requirements. The vast majority (n = 19, 76%) of the papers included in the review adopted this technique (Roos *et al.*, 1997, 1999; Elisha *et al.*, 2004; Konrad *et al.*, 2009; Gallagher *et al.*, 2010; Bruckner *et al.*, 2011; Tomblin Murphy *et al.*, 2012, 2016; Burke *et al.*, 2013; Jansen *et al.*, 2014; Ansah *et al.*, 2015; Sukeri *et al.*, 2015; Laurence and Karnon, 2016; Laurence *et al.*, 2018; MacKenzie *et al.*, 2019; Birch *et al.*, 2020). In these studies, no individual patient-level information or assumptions were made or required to derive the population need for health services. The analytical applications were almost exclusively broad in scope, being either multi-country in nature or covering a range of disease/program areas in a national or sub-national health system. The main feature is the exclusive use of population-based estimates of need variables, often obtainable from large surveys, routine administrative data, or burden of disease reports.

2.4.3.3.2 Needs-based micro-simulation models

Studies that employed micro-simulation approaches to the modelling used best-practice clinical guidelines and patient-level attributes – from routine data, treatment guidelines or expert opinion to adjust population-based estimates of disease prevalence for deriving the health service needs which were then translated into health workforce requirements. For example, Segal *et al.* (2013) developed a need-based model for diabetes in which treatment protocols and practice guidelines were used to identify 26 unique attributes of individual patient needs that were then translated into clinician contact hours required to deliver the best-practice care. A similar approach was replicated in the area of mental health care for distressed infants, children, and adolescents (Segal *et al.*, 2018). A recent study in Kenya also adopted a similar approach to identify the needs of hypertensive patients (Vedanthan *et al.*, 2019). In another application, Ahern *et al.* (2019) made use of an international survey of self-reported health that elicited individual-level data on their health status to estimate the need for dental services. Thus, the distinguishing feature of the microsimulation models is the use of patient-level data (or the explicit assumptions of individual-level variables) for the derivation of health service needs. Six (24%) of the included studies adopted the microsimulation approach for modelling need-based requirement for the health workforce, (Gallagher *et al.*, 2013; Segal *et al.*, 2013, 2018; Murphy *et al.*, 2017; Ahern *et al.*, 2019; Vedanthan *et al.*, 2019). All but one of these studies did not extrapolate the need beyond a one-time point (current situation) analysis. By the very nature of detailed information required at the patient level to determine the needs, the microsimulation models were mostly applied to specific (single) disease areas such as diabetes and hypertension, among others.

2.4.3.3.3 Needs-informed demand models versus complete needs-based models

Across the micro and macro simulations, the analytical application of the needs-based framework also was either completely applied for the estimation of health workforce requirements (complete needs-based models) or adjusted with the currently observed levels of demand for health services (needs-informed demand models) (Murphy *et al.*, 2016)). In the 'needs-informed demand analysis' or what Gallagher *et al.* (2013) considered as a 'demand-weighted' needs-based analysis, the need for dental health services in England was estimated using a measure of health and demographic variables. However, in translating into the health workforce requirements, the estimated need was adjusted by the observed levels of service utilisation (Gallagher *et al.*, 2010, 2013). In one such study, the authors justify "that the change in the number of all new patients seeking care will be proportional to the change in the prevalence of [disease] conditions among residents" (Ansah *et al.*, 2015). Two other earlier attempts at need-based health workforce planning made similar assumptions based on regression analysis of observed service utilisation by age cohorts (Roos *et al.*, 1997, 1999). However, most of the included papers (n = 20, 80%) reported applying the need-based framework without adjusting the needs for the currently observed levels of service utilisation or demand.

2.4.4 Synthesis of Needs-Based Health Workforce Modelling Considerations

At least five of the papers proposed explicit processes or steps for undertaking needs-based analysis upon which their application was based (Segal *et al.*, 2013, 2018; Jansen *et al.*, 2014; Laurence and Karnon, 2016; Tomblin Murphy *et al.*, 2016). In particular, Segal *et al.* (2018) proposed seven core questions of the needs-based workforce modelling while seven criteria guided the work of other authors for identifying health workforce planning approaches appropriate to a given country or jurisdiction (Tomblin Murphy *et al.*, 2016). However, a synthesis of the reported methods across the included studies revealed six broad methodological and process considerations that were typical in the needs-based health workforce modelling, albeit with some variations in how they were analytically operationalised or implemented.

2.4.4.1 Defining the scope

The papers that provided a process blueprint identified defining the scope of the needs-based analysis as a critical first step. The scope, which various authors contend that must be in alignment with a health system objective (such as the attainment of UHC, addressing demographic changes etc.); and being explicit with the jurisdictional coverage of the planning (e.g. country, region etc.) (Segal *et al.*, 2013; Tomblin Murphy *et al.*, 2016). Additionally, specifying the planning horizon or timeframe (e.g. consistent with funding), the population (or the section of it) that is being planned for as well as the health workers being prioritised (Segal *et al.*, 2013; Jansen *et al.*, 2014; Laurence and Karnon, 2016; Vedanthan *et al.*, 2019) were considered the initial basics. In this process, some of the papers highlighted the importance of stakeholder engagement which eventually strengthened ownership of both the modelling process and the findings (Jansen *et al.*, 2014; Murphy *et al.*, 2014; Ansah *et al.*, 2015).

2.4.4.2 Analysing the Population's Need for Health Services

One of the critical components and distinguishing features of needs-based models is the explicit quantification of the population's need for health services from which health workforce requirements can be derived. Across the studies, the population and demographic variables, measures of the population's level of health (or health deficit) and level of service (or frequency of service) were the key components used to identify and quantify the health service needs of a given population.

2.4.4.2.1 Population size and demography

All the studies included in the review considered the size of the population within the defined jurisdiction in estimating the need for services. In addition to the population size, twenty (80%) of the studies also conducted the analysis by the age cohorts of the population with seventeen studies (68%) incorporating the gender dimension of the population. Only a few studies further disaggregated the population by rural versus urban (Laurence *et al.*, 2018), family characteristics (Segal *et al.*, 2018) and other socioeconomic considerations (Segal *et al.*, 2013).

2.4.4.2.2 Measures of population's level of health

The studies mainly used prevalence rates of diseases, health risk factors, self-reported state of health, rates of disease complications and premature mortality rates as the main measures of population health or its deficit. In most of the studies (60%), population-based prevalence rates of priority diseases and risk factors in the population (or epidemiology) were used as the measures of population-level of health (Konrad *et al.*, 2009; Gallagher *et al.*, 2010; Bruckner *et al.*, 2011; Tomblin Murphy *et al.*, 2012, 2016; Birch *et al.*, 2013, 2020; Burke *et al.*, 2013; Murphy *et al.*, 2014; Ansah *et al.*, 2015, 2019; Sukeri *et al.*, 2015; Laurence and Karnon, 2016; Laurence *et al.*, 2018; MacKenzie *et al.*, 2019). In these studies, the size of the population faced with diseases or risk factors (measured by prevalence rates) represented the areas and magnitude of health service needs. In another study, self-reported health problems were also used as a marker of needs areas (Ahern *et al.*, 2019). In disease-specific microsimulation models, rate of complications (e.g. in a diabetes model) and level of control (e.g. in a hypertension model) and risk factors (e.g. in mental health) were used as markers of need (Segal *et al.*, 2013, 2018a; Vedanthan *et al.*, 2019). Two earlier studies also used premature mortality rates (defined as death younger than 75 years) as a marker of the population's level of health (Roos *et al.*, 1997, 1999). Explicitly defining the areas of population's health need through a strategic review of documents (desk review) and discussions with experts or stakeholders was highlighted as a central part, if not the ideal way, of identifying the area and magnitude of need in the modelling process (Jansen *et al.*, 2014; Murphy *et al.*, 2014; Segal *et al.*, 2018).

2.4.4.2.3 Level of service

Identifying the 'basket of interventions' or 'services tasks' that a health care system plans, or ought to plan, to deliver that will address deficits in the level of health were reported in many of the studies as a critical part of what constitutes the population's service needs. It also involves the frequency or number of times a particular service(s) should be received within a period (say one year) by each member of the population that is in need of the service(s). There was, however, no uniformity across studies on how this was incorporated in the analytical work. For example, various works by Segal made use of best practice clinical guidelines for identifying the services or interventions for different attributes of patients (Segal *et al.*, 2013, 2018). In some studies, clinical expert panels were used to decide the basket of services and frequency (Murphy *et al.*, 2017; Vedanthan *et al.*, 2019) while in some the currently observed patterns of service delivery and frequency of use or the observed contact rates were used (Roos *et al.*, 1997, 1999; Elisha *et al.*, 2004; Konrad *et al.*, 2009; Gallagher *et al.*, 2010). Jansen and colleagues also used a nationally defined essential package of health services as the basis (Jansen *et al.*, 2014). Irrespective of the approach, what seems to be clear across the studies is that the required service tasks identified, must be consistent with local clinical practices, policy direction or experts' opinion or a combination of all.

2.4.4.2.4 Estimating the evidence-based service requirements

Across eighteen (72%) of the included studies, a statistical procedure, or formulae for deriving the need for services was clearly stated or referenced. Most of the analytical framework or formulae reflected 'the evidence-based service requirements by the patient group' as a sum of the product of the population size, the level of health (proportion of the population with disease or risk factors) and the level of service needed (service task/interventions and frequency in a given year) (Sukeri *et al.*, 2015; MacKenzie *et al.*, 2019; Vedanthan *et al.*, 2019; Birch *et al.*, 2020). However, only three studies provided explicit assumptions of how the current estimates of needs were extrapolated into the future for long-term projections (Ansah *et al.*, 2015, 2019; Vedanthan *et al.*, 2019). Most of the studies that included long-term projections tended to make implicit assumptions of a constant level of health (such as disease prevalence) and level of service for estimating the future requirements, with only the population size being the changing variable into the future.

2.4.4.3 Translating the Evidence-Based Service Requirements into Health Workforce Requirements

To translate the evidence-based or needs-based service requirements into health workforce requirements, in the analytic models, some authors reported dividing the estimated evidence-based service requirements by a measure of the rate of working or productivity standard of the concerned health worker (Segal *et al.*, 2018; Ahern *et al.*, 2019; MacKenzie *et al.*, 2019; Birch *et al.*, 2020). The main considerations the authors took into account were matching the competencies of health workers to the service delivery tasks and eliciting (or making assumptions about) the standard workload or productivity of the health workers.

2.4.4.3.1 Matching skills and competencies with identified interventions to address needs

In some studies, the authors reported matching the skills and competencies health workers needed to have to undertake service delivery tasks for the identified health services requirements (Segal *et al.*, 2013, 2018; Murphy *et al.*, 2017; Birch *et al.*, 2020). This approach answers a critical question posed by Segal et al., "what broad roles, skill sets, and competencies are required by clinicians to deliver appropriate care [when the population health need is established]?" (Segal *et al.*, 2018, P.e298). Eliciting the skills and competencies was either done through the views of clinician expert (Segal *et al.*, 2018), a self-reported survey from clinicians or time-motion analysis or scope of professional practice by professional licensing authorities (Vedanthan *et al.*, 2019; Birch *et al.*, 2020). In some studies where different health professionals could competently undertake the same service delivery tasks, assumptions of proportions for work division between the cadres were made (Elisha *et al.*, 2004; MacKenzie *et al.*, 2019; Birch *et al.*, 2020), and in some instances, professional staffing ratios were used (Bruckner *et al.*, 2011). However, in such studies, the conclusions made from model results in respect of a particular cadre were highly sensitive to the assumptions made about the proportion of workload assigned to the health worker (work division) (Birch *et al.*, 2020) or the staffing ratios (Bruckner *et al.*, 2011; Sukeri *et al.*, 2015).

2.4.4.3.2 Eliciting standard workload or productivity measures

The vast majority of studies (n = 21, 84%) explicitly considered some measure of workforce productivity – either the rate of work (units of service per hour of work) or a standard service delivery time (amount of time it will take a health professional to deliver one unit of service). Four studies (16%) reported directly eliciting productivity standards from health professionals either through a survey (Segal *et al.*, 2018; Birch *et al.*, 2020) or clinician expert panels (Murphy *et al.*, 2017; MacKenzie *et al.*, 2019) or a combination of both. One microsimulation study employed time-motion observation to determine the average time it took health professionals to deliver a given task (Vedanthan *et al.*, 2019) while earlier works used observed levels of workload for benchmarking (Roos *et al.*, 1997, 1999). Another study assumed 'equal length' of physician consultation time (service standard) for all conditions (Laurence and Karnon, 2016). Elisha *et al.* (2004) also introduced a concept of the 'Basic Unit of Care' (BUC), defined as "the shortest time required on average" for a standard intervention or service task to be undertaken. The activity standard for all services can then be set as a multiple (or fraction) of the BUC. Productivity is then defined as the available working time for a health professional (in hours) multiplied by the BUCs per hour. In some studies that explored the impact of productivity assumptions, the conclusions of either a needs-based shortage, surplus or a balance were significantly impacted by even small changes in the standard service delivery time, or productivity measure assumed (Tomblin Murphy *et al.*, 2012, 2016).

2.4.4.4 Exploring the Resource Implications

The majority (n = 13, 52%) of the studies compared the estimated needs-based health workforce requirements with the existing or anticipated supply of the health workforce. Although exploring the cost implications of both the supply and requirements has been acknowledged as an essential aspect of planning (Segal *et al.*, 2013; Murphy *et al.*, 2016), only six of the studies (24%) included considerations of cost or wage bill implications of the estimated health workforce requirements (Roos *et al.*, 1997; Gallagher *et al.*, 2013; Segal *et al.*, 2013, 2018; Sukeri *et al.*, 2015; Birch *et al.*, 2020) and only one compared it with an available budget (Segal *et al.*, 2018) while none of the studies examined the estimated cost in the context of the future anticipated budget or economic capacity of the jurisdiction.

2.4.4.5 Conducting Sensitivity Analyses

Across studies, two types of sensitivity analysis or modes of analysing uncertainties were undertaken – parameter uncertainty analysis and policy scenarios (or structural uncertainty analysis).

2.4.4.5.1 Parameter uncertainty

A few studies explored the sensitivity of input parameters on service requirements using univariate or multivariate sensitivity analysis and provided confidence, or predictive intervals around the base estimated needs and health workforce requirements (Ansah *et al.*, 2015, 2019; Laurence *et al.*, 2018). The most commonly varied input parameters to explore its impact on health workforce requirements were measures of productivity and work divisions (Ahern *et al.*, 2019; MacKenzie *et al.*, 2019; Birch *et al.*, 2020). In all studies that included parameter uncertainty analysis, they generally showed that the projections regarding the future health workforce situation were highly sensitive to even small changes in these parameters. However, only a few of the studies reported workforce requirements with predictive intervals accounting for the level of uncertainty in the parameter values used (Ansah *et al.*, 2015, 2019; Laurence *et al.*, 2018). Instead, most studies conducted policy scenario analysis as a way of exploring uncertainty.

2.4.4.5.2 Structural uncertainty or policy scenarios

Most studies (n = 13, 52%) explored the impact of different policy scenarios on the conclusions drawn – either shortage or surplus (Gallagher *et al.*, 2010, 2013; Tomblin Murphy *et al.*, 2012, 2016; Murphy *et al.*, 2017; Jansen *et al.*, 2014; Murphy *et al.*, 2014; Ansah *et al.*, 2015, 2019; Laurence and Karnon, 2016; Laurence *et al.*, 2018; Ahern *et al.*, 2019; MacKenzie *et al.*, 2019). The policy scenarios were mostly on the factors that influence the supply side of the health workforce rather than the needs-based requirements, which is the thrust of this review.

Nevertheless, some conducted multivariate sensitivity analysis (Tomblin Murphy *et al.*, 2012) whereby all the policy scenarios were concurrently varied from the best to worst-case scenarios which provided a plausible range of results that are expected to contain the true situation in the future even if the input values and assumptions used were imprecise.

2.4.4.6 Conducting Model Validation

Two levels of model validation were used in some of the studies. A few studies used formal statistical approaches to establish the validity of the model (Ansah *et al.*, 2015, 2019; Laurence and Karnon, 2016). On the other hand, many of the studies (n = 10, 40%) used clinical experts and/or stakeholders to validate the assumptions or findings of the modelling (Roos *et al.*, 1997, 1999; Segal *et al.*, 2013, 2018; Jansen *et al.*, 2014; Murphy *et al.*, 2014, 2017; Ansah *et al.*, 2015, 2019; Laurence and Karnon, 2016). Others used a 'group modelling' approach in which the clinical committees, expert panels, policy actors or other interest groups were part of the discussions and decision making throughout the modelling process, or at critical checkpoints in the process (Murphy *et al.*, 2014; Laurence and Karnon, 2016; Segal *et al.*, 2018; Ansah *et al.*, 2019).

2.5 DISCUSSION

This review finds that there has been an increased uptake of the needs-based framework for modelling health workforce requirements since 2010. However, there were more illustrative analytical applications with very few analyses intended to inform policy or strategy in countries. This finding corroborates with a review of planning documents at the country-level from 32 high-income countries of the Organisation for Economic Co-operation and Development (OECD) by Murphy *et al.* (2016) which showed that only 14% (18 out of 130) of country planning models were rooted on the needs-based approach. The increasing popularity but limited policy-oriented applications could be attributable to the lack of comprehensive guidelines and open-access tools to guide new users especially in low-and-middle-income countries where only 16% of the studies included in the current review originated. Also, the review found that most of the empirical analysis focused on specific disease areas, programs or sub-national levels with limited or no comprehensive national analysis involving multiple health professionals and covering most of the diseases and health priorities of a country. Indeed, the seemingly laborious and data-intensive nature of the needs-based approach coupled with limited expertise in the area has been cited as a drawback to its widespread use in countries, especially in resource-constrained settings where data and analytical capacity challenges abound (Lopes *et al.*, 2015). Murphy *et al.* (2016) have, however, argued that: “it is better to base plans on appropriate [needs-based] concepts imperfectly measured than on inappropriate concepts that can be easily measured” (p.13). Thus, the need for open-access needs-based models and guidelines for policy-oriented country-level use is not only imperative but urgent if countries are to align their health workforce planning and investments with the aspiration for UHC and the SDGs.

Our review found enormous innovations that attempt to model service needs and workforce requirements in a very nuanced way – incorporating local (or best practice) treatment protocols (for example Segal *et al.*, 2013, 2018); health workforce professional competence and pay (for example, Birch *et al.*, 2020) and disaggregation of need by rural versus urban population as well as other socio-demographic variables (Laurence *et al.*, 2018). The use of sophisticated techniques such as system dynamics modelling has been employed to apply the needs-based approach to health workforce modelling (Ansah *et al.*, 2015, 2019). However, less standardisation of health workforce modelling in general, and the emerging needs-based approach in particular, have culminated in significant methodological diversity, less rigour and transparency in the modelling process. Initial attempts to define key questions to guide needs-based health workforce modelling and criteria for fit-for-purpose health workforce planning tools (Segal *et al.*, 2013; Murphy *et al.*, 2016) may provide a starting point for a discourse towards standardisation and harmonisation of analytical modelling of needs-based health workforce requirements, but it appears that no consensus has yet been reached. Based on the methodological characteristics of the studies reviewed and ‘good practice’ guidelines for modelling in health (Philips *et al.*, 2006; Moons *et al.*, 2014), we consolidated the proposals by Segal *et al.* (2013, 2018) and Murphy *et al.* (2016) which we used to assess the various studies included in this review. We believe future work for consensus-based validation of our adapted checklist and scoring approach will be one further step towards more comprehensive ‘good practice’ guidelines in needs-based health workforce modelling. Overall, the studies were moderate in the level of comprehensiveness and quality (or at least how they were reported) which widely varied ranging from 56.7% to 88.5% with less than half (48%) considered as either of good (28%) or high (20%) quality.

One of the main weaknesses we observed in many of the studies is that the models used a constant rate of disease prevalence from the baseline values to extrapolate into the future with only the population size being the changing variable. However, it is intuitively anticipated that disease burden will change over time where some diseases may be declining and others increasing. Thus, assuming a constant rate of disease burden is akin to implicitly assuming a monotonous population change that influences future workforce requirements – a central point of departure between the needs-based and population ratio approaches to health workforce planning (Murphy, 2001; Tomblin Murphy *et al.*, 2009). This finding is not different from the work by Murphy *et al.* (2016) who reported finding "…no documents that modelled the impacts of changes in needs and potential associated changes in skill mix or care models in terms of their impacts on HRH requirements" (p.6). Understandably, there are rarely routine projections of the future trajectory of all diseases or risk factors in most countries, hence attempting to undertake such epidemiological modelling for all diseases of interest becomes an overly burdensome enterprise for the health workforce planner or modeller.

Nevertheless, overcoming the limitation of using monotonous population change for needs-based projection is critical. Under the circumstance, it may be useful to examine the differentials in the disease burden in previous years (e.g., the difference in prevalence between the baseline year and the previous ten years) – or any duration commensurate with the time horizon (or timeframe) of the intended projection. The observed change can then be assumed to be a trend that is likely to be observed over the projection period, all things being equal. In so doing, undertaking sensitivity analysis is critical to quantify the level of uncertainty in the resulting estimates and if feasible, characterising it in terms of a range (predictive interval) of the projected needs and workforce requirements.

2.6 LIMITATIONS OF THE STUDY

Despite the systematic approach used for the literature search, the search was limited to only peer-reviewed papers and those published in the English language. It is possible that some analytical applications of the needs-based approach were missed if they were in grey literature or policy documents and not in the English language, particularly from countries where English is not an official language. The review focused on the methodological considerations of needs-based health workforce modelling rather than comparing or synthesising the results of the analytical applications. Thus, the review is unable to make a judgement on the impact of the methodological diversity within the needs-based approach on the resulting health workforce plan.

2.7 CONCLUSIONS

There is increasing uptake of the needs-based approach of health workforce planning since 2010, but holistic country-level applications are still limited. There have been several innovations in advancing the analytical application of the needs-based modelling approach, but less methodological standardisation characterised by diversity, less rigour and transparency in the modelling process. Six broad methodological and process considerations were, nonetheless, typical and should be taken into account in future analytical applications of needs-based health workforce planning models. These are:

(1) Defining the scope (including jurisdictional coverage; alignment with the health system objective; and specifying the planning horizon or timeframe)

(2) Analysis of the population health service needs (population demography; measures of population-level of health; the level of service; and estimating the evidence-based service requirements)

(3) Translating the evidence-based service requirements into health workforce requirements (which included matching skills and competencies with identified interventions to address needs; and eliciting standard workload or measures of productivity)

(4) Exploring the resource implications (comparing the needs-based requirements with supply; exploring cost implications viz-a-viz available and anticipated budget).

(5) Conducting sensitivity analyses (including parameter uncertainty; and structural uncertainty or policy scenarios)

(6) Conducting model validation using statistical procedures and stakeholder consultation.

As countries aspire to align health workforce investments with population health needs, the need for some level of methodological harmonisation, availability of open-access needs-based models and guidelines for policy-oriented country-level use is not only imperative but urgent.

Consent

All authors have approved the manuscript for submission.

Acknowledgements

We are thankful to the following subject matter experts who critically reviewed an earlier draft of the manuscript and provided feedback: Hamza Ismaila (Health Economist and Health Workforce Planner, Ghana Health Service), Mollent Okech (Independent Consultant on Health Workforce) and Teena Kunjumen (Technical Officer, Health Workforce Data and Evidence, World Health Organisation). We are also grateful to the Scientific Committee of the Centre for Health

Professions Education (CHPE) at the North-West University, especially Dr Yolande Heymans and Mrs Paula Jardim who reviewed and approved the study protocol as part of a larger doctoral project.

Conflict of interest statement: None declared.

Ethical approval. As part of a larger doctoral project, the study received ethics approval from the Health Research Ethics Committee (HREC) of NWU (ethics approval number: NWU-00416-20-A1) and the Ghana Health Service Ethics Committee (ethics approval number: GHS-ER17/07/20).

2.8 REFERENCES

Ahern S, Woods N, Kalmus O, Birch S, Listl S. 2019. Needs-based planning for the oral health workforce - Development and application of a simulation model. *Human Resources for Health* **17**.

Andalón M, Fields G. 2011. A Labor Market Approach to the Crisis of Health Care Professionals in Africa. *IZA Discussion Paper* **5483**.

Ansah JP, Koh V, De Korne D, Jayabaskar T, Matchar DB, Quek D. 2019. Modeling manpower requirement for a changing population health needs: The case of ophthalmic nurses and allied health ophthalmic professionals. *Health Policy and Technology*.

Ansah JP, De Korne D, Bayer S, *et al.* 2015. Future requirements for and supply of ophthalmologists for an aging population in Singapore. *Human Resources for Health* **13**.

Araujo EC, Evans TG, Maeda A. 2016. Using economic analysis in health workforce policy-making. *Oxford Review of Economic Policy* **32**: 41–63.

Arksey H, O'Malley L. 2005. Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology* **8**: 19–32.

Asamani JA, Amertil NP, Ismaila H, Akugri FA, Nabyonga-Orem J. 2020. The imperative of evidence-based health workforce planning and implementation: Lessons from nurses and midwives unemployment crisis in Ghana. *Human Resources for Health* **18**.

Birch S. 1988. The identification of supplier-inducement in a fixed price system of health care provision. The case of dentistry in the United Kingdom. *Journal of Health Economics* **7**: 129–50.

Birch S, Gibson J, McBride A, Munros team. 2020. Opportunities for, and implications of, skill mix changes in health care pathways: Pay, productivity and practice variations in a needs-based planning framework. *Social Science and Medicine* **250**.

Birch S, Kephart G, Tomblin-Murphy G, O'Brien-Pallas L, Alder R, MacKenzie A. 2007. Human resources planning and the production of health: A needs-based analytical framework. *Canadian Public Policy* **33**: S1–16.

Birch S, Mason T, Sutton M, Whittaker W. 2013. Not enough doctors or not enough needs? Refocusing health workforce planning from providers and services to populations and needs. *Journal of Health Services Research and Policy* **18**: 107–13.

Bruckner TA, Scheffler RM, Shen G, *et al.* 2011. The mental health workforce gap in low- and middle-income countries: A needs-based approach. *Bulletin of the World Health Organization* **89**: 184–94.

Burke BT, Miller BF, Proser M, *et al.* 2013. A needs-based method for estimating the behavioral health staff needs of community health centers. *BMC Health Services Research* **13**.

Centre for Reviews and Dissemination. 2009. *Systematic review: CRD's guidance for undertaking reviews in healthcare*. University of York: York, United Kingdom.

Cometto G, Campbell J. 2016. Human resources for health. *The Lancet* **388**: 2993.

Dal Poz M, Dreesch N, Fletcher S, *et al.* 2010. Models and tools for health workforce planning and projections. *Human Resources for Health Observer*: 1–19.

Dreesch N, Dolea C, Dal Poz MR, *et al.* 2005. An approach to estimating human resource requirements to achieve the Millennium Development Goals. *Health Policy and Planning* **20**: 267–76.

Elisha D, Levinson D, Grinshpoon A. 2004. A need-based model for determining staffing needs for the public sector outpatient mental health service system. *Journal of Behavioral Health Services and Research* **31**: 324–33.

Gallagher JE, Kleinman ER, Harper PR. 2010. Modelling workforce skill-mix: How can dental professionals meet the needs and demands of older people in England? *British Dental Journal*.

Gallagher JE, Lim Z, Harper PR. 2013. Workforce skill mix: Modelling the potential for dental therapists in state-funded primary dental care. *International Dental Journal*.

Jansen C, Codjia L, Cometto G, Yansané ML, Dieleman M. 2014. Realising universal health coverage for maternal health services in the Republic of Guinea: The use of workforce projections to design health labor market interventions. *Risk Management and Healthcare Policy* **7**: 219–32.

Kavya S, Sanjay PZ, Abhay G, Syed ZQ. 2014. Methodological issues in estimating and forecasting health manpower requirement. *Journal of Public Administration and Policy Research* **6**: 25–33.

Konrad TR, Ellis AR, Thomas KC, Holzer CE, Morrissey JP. 2009. County-level estimates of need for mental health professionals in the United States. *Psychiatric Services* **60**: 1307–14.

Laurence CO, Karnon J. 2016. Improving the planning of the GP workforce in Australia: A simulation model incorporating work transitions, health need and service usage. *Human Resources for Health* **14**: 13.

Laurence CO, Heywood T, Bell J, Atkinson K, Karnon J. 2018. The never ending road: Improving, adapting and refining a needs-based model to estimate future general practitioner requirements in two Australian states. *Family Practice* **35**: 193–8.

Liu JX, Goryakin Y, Maeda A, Bruckner T, Scheffler R. 2017. Global Health Workforce Labor Market Projections for 2030. *Human Resources for Health* **15**.

Lockwood C, Tricco AC. 2020. Preparing scoping reviews for publication using methodological guides and reporting standards. *Nursing and Health Sciences* **22**: 1–4.

Lopes MA, Almeida ÁS, Almada-Lobo B. 2015. Handling healthcare workforce planning with care: where do we stand? *Human resources for health* **13**: 38.

MacKenzie A, Tomblin Murphy G, Audas R. 2019. A dynamic, multi-professional, needs-based simulation model to inform human resources for health planning. *Human Resources for Health* **17**: 1–13.

Moons KGM, de Groot JAH, Bouwmeester W, *et al.* 2014. Critical Appraisal and Data Extraction for Systematic Reviews of Prediction Modelling Studies: The CHARMS Checklist. *PLoS Medicine* **11**: e1001744.

Murphy GT. 2001. Methodological issues in health human resource planning: cataloguing assumptions and controlling for variables in needs-based modelling. *The Canadian journal of nursing research = Revue canadienne de recherche en sciences infirmières* **33**: 51–70.

Murphy GT, Birch S, MacKenzie A, Bradish S, Rose AE. 2016. A synthesis of recent analyses of human resources for health requirements and labour market dynamics in high-income OECD countries. *Human resources for health* **14**: 59.

Murphy GT, Birch S, Mackenzie A, Rigby J, Langley J. 2017. An integrated needs-based approach to health service and health workforce planning: Applications for pandemic influenza. *Healthcare Policy* **13**: 28–42.

Murphy GT, MacKenzie A, Alder R, Langley J, Hickey M, Cook A. 2013. Pilot-testing an applied competency-based approach to health human resources planning. *Health Policy and Planning* **28**: 739–49.

Murphy GT, MacKenzie A, Guy-Walker J, Walker C. 2014. Needs-based human resources for health planning in Jamaica: Using simulation modelling to inform policy options for pharmacists in the public sector. *Human Resources for Health*.

O'Brien-Pallas L-L, others. 2007. *Health human resources modelling: challenging the past, creating the future*. Canadian Health Services Research Foundation Ottawa.

O'Brien-Pallas L, Baumann A, Donner G, Murphy GT, Lochhaas-Gerlach J, Luba M. 2001. Forecasting models for human resources in health care. *Journal of Advanced Nursing* **33**: 120–9.

Ono T, Lafortune G, Schoenstein M, Ono T Schoenstein M LG, Publishing O. 2013. Health workforce planning in OECD countries: a review of 26 projection models from 18 countries. *In OECD Health Working Papers,* **No. 62**: 8–11.

Peters MDJ, Geofrey C, McInerney P, Munn Z, Tricco AC, Khalil H. 2020. Chapter 11: Scoping reviews - Juana Briggs Institute Reviewer's Manual. In: *Juana Briggs Institute Reviewer's Manual*. Juana Briggs Institute: JBI

Philips Z, Bojke L, Sculpher M, Claxton K, Golder S. 2006. Good practice guidelines for decision-analytic modelling in health technology assessment: A review and consolidation of quality assessment. *PharmacoEconomics* **24**: 355–71.

Rees GH, Crampton P, Gauld R, MacDonell S. 2018a. The promise of complementarity: using the methods of foresight for health workforce planning. *Health services management research* **31**: 97–105.

Rees GH, Crampton P, Gauld R, MacDonell S. 2018b. Rethinking health workforce planning: Capturing health system social and power interactions through actor analysis. *Futures* **99**: 16–27.

Roos NP, Fransoo R, Bogdanovic B, *et al.* 1999. Needs-based planning for generalist physicians. *Medical Care* **37**: JS206–28.

Roos NP, Fransoo R, Carrière KC, *et al.* 1997. Needs-based planning: The case of Manitoba. *CMAJ* **157**: 1215–21.

Safarishahrbijari A. 2018. Workforce forecasting models: A systematic review. *Journal of Forecasting* **37**: 739–53.

Scheffler RM, Liu JX, Kinfu Y, Dal Poz MR. 2008. Forecasting the global shortage of physicians: An economic- and needs-based approach. *Bulletin of the World Health Organization*.

Segal L, Leach MJ. 2011. An evidence-based health workforce model for primary and community care. *Implementation Science* **6**.

Segal L, Guy S, Leach M, Groves A, Turnbull C, Furber G. 2018. A needs-based workforce model to deliver tertiary-level community mental health care for distressed infants, children, and adolescents in South Australia: a mixed-methods study. *The Lancet Public Health* **3**: e296–303.

Segal L, Leach MJ, May E, Turnbull C. 2013. Regional Primary Care Team to Deliver Best-Practice Diabetes Care. *Diabetes Care* **36**: 1898–907.

Stuckless T, Milosevic M, De Metz C, Parliament M, Tompkins B, Brundage M. 2012. Managing a national radiation oncologist workforce: A workforce planning model. *Radiotherapy and Oncology*.

Sukeri K, Alonso-Betancourt O, Emsley R. 2015. Needs-based gap analysis for service transformation in the Eastern Cape. *South African Journal of Psychiatry* **21**: 3–7.

Tomblin Murphy G, Birch S, MacKenzie A, *et al.* 2016. Simulating future supply of and requirements for human resources for health in high-income OECD countries. *Human Resources for Health* **14**: 77.

Tomblin Murphy G, Birch S, MacKenzie A, Alder R, Lethbridge L, Little L. 2012. Eliminating the shortage of registered nurses in Canada: An exercise in applied needs-based planning. *Health Policy* **105**: 192–202.

Tomblin Murphy G, Kephart G, Lethbridge L, O'Brien-Pallas L, Birch S. 2009. Planning for what? Challenging the assumptions of health human resources planning. *Health Policy* **92**: 225–33.

Tricco AC, Lillie E, Zarin W, *et al.* 2018. PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Annals of Internal Medicine* **169**: 467–73.

Vedanthan R, Lee DJ, Kamano JH, *et al.* 2019. Hypertension management in rural western Kenya: A needs-based health workforce estimation model. *Human Resources for Health* **17**.

World Health Organization. 2016. Global strategy on human resources for health: Workforce 2030. *Who*: 64.

CHAPTER 3:
ARTICLE 2: ADVANCING THE POPULATION NEEDS-BASED HEALTH WORKFORCE PLANNING METHODOLOGY: A SIMULATION TOOL FOR COUNTRY APPLICATION

James Avoka Asamani [1,2], Christmal Dela Christmals [2,]* and Gerda Marie Reitsma [2]

[1] Centre for Health Professions Education, Faculty of Health Sciences, North-West University, Potchefstroom Campus, Building PC-G16, Office 101,11 Hoffman St, Potchefstroom 2520, South Africa; christmal.christmals@nwu.ac.za (J.A.A.); gerda.reitsma@nwu.ac.za (G.M.R.)

[2] Intercountry Support Team for Eastern and Southern Africa, Health Workforce Unit, Regional Office for Africa, World Health Organisation, 82-86 Cnr Enterprise/Glenara Roads, Harare CY 348, Zimbabwe; asamanij@who.int

* Correspondence: christmal.christmals@nwu.ac.za; Tel.: +27-642-379-552.

This article was published in the Global Health Section of the International Journal of Environmental Research and Public Health (link to the publication https://doi.org/10.3390/ijerph18042113). Based on the 2021 Journals' Citation Report, the International Journal of Environmental Research and Public Health has an impact factor of 3.390. The article is presented in this chapter in accordance with the specific guidelines for the journal, which is available at https://www.mdpi.com/journal/ijerph/instructions. Exceptions were made for the prescribed margins, line-spacing, fonts and formatting of tables. Also, the chapter is presented in one column per page instead of two columns per page by the journal. These modifications were made to adhere to the North-West University guidelines and to maintain uniformity of the thesis. Tables and figures are included with the text to facilitate easier reading.

3.1 ABSTRACT

Although the conceptual underpinnings of needs-based health workforce planning have developed over the last two decades, lingering gaps in empirical models and lack of open access tools have partly constrained its uptake in health workforce planning processes in countries. This paper presents an advanced empirical framework for the needs-based approach to health workforce planning with an open-access simulation tool in Microsoft® Excel to facilitate real-life health workforce planning in countries. Two fundamental mathematical models are used to quantify the supply of, and need for, health professionals, respectively. The supply-side model is based on a stock-and-flow process, and the need-side model extends a previously published analytical framework using the population health needs-based approach. We integrate the supply and need analyses by comparing them to establish the gaps in both absolute and relative terms, and then explore their cost implications for health workforce policy and strategy. To illustrate its use, the model was used to simulate a real-life example using midwives and obstetricians/gynaecologists in the context of maternal and new-born care in Ghana. Sensitivity analysis showed that if a constant level of health was assumed (as in previous works), the need for health professionals could have been underestimated in the long-term. Towards universal health coverage, the findings reveal a need to adopt the needs-based approach for health workforce planning and to adjust health workforce supply in line with population health needs.

Keywords: population health needs; needs-based health workforce; health workforce planning; health service planning; human resources for health; workforce modelling; needs-based modelling.

3.2 INTRODUCTION

The attainment of health objectives, including universal health coverage (UHC), requires a responsive health system underpinned by an adequate number of multidisciplinary health professionals with an appropriate skills mix, trained, motivated, committed, and supported to perform [1,2]. However, a looming global health workforce (HWF) shortage of 18 million by 2030, predominantly in low- and middle-income countries [1] is a serious threat. The deficit is traced to inadequate production capacity on the part of health professions education institutions, coupled with budgetary restrictions for employment and rapid attrition of existing health workers through migration and retirements [3–6]. It is thus estimated that more than half of some US$3.9 trillion needed in health investments by 2030 must be in HWF education and employment [7]. Although this demonstrates the centrality of the HWF in global health goals, chronic underinvestment continues to be a drawback, and it is linked to defective and ad-hoc HWF planning [1,8,9], which is a part of and cannot be delinked from, the overall health service planning [10].

The HWF component of health service planning is a complex, multi-sectoral and multifaceted process aimed at achieving an optimal balance between the supply of the different categories of health professionals (in the right mix) and the optimal need and demand for such professionals in both the short and long-term [11]. Roberfroid et al. [12] outlined three aspects of analyses that inform HWF policy and plans: supply analysis, needs (and demand) analysis, and gap analysis [12]. Besides, understanding the resource implications (in terms of cost) of the HWF supply and need viz-a-viz the available and anticipated budget (or fiscal space) is critical for policy and strategic decisions within the broader context of health service planning.

The supply-side analysis of the HWF planning involves taking stock of the available health professionals and determining (or forecasting) the future inflows and outflows [13,14]. A careful application of the stock-and-flow approach has shown promise in modelling the supply of health workers [15,16] but will mostly be dependent on the assumptions, accuracy, and relevance of the input data.

The second part of health workforce planning involves analysing the required calibre and number of health professionals in a specific jurisdiction necessary to meet its health system objectives [14,17]. There are several approaches with varied conceptual underpinnings for this analysis. Some are based on the observed levels of health service utilisation (service demand); health services targets; number and size of health facilities (health facilities staffing norms); simple population ratios; and population health needs (or epidemiological approach). Several texts examine each of these approaches in depth [see, for example, [14,18–24]]. Although each method has its merits and downsides, and none has been explicitly shown to be superior in all contexts, the needs-based approach to health workforce planning has a strong instinctive appeal in line with the UHC efforts. For instance, the World Health Assembly (WHA) adopted resolution WHA69.19 in 2016 which profoundly urged countries to make a paradigm shift in health workforce planning toward matching '…the supply of health workers to population needs, now and in the future' [1].

The needs-based approach makes '… explicit consideration of population health needs [using] direct measures of levels of health [or health status] that give rise to need for care—and the planned [or otherwise needed] number and type of services to be provided to address those needs' [25]. To apply this approach, one has to 'combine information on the health status of the population with disease prevalence, demographics and appropriate standards of care [within the jurisdiction]' [12]. Even though the theoretical foundations of the needs-based approach have been well advanced and empirically tested in different settings [26–31], its applications for policy and planning in countries are still limited [32] even in high-income countries [17]. This is not only blamed on the intensity of data requirements [33] but also the lack of ready-for-use, open-access models or software for use by health planners and human resource practitioners.

This paper presents an open-access, ready-to-use needs-based HWF planning model that integrates supply analysis with needs-based requirements to address methodological gaps and enhance the uptake of the needs-based approach planning in countries and their cost implications for training and employment viz-a-viz available budgets. To illustrate its value, we applied the model for midwives and obstetricians/gynaecologists in the context of maternal and new-born care in Ghana. The rest of the paper is divided into a conceptual framework, an empirical framework, results of an applied example, discussion and conclusion.

3.3 CONCEPTUAL FRAMEWORK

The need for health professionals is derived from the 'need for health services', not for its sake but as a means to remain healthy [14,34]. Thus, it can be assumed that the population in any jurisdiction has a specific need for health services whether or not they have demanded it and can afford it [14]. Therefore, to estimate the optimal need for health professionals, one would first have to model the population's need for health services [28]. Building on the conceptual framework proposed by Birch and colleagues [35], the population's need for health services is a function of three main drivers: (a) The size of the population and its demographic characteristics; (b) the state of health or level of health of the population; and (c) the level of services (type and frequency) that is planned or otherwise necessary to attain and maintain optimal health by the population. The interaction between these variables determines the population's 'Need for Health Services'.

The model presented in this paper differs from other models on several levels. Whereas previous models implicitly used a constant rate of disease prevalence (level of health) from the baseline to extrapolate into the future, this model makes adjustments for the expected rate of change over time in the population's level of health. In one review, Murphy et al. [17] noted that there were '…no documents [health workforce plans] that modelled the impacts of changes in [population] needs and potential associated changes … in terms of their impacts on HRH requirements' (p. 6). This represents a significant limitation in previous works which this model attempts to address in determining the future need for health services and ultimately the needs-based health workforce requirements. The need for health services can then be translated into the health workforce requirements if the category of health professionals competent to deliver the service is identified [30] with clear work division [29], and a measure of their productivity is established [27,28].

Where previous needs-based models incorporated productivity [26,29–31,33,36], this model defines the productivity measure in terms of a 'standard workload' which is the amount of work within one health service activity that a health professional (of a particular type who is competent and well-trained relative to the job specifications) may be able to perform within a given year [37]. The standard workload is, in turn, a function of the available working time of the health professional and the service standard (the amount of time necessary to deliver the given service task within professionally acceptable standards in the jurisdiction or based on service delivery protocols). When the need for health services (the evidence-based health service requirement) is compared with (divided by) the standard workload, the needs-based health workforce requirements are established but only for services that can be counted or measured per person. To account for the support or catalytic activities that are undertaken by health workers to enhance the delivery of direct patient/person care, the estimated requirement has to be adjusted for these activities.

On the supply side, for any type of health worker, the model starts by taking into account the annual enrolments of students into health professions training institutions. The total annual enrolment is then adjusted for the average rate of dropouts from each cohort of in-take. The aggregate output from the education pipeline (the number of those who pass successfully through the health professions training institutions) together with those who may migrate into the jurisdiction is adjusted by the average pass rate of any mandatory licensing examination that they may have to sit to make them eligible to practice. This represents the anticipated annual inflow into the existing stock of health professionals (the active workforce stock). The model recognises that not all the active stock (those qualified and with a valid license to practice) will find or take up jobs at frontline service delivery areas. Hence, the active stock is further adjusted by a rate of participation (the proportion of the active health workforce that are practising) to derive the effective supply (practicing stock) of the health workforce.

The model then compares the needs-based requirement for health professionals with the anticipated supply establishing current and future health workforce gaps [12] in both absolute and relative terms. The cost implications of the supply and the needs-based requirements are computed, which can then be compared with the current and anticipated budgets or other economic indicators. Depending on the resource implications, policymakers can then make adjustments to policies on student enrolment and recruitment, including wages, to improve the supply situation or consider amending service delivery models to adjust the needs-based requirements or a combination of both. Figure 1 illustrates the conceptual framework.

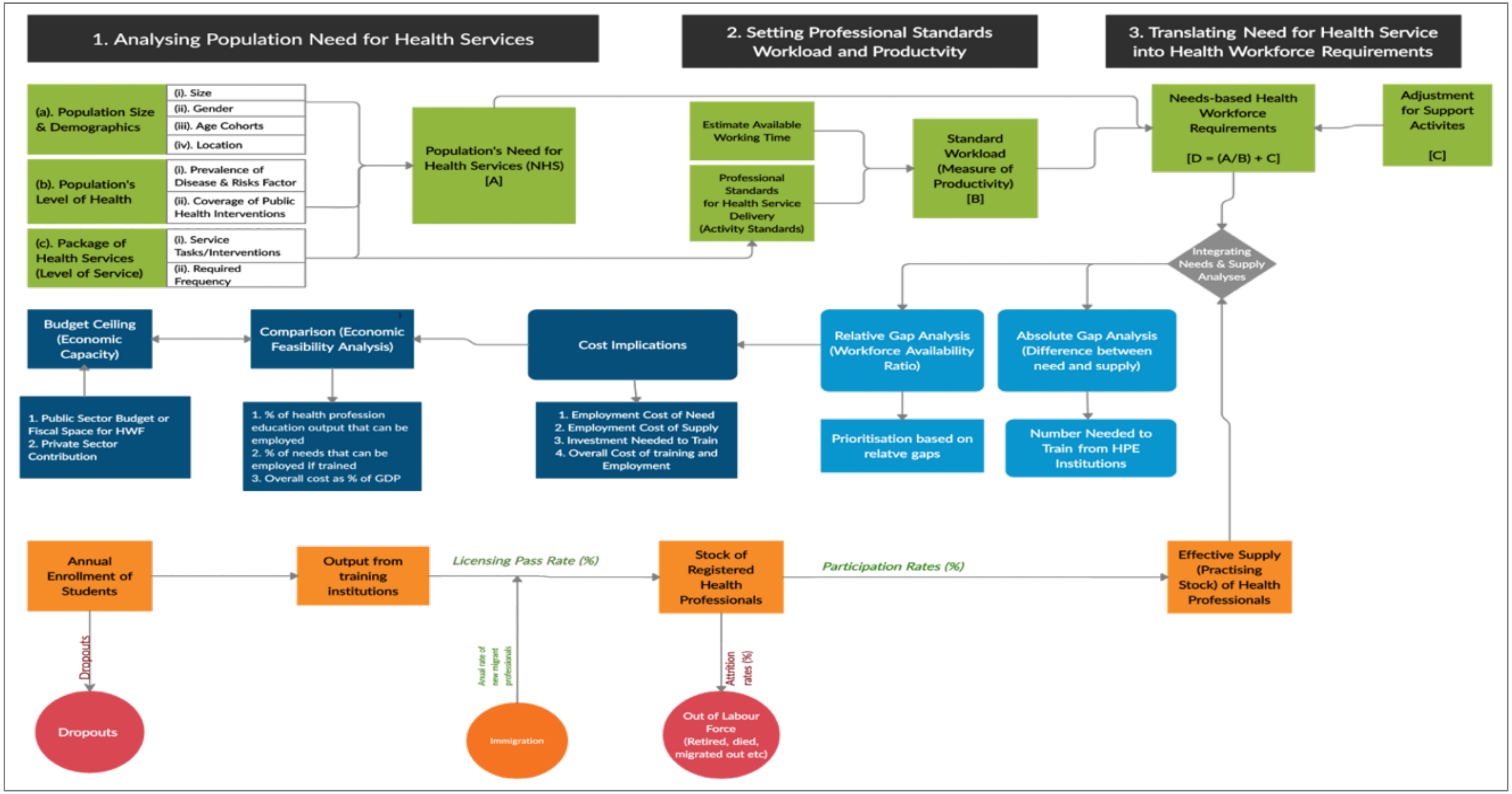

Figure 1: A conceptual framework for comprehensive needs-based health workforce planning.
Source: Author's adaptation from Tomblin Murphy et al. [25]; Birch et al. [35]; Roberfroid et al. [12]; and MacKenzie et al. [29].
Notes: There are different ways people have used the needs-based framework—either needs-based demand weighted analysis or full (unweighted) needs-based analysis. Asamani et al. [32] have distinguished these. The present model is for complete (unweighted) needs-based analysis, hence do not make assumptions of weighting needs with demand/utilisation.

3.4 MATERIALS AND METHODS

3.4.1 The Empirical Framework

In operationalising the conceptual framework, we present an analytical framework in which we identify four interrelated estimations of the supply of health workers; the need for health workers; gap analysis; and cost implications. Two distinct, fundamental mathematical models have been defined to quantify the supply of, and need for, health professionals, respectively. These are then compared to establish the gaps in both absolute and relative terms as well as the cost to be compared with available (and anticipated) budget or fiscal space—the main driver of how needs are translated into actual demand for health workers.

3.4.1.1 Modelling the Supply of Health Workforce

The supply of health professionals refers to the pool of qualified health professionals who are willing to find appropriate jobs to offer health services. Thus, the supply (S) depends on the 'stock' (T) and 'flows' of the health workforce. The stock refers to the current number of the active health workforce, while the flows have two components: inflow and outflow. The inflow represents new entrants to the labour market from domestic training pathways and through immigration, whereas the outflow represents both voluntary exits (loss to other sectors, emigration) and involuntary exits such as retirement, ill health and death [14].

As defined in the National Health Workforce Account (NHWA) [38] adopted by the World Health Assembly in 2017, the stock of any group of health professionals can be categorised into three groups: registered/overall stock; professionally active stock; and the practicing stock. The registered/overall stock comprises all those who have registered with the relevant professional regulatory body or authority within a jurisdiction to practice a health profession, irrespective of whether they are within the jurisdiction and practicing or not. Within the overall stock (registered), those that maintain good standing with the professional regulatory body by renewing their licenses, are considered the professionally active stock—some of whom may be engaged in other career interests (such as teaching, research and policy) rather than direct health service delivery. Out of the professionally active stock, those that are engaged in (or are willing to find jobs to be engaged in) direct health service delivery are considered the practicing stock of health workers. The interest in health service planning is to estimate as close as possible, the current and future stock of the practicing health workforce. We modelled the supply using a stock and flow process [29,39] as represented in Figure 1 and illustrated in the following equation:

$$\boldsymbol{S_{n,t}} = \left[\boldsymbol{T_{n,t-1}} \times (\boldsymbol{1} - \boldsymbol{a_n}) + \boldsymbol{I_n}\right] \times \mathbf{P} \quad (1)$$

- $\boldsymbol{S_{n,t}}$ is the effective supply of health professional of category $\boldsymbol{n}$, at time $\boldsymbol{t}$.
- $\boldsymbol{T_{n,t}}$ is the overall stock of health professionals (number registered) category $\boldsymbol{n}$ at time $\boldsymbol{t}$.
- $\boldsymbol{a_n}$ is the rate of attrition (the proportion of the stock, $\boldsymbol{T_{n,t-1}}$ that died, retired, could not work due to ill-health or migrated out) which adjusts the overall stock to get the professionally active health professional of category $\boldsymbol{n}$.
- $\boldsymbol{I_n}$ is the inflows of the health professional of category $\boldsymbol{n}$ from both domestic and foreign sources.
- **P** is the rate of labour participation which reflects the proportion of the professionally active health professionals that are engaged in direct health service delivery.

Formulae for attrition rate and inflows as defined in equation one is contained in Supplementary Material 2 (provided at the end of this chapter).

3.4.1.2 Modelling Population's Health Need for Health Professionals

Before the model development, we undertook a scoping review of analytical applications of the needs-based approach of health workforce planning [32] in which we synthesised the main considerations towards methodological harmonisation and increased transparency in needs-based health workforce modelling which mostly informed this empirical framework (see box 1 for a summary of the critical considerations for needs-based health workforce planning synthesised from the scoping review).

Box 1. Key considerations for comprehensive needs-based health workforce planning.

1) Defining the scope:
   - Jurisdictional coverage
   - The objective of analysis (aligned with health system objective)
   - Planning horizon or timeframe
2) Analysis of the population health service needs:
   - Population size and demography
   - Measures of the population's level of health (disease burden and health priorities)

- o Level of service (identified interventions and their frequencies necessary to address needs)
- o Estimating the evidence-based service requirements

3) Translating the evidence-based service requirements into health workforce requirement
- o Matching skills and competencies with identified interventions to address needs
- o Eliciting standard workload or measures of productivity

4) Exploring resource implications:
- o Comparing the needs-based requirements with anticipated supply
- o Estimate cost implications viz-a-viz available and anticipated budget

5) Conducting sensitivity analyses:
- o Parameter uncertainty (varying input values across their plausible range to explore the impact on the results)
- o Structural uncertainty or policy scenarios (varying key assumptions and course of actions to explore the impact on the results)

6) Conducting model validation:
- o Statistical comparison with previous estimates (if available)
- o Stakeholder consultation and feedback

Source: Asamani et al. [32].

2.2.1.1.1 Analysing the Population's Need for Health Services (Estimating the Evidence-based Service Requirements)

The need for health services is a function of three broad parameters, namely, demographic characteristics of the population (size, gender, age distribution and geographical location); their level of health or health status (disease prevalence and risk factors); and the services planned to address the health deficits or otherwise necessary to maintain optimal health. Building on the works of Birch and colleagues [35] which was further developed by Mackenzie and colleagues [29], we introduce an explicit adjustment for the instantaneous rate of change of the health status or level of health of the population. The relationship between parameters determining the need for health services could then be mathematically expressed as:

$$NHS_t = \sum P_{i,j,g,t} \times [\, H_{h,i,j,t-1} \times (1 + R_h)] \times \; L_{y,h,i,j,t} \qquad (2)$$

where:

- NHS_t represents the 'Needed Health Services' by a given population under a given service model, $L_{i,j,t}$ over a period of time *t*.

- $P_{i,j,g,t}$ represents the size of the given population of age cohort *i,* gender *j* in location (rural or urban) *g* at time *t* in a given jurisdiction (this represents the population and its demographic characteristics).

- $H_{h,i,j,g,t}$ represents the proportion of the given population with health status *h*, of age cohort *i,* gender *j* in location *g* at time *t* (this represents the level of health of the population).

- $L_{y,h,i,j,g,t}$ represents the frequency of health services of type *y* planned or otherwise required, under a specified service model, to address the needs of individuals of health status *h* among age cohort *i*, gender *j* in location *g* over time *t* (this represents the level of service required by the population).

- R_h is the instantaneous rate of change of the health status, *h* (supplementary material 2 for formula).

Equation (2) represents the evidence-based need for services that address the fundamental equation of how many of the population by age cohort, gender, in a particular location will need a specific type of services. This is vital for any aspect of health service planning - health workforce, essential medicines, infrastructure, or equipment, among others.

2.2.1.1.2 Translating the Evidence-Based Health Service Requirements into Health Workforce Requirements

Translating the need for health services or evidence-based service requirements generated from Equation (2) into health workforce requirements is only feasible by making explicit assumptions about some measure(s) of the productivity of health professionals for the specific services that are planned or otherwise required by the population. We define the measure of the productivity of health professionals borrowing the concept of Standard Workload (SW), which underpins the widely used and well-documented Workload Indicators of Staffing Need (WISN) tool developed by the World Health Organisation [37,40,41]. The standard workload is defined as the amount of work of a particular service delivery task that one health professional who is well trained could perform in a year if the health professional dedicated all his/her working to delivering that service [37]. It is a function of two components: (a) The service standard (SS) for the activity to be performed - the average time that a well-trained and motivated health professional will spend to perform the service delivery activity to acceptable professional standards in the context of the jurisdiction; and (b) the available working time (AWT) - the time a health worker was available in one year to do his/her work, taking into account all absences. Equation (3) illustrates the concept of standard workload and Supplementary Material 2 contains a formula for calculating the available working time.

$$SW_{n,y} = \frac{AWT_n}{SS_{y,n}} \tag{3}$$

where:

- $SW_{n,y}$ is the standard workload for health professional of category n when performing health service activity y.
- AWT_n is the available working time of the health professional of category n
- $SS_{y,n}$ is the service standard or the time it takes a well-trained health professional of category n to deliver the service activity, y.

When more than one type of health professional category performs a service delivery task, MacKenzie and colleagues defined a variable for work division [29]. To account for this variable, the estimated need for health services derived in Equation (2) is adjusted for the proportion of work division (which can be represented by W) to get the number of service activity, y to be performed by a health professional of category n for individuals of health status h, age group i, gender j at location g over time t. The workload division adjusted need for health services can then be divided by the standard workload (defined in Equation (3)), as illustrated in Equation (4).

$$N_{n,t} = \sum_{y} \frac{\sum(P_{i,j,g,t} \times [H_{h,i,j,t-1} \times (1 + R_h)] \times L_{y,i,j,t}) \times W_{y,n,h,i,j,t}}{SW_{n,y}} \tag{4}$$

- $N_{n,t}$ is the number of health professionals of category n required to deliver a given service model $L_{y,i,j,}$ to a given population over a period of time t.
- $W_{y,n,h,i,j,t}$ is the proportion of services of type y to be performed by a health professional of category n for individuals of health status h, age cohort i, and gender j at time t.

It is worth noting that the standard workload is a measure of productivity relating only to direct patient/client service delivery activities that can be counted per person (or patient). Therefore, the needs-based health workforce requirements estimated using Equation (4) relates mainly to direct person services and excludes indirect patient care or catalytic activities of the health professional.

2.2.1.1.3 Adjusting the Health Workforce Requirements for Indirect Patient Care Activities of Health Workers

As demonstrated by Birch et al. [27] and MacKenzie et al. [29], needs-based models recognise that health workers spend some time performing the activities that are essential for supporting the delivery of direct patient/person services, but such activities are not linked to individual patients/clients. While the previous needs-based models accounted for the phenomenon from a supply perspective by defining and adjusting health workforce supply by activity rates (the proportion of health worker's time spent on direct care) [29], we take the view that for planning, it is appropriate to estimate the number of health professionals needed to cover such support activities that are catalytic for the direct patient care. For example, the process of handing over from one group of nurses in a shift to another group is a crucial component for continuity of care, but because the activity may not necessarily be counted per patient, it could be ignored in needs-based models. Leveraging on the WISN methodology [37], we define a support allowance standard (SAS) as the proportion of a health worker's time that is spent on support (or indirect patient care) activities. When the total SAS (in a proportion) is subtracted from the whole, the difference represents a proportion of the health worker's AWT that is devoted to direct patient/person services [37]. To incorporate the SAS into Equation (4), an adjustment factor known as the support activities adjustment factor (SAAF) is defined - mathematically expressed as the inverse of the proportion of a health professional time left for direct per person care activities [37]. Thus, the overall needs-based requirement with both direct and indirect services can be expressed as:

$$N_{n,t} = \left(\sum_{y} \frac{\sum(P_{i,j,g,t} \times [H_{h,i,j,t-1} \times (1 + R_h)] \times L_{y,i,j,t}) \times W_{y,n,h,i,j,t}}{SW_{n,y}}\right) \times SAAF \quad (5)$$

where:

- SAAF = $\frac{1}{(1-\Sigma SAS)}$
- *SAS* = proportion of health professional time spent on support activities.

3.4.1.3 Needs Versus Supply Gap Analysis

The two main quantities estimated in Equations (1) and (5) above (supply and needs-based requirements) can be analytically integrated to compare the current and anticipated gaps in the health workforce in absolute and relative terms.

3.4.1.4 Establishing the Absolute Gaps

The difference between the projected supply levels and the projected need for a particular health worker category is considered the absolute gap whereby a negative gap is indicative of a supply shortfall, which will be deemed as the number 'needed to be trained' by the health professions education institutions [42]. In contrast, a positive gap is indicative of an over-supply from the health professions education institutions in comparison with the need.

$$Absolute\ Gap_{n,t} = S_{n,t} - N_{n,t} \qquad (6)$$

where:

- *Absolute* $Gap_{n,t}$ is the absolute gap for health professional of type ***n*** at time ***t***.
- $S_{n,t}$ is the supply of health professional of category ***n*** at time ***t.***
- $N_{n,t}$ is the needs-based requirements of a health professional of category ***n*** at time ***t.***

2.2.1.1.4 Relative Health Workforce Gaps (Staff Availability Ratio, SAR)

This is the ratio of the needs-based health workforce requirement that will be met by the anticipated supply

$$SAR_{n,t} = \frac{S_{n,t}}{N_{n,t}} \qquad (7)$$

The *SAR* shows the anticipated amount of needs-based workload pressure that will be on the current and future health workforce or the proportion of professional standards that can be maintained if interventions are not put in place to influence the supply (and employment) of health professionals. For interpretation, *SAR* of 1 indicates that the anticipated supply will optimally meet the needs-based requirements, whilst a *SAR* of less than one shows that the anticipated supply is failing to meet the needs-based requirements. On the other hand, when the *SAR* is greater than 1, it is indicative of supply outstripping the projected need for health professionals.

3.4.2 Cost Implications for the Estimated Supply and Needs-Based Requirements

To understand the cost implications and investments requirements for employing health workers, the following is conservatively specified:

$$TCS_{n,t} = \sum (S_{n,t} \times K_{n,t}) \qquad (8)$$

where:

- $TCS_{n,t}$ is the total wage bill cost of the anticipated supply of health professional category *n* at time point *t*.
- $S_{n,t}$ is the anticipated supply of health worker category *n* at time point *t*.
- $K_{n,t}$ is the average income (made up of salaries, allowances and monetary benefits and adjusted for inflation) for health professional of category *n* at time point *t*.

Similarly, assuming there is sufficient supply, the cost implications for filling the needs-based health workforce requirements is conservatively specified as:

$$TCN_{n,t} = \sum (N_{n,t} \times K_{n,t}) \qquad (9)$$

- $TCN_{n,t}$ is the total wage bill cost of needs-based requirements of a health professional of category *n* at time point *t*.
- $N_{n,t}$ is the needs-based requirements of a health professional of category *n* at time point *t*.
- $K_{n,t}$ is the average income (made up of salaries, allowances and monetary benefits and adjusted for inflation) for health professional of category *n* at time point *t*.

3.4.3 An Applied Example for Maternal and New-Born Care

To demonstrate its application and added value, we applied the comprehensive simulation model to estimate the health workforce supply and the requirement for maternal and new-born care in Ghana. The model is designed to allow for disaggregated analysis by sub-national levels (such as regions, states, counties) and differentiation by rural and urban residence. However, for this example, we focused on a composite analysis of the requirements for Ghana. The categories of health workers considered are midwives and obstetricians and gynaecologists because these are the categories of health worker primarily mandated to provide maternal and new-born care in Ghana.

In estimating the needs-based requirements, data on the size and demographic characteristics of the population were obtained from Ghana Statistical Service projections [43]. The maternal and new-born levels of health (health status and coverage of essential services) were taken from the 2007 and 2017 Ghana Maternal Health Surveys [44,45] which were compared to establish the instantaneous rate of change. The available working time for the health professionals, the required services to address the gaps in the level of health and the corresponding activity standards, were obtained from the WISN report [46] and Ghana Maternal Health Policy respectively.

For the supply side, the number of students enrolled at health training institutions and pass rates was extracted from the database of the Health Training Institutions Secretariat of the MOH and the professional regulatory bodies (Medical and Dental Council, Nursing and Midwifery Council). Data on the current stock of the health professionals and attrition rate were obtained and triangulated from administrative data of the Ghana Health Service (GHS) [47–49], the holistic assessment report of the Ministry of Health [50–53] as well as the websites of the professional regulatory bodies [54]. See the simulation tool in Microsoft® Excel in Supplementary Material 1 for the detailed dataset.

3.5 RESULTS

This section briefly describes the excel-based simulation tool based on the model (see supplementary material 1) and the results of the applied example in terms of (1) estimated needs-based requirements, (2) estimated supply, (3) gap analyses, (4) cost implications and (5) some sensitivity analyses.

3.5.1 Description of the Simulation Tool in Microsoft Excel

As argued previously by Tomblin Murphy and colleagues [25,55] and recently echoed by MacKenzie et al. [29], needs-based simulation models are not necessarily intended to predict the future but '…to integrate the knowledge of different types of HRH (human resources for health) and other aspects of the health care system, such as planned service levels, into a single planning and communication tool to promote understanding of how various factors affect the supply of and requirements for HRH and identify policy levers for influencing these' (p. 4). The empirical framework was implemented in several linked spreadsheets in a Microsoft® Excel workbook as a deterministic simulation tool (see version 1.2 of the tool as supplementary material 1). The tool is organised into four modules, each with several worksheets that are linked. Modules 1–3 contain the inputs to be entered, while Module 4 contains the outputs or results.

3.5.2 Estimated Needs-Based Requirements and Anticipated Supply

The simulation shows that the needs-based requirement for midwives was about 16,462 in 2020 which will, on average, increase steadily by 3.5% (range: 3.2–4.0%) annually to 23,161 by 2030. By 2025, the needs-based requirement for midwives would increase to 19,409 which represents a 17.9% increase over the estimated requirement in 2020; and a further increase of 19.3% is estimated from the 2025 requirement to reach the 23,161 by 2030. Similarly, the model estimates that 723 obstetricians/gynaecologists are the needs-based requirement in 2020 which will increase at an average rate of 3.4% annually (range: 3.3–3.7%) to about 854 by 2025, an 18% increase from the base requirement in 2020. A further increase of 18.7% from the 2025 estimates is projected for 2030, which brings the total needs-based requirement for obstetricians/gynaecologists to 1013 by 2030.

At the supply side, the simulation reveals that the existing stock of midwives using a labour participation rate of 93% is about 11,930 in 2020 which could reach about 19,919 (or 67% increase from the baseline) by 2025 and a further 18.5% increase from the 2025 supply levels to 23,602 by 2030. For obstetricians/gynaecologists, they are usually practicing general practitioners who undergo specialist training while keeping their jobs; hence they are all placed back to their institutions of employment upon completion. In this context, a 100% labour participation rate was assumed which was the baseline supply of 189 in 2020. It is anticipated that the supply would increase by some 65.7% to 313 in 2025 and a further increase of 32.5% to 415 by 2030. Tables 1 and 2 show the annual estimates of the needs-based requirement and the anticipated supply, respectively. These estimates are also presented graphically in Figures 2 and 3 as the needs-based requirements versus the anticipated supply for midwives and obstetrician/gynaecologist respectively for the period 2020–2030.

Table 1: Needs-based requirements for midwives, and obstetricians and gynaecologists

No.	Health Professionals	Needs-Based Requirements										
		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1	Midwife	16,462	16,997	17,556	18,139	18,749	19,409	20,076	20,774	21,504	22,268	23,161
2	Obstetrician/Gynaecologist	723	747	772	798	825	854	883	913	945	977	1013
Total		17,186	17,745	18,328	18,937	19,574	20,263	20,959	21,687	22,448	23,245	24,174

Table 2: Estimated supply of midwives, obstetricians and gynaecologists

No.	Health Professionals	Estimated Aggregate Supply										
		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
1	Midwife	11,930	14,057	15,878	17,438	18,775	19,919	20,900	21,739	22,459	23,075	23,602
2	Obstetrician/Gynaecologist	189	216	242	266	290	313	335	356	377	396	415
Total		12,119	14,272	16,120	17,705	19,065	20,232	21,235	22,096	22,835	23,471	24,017

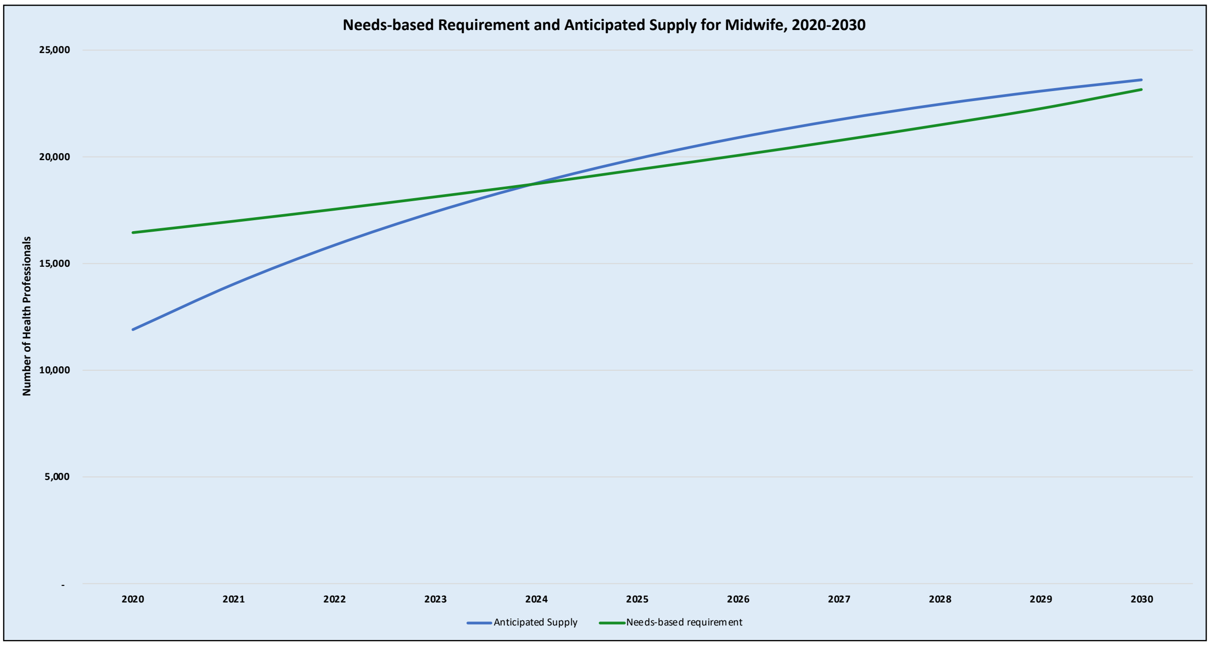

Figure 2: Needs-based requirements and anticipated supply of midwives

Notes: Figure 2 illustrates the projected trend of the needs-based requirement for midwives (the green line) as compared to the anticipated trend of supply in the blue line.

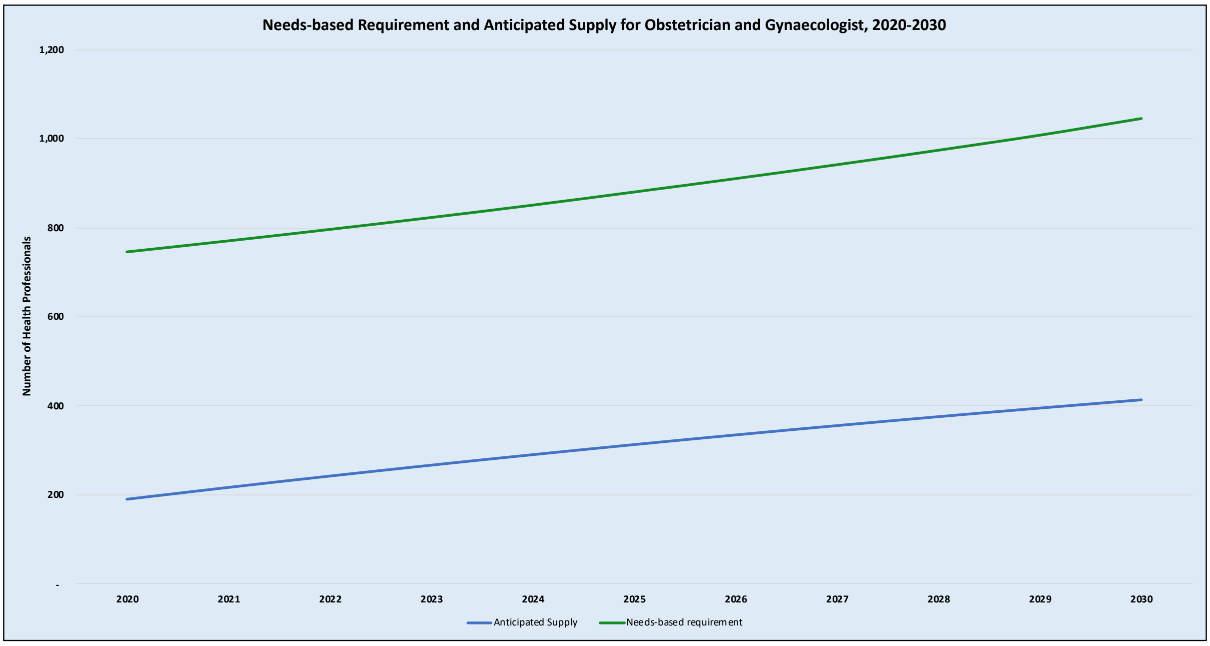

Figure 3: Needs-based requirements and anticipated supply of obstetricians/gynaecologists

Notes: Figure 3 illustrates the projected trend of the needs-based requirement for obstetricians/gynaecologists (the green line) as compared to the anticipated trend of supply in the blue line.

3.5.3 Absolute and Relative Gaps Analyses—Comparing the Needs-Based Requirements and Anticipated Supply

The results of the applied example reveal that initially, the needs-based requirements for midwives outstrip that of the anticipated supply, resulting in a needs-based shortage of 4532 midwives. Comparing the needs-based requirement to the anticipated supply in relative terms, the staff availability ratio, SAR (the proportion of needs-based requirements that is met by the level of supply) for midwives is about 72.5% which implies a shortfall of 27.5% at baseline in 2020. However, an equilibrium is likely to be reached between the supply and needs-based requirement by 2024 if the current trend of production and attrition of midwives continues without further intervention. From 2025, the anticipated supply would then appear to exceed the needs-based requirement marginally, almost at the brink of needs-based oversupply—with SAR of 102.6% by 2025 and a marginal reduction to 101.9% by 2030 (see Table 3).

Table 3: Gap analysis between needs-based requirements and anticipated supply

No.	Health Professionals	2020				2025				2030			
		Need (a)	Supply (b)	Gap (b-a)	SAR (b/a)	Need (a)	Supply (b)	Gap (b-a)	SAR (b/a)	Need (a)	Supply (b)	Gap (b-a)	SAR (b/a)
1	Midwife	16,462	11,930	(4532)	72.5%	19,409	19,919	510	102.6%	23,161	23,602	442	101.9%
2	Obstetrician/ Gynaecologist	723	189	(534)	26.1%	854	313	(541)	36.7%	1013	415	(599)	40.9%

SAR: staff availability ratio.

For obstetricians/gynaecologists, the simulation shows that the needs-based requirement far exceeds that of the anticipated supply throughout the horizon of the projection. As shown in Table 3, the needs-based shortage of obstetrician/gynaecologist specialists is about 534 in 2020, which could reach 599 by 2030 if there is no new intervention to increase the rate of supply or decrease the need or both. The SAR for obstetrician/gynaecologists is a paltry 26.1% in 2020, which is expected to improve to 36.7% by 2025 and 40.9% by 2030. Therefore, under the assumption of maintaining the current rate of production, the model suggests a needs-based shortage of obstetricians/gynaecologists by 74% in 2020 which may only reduce by 15 percentage points to 59% by 2030 (see Table 3).

3.5.4 Implications for Health Professions Education

Assuming that the applied example was a comprehensive analysis, it signals that production/supply of midwives will reach equilibrium with the needs-based by 2024 and after that exceed the needs by roughly 3% by 2025 and then 2% by 2030. Thus, from the health profession education perspective, scaling up the training of midwives may not be warranted beyond the current rate of production. Efforts in the production of midwives could, therefore, be focused on improving the quality rather than further quantitative expansion. On the other hand, the massive needs-based shortage of obstetrician/gynaecologist signals the need to ramp up training by some 599 within the next ten years in addition to the current rate of production. Thus, roughly 60 obstetricians/gynaecologists must be produced per year in addition to the current rate of production. Given that enrolments into specialist medical education such as obstetrician/gynaecologist are drawn from the existing stock of general medical practitioners, it will have a knock-on effect on the need to scale up the training of general practitioners too.

3.5.5 The Cost Implications of the Estimated Needs-Based Requirements and Anticipated Supply

The simulation shows that filling the needs-based requirement for midwives is estimated to cost US$177 million in terms of wage bill which will increase nearly 2.5-folds to US$433.5 million by 2030, due to the expanding needs and adjustments for inflation. The wage bill cost of the anticipated supply of midwives is estimated to be US$118.8 million in 2020 and rising steadily to US$441.7 million by 2030, with the assumption that the rate of labour participation for midwives would remain at 93%. However, if a 100% participation rate is assumed, the wage bill cost of the anticipated supply of midwives could be US$127.7 million in 2020 and gallop to US$653.8 million by 2030.

The needs-based requirement for obstetricians/gynaecologists is estimated to cost about US$14.3 million in terms of salaries, which will gradually increase to US$34.8 million, taking into account both the inflation and expansion in need for obstetricians/gynaecologists. The wage bill cost of the current supply of obstetricians/gynaecologists is estimated to be US$3.5 million in 2020, which may increase by nearly six-folds to US$20.9 million.

The overall needs-based requirement for both midwives and obstetrician/gynaecologist is about US$191.3 million in 2020, which may increase to US$309 million by 2025 and US$468.3 million by 2030. By contrast, the aggregate supply of these categories of health workers (midwives and obstetrician/gynaecologist) is estimated to cost US$122.2 million in 2020; US$304.7 million by 2025; and US$462.6 million by 2030 (see Table 4 for details).

Table 4: Cost implications of the needs-based requirements and anticipated supply

No.	Health Professional	The Estimated Wage Bill in United States Dollars (US$)					
		2020		2025		2030	
		Need	Supply	Need	Supply	Need	Supply
1	Midwife	176,988,192.56	118,759,613	285,949,683.80	293,467,630	433,445,908.15	441,711,580
3	Obstetrician/ Gynaecologist	14,278,392.77	3,454,061	23,090,373.91	11,214,559	34,820,936.99	20,921,755
	Total	191,266,585.33	122,213,674.52	309,040,058	304,682,188	468,266,845	462,633,335

3.5.6 Sensitivity Analyses

To explore the impact of the main assumptions made in this model, we varied a number of the variables to document their impact on the output of the model.

Instantaneous rate of change in the level of health (health status) based on past trends**:** The effect of not including the instantaneous rate of change in the health status indicators (eliminating Equation (5) in the empirical framework) reduced the overall requirements up to 17.4% (n = 3438) for midwives and 23% (n = 189) for obstetricians/gynaecologists by 2030. The SAR for obstetrician/gynaecologist then becomes 28.4% in 2020 (versus 26.1% with the assumption kept) which increases to 50.1% in 2030 (versus 40.9% with the assumption kept). Similarly, the SAR for midwives without the assumption in 2020 is 75.1%, compared with 72.5% when the assumption is kept. Without the assumption, SAR for midwives by 2030 is estimated to be 119.7% as compared to 101.9% when the assumption is kept. From the foregoing, therefore, the further into the future the needs-based projection is made, the more sensitive the results become to the assumption of applying an instantaneous rate of change in the health status of the population.

Support activities adjustment factor: Using available data from previous work in Ghana [56], it was estimated in the applied example that two support activities of midwives together consume about 17.5% of their available working time. Similarly, the obstetrician/gynaecologist spends about 6 h per week on clinical meetings and capacity building seminars which represents 15% of the available working time. These translate into support activities adjustment of 21.2% and 17.6% of the needs-based requirements for midwives and obstetrician/gynaecologist, respectively (see Table 5).

Table 5: Exploring the effect of incorporating support activities in the needs-based estimation

No	Health Professional	Intervention	Measurement	Support Allowance Standard (SAS)	Support Allowance Factor (SAAF)	*% Adjustment Required to Cater for Support Activities*
1.	Midwife	Handing over	1 h per day	12.5%	1.212	*21.2%*
		Clinical/unit meetings	2 h per week	5.0%		
2.	*Obstetrician/Gynaecologist*	*Clinical/unit meetings*	*6 h per week*	*15.0%*	*1.212*	*17.6%*

Exploring the impact of practice variations and standard workloads: The WISN activity standards in Ghana which was adopted for the applied example had a different set of standard times for accomplishing similar tasks between midwives in primary care health facilities (district hospitals, polyclinics, health centres and CHPS) and secondary/tertiary health facilities. These differences stem from variations in clinical protocols between primary care and tertiary health facilities; and differences in available technology and resources. In the base analysis, the activity standards in the primary care facilities were used since that represents more than 95% of health facilities in Ghana [57]. We explored the potential impact on the model output if the tertiary health facilities' standard time (activity standards) were used. As illustrated in Figure 4, the results show that the effect of using the tertiary facilities’ standard time is about 20.3% increase in the needs-based requirements for midwives but weans marginally to 19.3% by 2030. Under this scenario, there was a needs-based shortage of midwives of 7875 (compared to 4532 in the base case) in 2020. Under this alternative analysis, the staff availability ratio for midwives will be 60.2% in 2020 (versus 72.5% in the base estimation) and 85.4% in 2030 (compared with 101.9% in the base estimation). As shown in previous needs-based models, this finding tends to validate the suggestion that needs-based analysis is highly sensitive to the measures of productivity chosen [25,58], the setting and that of practice variations [27] as well as changing health technology are essential factors to consider in long-term health workforce planning.

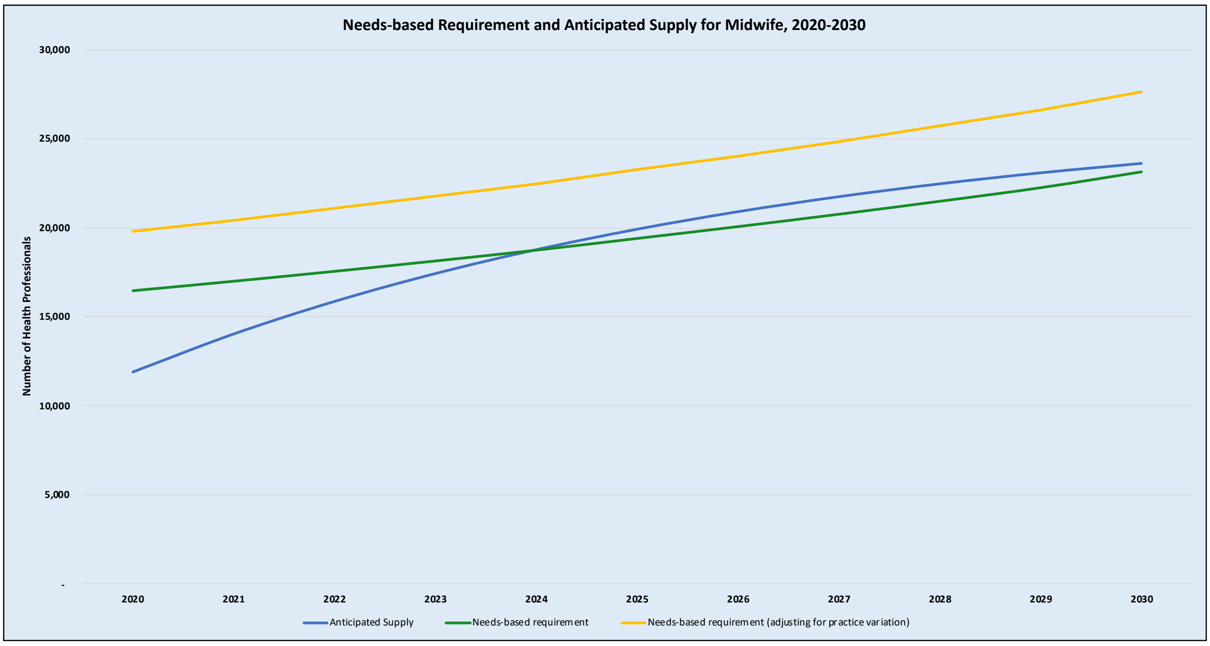

Figure 4: Exploring the effect of variations in activity standards on the needs-based requirements for midwives

Notes: Figure 4 illustrates the impact of practice variation on the projected trend of the needs-based requirement of midwives (yellow line) as compared to the original trend (green line) and the anticipated trend of supply (blue line).

3.6 DISCUSSION

The needs-based framework for health workforce planning has been developed and tested by pioneering scholars for the last two decades and continues to evolve [25–27,29–31,35,59,60]. Recent advances in the methodology [27,29] have improved its clarity and appeal. Nonetheless, previous long-range projections (dynamic models) made an implicit assumption of monotonously applying baseline levels of health (health status) to future population demographics. Also, previous models did not take into account the support activities undertaken by health workers which are not direct patient care activities but are imperative to facilitate direct patient care. The present model adapted mathematical equations that have been tested over the last two decades for needs-based modelling by incorporating assumptions that were not explicit in previous works to address the aforementioned gaps. In addition, different from previous ones, a measure of productivity was incorporated using the concept of standard workload, which can be directly elicited from health professionals based on the average time they spend in delivering various health service activities. Thus, the model presented in this paper represents a critical and much-needed improvement in the empirical framework for the application of the needs-based approach. The World Health Organisation has provided a wealth of description and guidance on the conditions necessary, and how to apply the different HWF modelling approaches [19,24]. However, to the best of our knowledge, there are no dynamic open-access, ready-to-use tools for health planners and human resource practitioners to easily apply the needs-based framework in real-life health workforce planning, especially in the context of low-and-middle-income countries, where the analytical capacity to develop sophisticated models locally is often limited. To bridge this gap and facilitate policy-driven uptake of the needs-based approach to health workforce planning, an easy-to-use, open-access simulation tool developed in Microsoft® Excel has been made available as Supplementary Material 1.

One fundamental difference between the present model and previous ones is the explicit assumption in the present model that the level of health of the population will likely change, based on previous trends. To account for this assumption, we incorporated an instantaneous rate of change in the population's need for health services. Murphy et al. [17] lamented that the needs-based models reviewed failed to take this into account, which represented a significant limitation. Our applied simulation shows that the impact of this assumption on the outcome of needs-based projection is more pronounced, and further into the future, the projection is extended. For example, when this assumption was relaxed in our applied example, and a fixed level of health was applied throughout the horizon of the projection (as used in previous models), the needs-based requirements for midwives decreased by up to 17.4%, and that of obstetricians/gynaecologists decreased by up to 23% over the ten years. However, in the base year, the difference was only 3.5% for midwives and 8.8% for obstetricians/gynaecologists. Therefore, not explicitly incorporating the assumption in the empirical framework could result in a substantial underestimation of the actual need for health professionals if longer-term planning is desired. For a one-time point (or static) analysis, the underestimation seems to be minimal and could be within reasonable planning limits, but for dynamic or longer-term analysis, it becomes imperative to take this assumption into account.

Also, the support activities undertaken by health workers were previously not being considered in the estimated needs-based requirements in the earlier models. Instead, some models defined a clinical focus term in the supply side of the analysis to adjust the anticipated supply to take into consideration only the proportion of time health professionals spent on direct clinical activities. It is our considered view that the support activities of health professionals are not a supply-side issue, for which reason it ought to be accounted for in the needs-based requirements to enable planning for the numbers needed to cover such support activities. For example, our applied simulation shows that 21% of the estimated requirement for midwives, and 18% for obstetrician/gynaecologist were needed to cover support activities. Incorporating these assumptions in the needs-based estimates is necessary to inform planning for health professions' education and employment to cover for both direct patient/person care and the support activities that catalyse direct care.

To roughly gauge the validity of the model output, we compared the results of the applied example with previous health workforce projections in Ghana [61,62]. Based on health facilities and staffing norms approach [61], it was estimated that Ghana needed 13,554 midwives by 2020 and 18,832 by 2025. Compared to the current estimate of 16,462 midwives needed in 2020 and 19,409 in 2025, the current model estimated 21.45% higher needs in 2020, but the two estimates converge towards 2025 with a variance of only 3.06%. Thus, despite the conceptual differences between the staffing norms and the needs-based approach, the medium-to-longer-term estimates seem to draw a similar conclusion from both approaches in this case of the midwives in Ghana. Furthermore, an administrative analysis of the Ghana Health Service suggested that the production of midwives is at the brink of exceeding the demand [62], whose direction of evidence tends to corroborate with our applied simulation for midwives.

Regarding the scenario for obstetrician/gynaecologists, the applied simulation did not consider other women's health issues typically handled in the context of gynaecology, but focused on obstetrics which relates to maternal and new-born care. Thus, the estimates in the applied simulation are by no means the comprehensive needs-based requirements for obstetrician/gynaecologists. Nevertheless, it was previously estimated that Ghana required 750 obstetricians/gynaecologists in 2020 (compared with 723 in the current estimation) and 1044 by

2025 (compared with 854 in the current estimation). Thus, the current estimation is about 3.6% lower in 2020 and 18.2% lower by 2025.

The wage bill in Ghana is centrally managed within the overall personnel emoluments budget of the Ministry of Health. Hence, there is no separate health workforce budget for maternal and new-born health. This made it unfeasible to compare the estimated wage bill cost of the needs-based requirements and supply with the available budget that is specific for these categories of health professionals. As part of the application of this model, a comprehensive needs-based health workforce analysis is being undertaken in the context of primary health care in Ghana.

3.7 LIMITATIONS

The well-acknowledged limitation of the needs-based workforce planning approach is its relatively intense data requirements [21,29] and lack of end-user tools [32], especially for settings where there is limited analytic capability. The present model partly addresses the latter but also requires extensive data on population size, demographic characteristics, the range of disease burden, health workforce absences and service delivery standards as well as data on the existing stock of health professionals, attrition rates, annual enrolments, pass rates and labour participation rates. Some of these data needs may not be routinely available in many low- and middle-income countries. However, as repeatedly put forward by Tomblin Murphy, Birch and colleagues [17,29,63], an imprecise estimation of health workforce requirements, based on appropriate conceptual underpinnings with the view of progressive improvement in the data adequacy and quality, is more useful than using conceptually invalid models. Cometto and colleagues [64] admonish that health workforce planning is an inexact science; hence the potential impact of data imprecision and uncertainty should always be taken into account. The present simulation model provides an opportunity to explore the impact of data uncertainty on the model needs-based estimates in the form of best and worst cases scenarios. With many countries striving to improve their health workforce data availability and quality through the implementation of the national health workforce account [38,65], the use of needs-based models could become less burdensome and easy to use than first thought.

Also, HWF requirements and supply may not always follow a linear process as (implicitly) implied in the mathematical equations, since needs depend on disease patterns, health-seeking behaviour of individuals, technological changes/evolution etc., which tend to be non-linear in character. Similarly, the supply side tends to respond to market-related forces, e.g., incentives, levels of pay, working conditions etc., and may not always follow a linear process. Hence, long-range projection with the model should be followed with intermittent revisions based on emerging information and data. In addition, uncertainties such as health emergencies as in the case of COVID-19 pandemic are extremely difficult to be foreseen in models like this. However, as demonstrated by Murphy et al. [33], needs-based models could be adapted for planning in times of health system disruption or emergencies.

Moreover, in the current simulation model, data on indicators for the populations' health status are required for at least two different time points to enable a calculation of their instantaneous rate of change to operationalise the assumption that the populations' health needs will be changing in the future based on past trends. This requires the use of consistent sources of data that measure the same indicators periodically, which may become a limitation where such data sources do not exist. In such circumstances, using targets set by local policymakers can be a viable option. Finally, the simulation model is designed on the back of some functions of Microsoft® Excel that were released in October 2020. Hence, those with lower versions may experience compatibility issues.

3.8 CONCLUSIONS

The paper builds on the decades of conceptual and empirical work by needs-based pioneering scholars to further advance the needs-based framework for health workforce planning by considering the changing patterns of the population's level of health (or health status) and support activities performed by health professionals. An open-access simulation tool in Microsoft® Excel has been included with the view of facilitating the use of the needs-based approach for health workforce planning. A real-life example using maternal and new-born care in Ghana is included to demonstrate the value and how the model works. A sensitivity analysis based on the applied example demonstrated that without explicitly incorporating the assumption of a changing future population health status (and need) in the empirical framework could have resulted in a substantial underestimation of the actual need for health professionals in the longer term by up to 17.4% for midwives and 23% for obstetrician/gynaecologists. Also, the simulation results were sensitive to practice variations between primary care facilities and tertiary health facilities by up to 20.3% for midwives. When support activities were considered, the need for midwives and obstetrician/gynaecologists was 21% and 18% respectively higher than if the support activities were not taken into consideration.

Supplementary Materials: The following are available online at https://www.mdpi.com/1660-4601/18/4/2113/s1. Material 1: Microsoft Excel-based model: population needs-based simulation model for health workforce planning; Material 2: Additional formulae.

Author Contributions: J.A.A. conceived the study as a PhD student under the supervision of C.D.C. and G.R. J.A.A. undertook the modelling which as was verified by C.D.C. and G.R. J.A.A. undertook data mining for the applied example which as was verified by C.D.C. and G.R. J.A.A. drafted the manuscript under the guidance of C.D.C. and G.R. C.D.C. and G.R. critically reviewed the draft manuscript and made substantial inputs. All the authors read and approved the final version for publication. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: As part of a larger doctoral research project, the study received ethics approval from the Health Research Ethics Committee (HREC) of North-West University in South Africa (ethics approval number: NWU-00416-20-A1) and the Ghana Health Service Ethics Committee (ethics approval number: GHS-ER17/07/20). Access to administrative datasets was granted by the Director-General of the Ghana Health Service.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article and supplementary material in Microsoft Excel.

Acknowledgments: We are grateful to Hamza Ismaila, Juliet Nabyonga-Orem, Charles Adjei Ampong, Samuel Alugsi, and Hilary Kipruto for reviewing the early drafts and providing useful comments.

Conflicts of Interest: The authors declare no conflict of interest.

3.9 REFERENCES

1. WHO. Global Strategy on Human Resources for Health: Workforce 2030; World Health Organization: Geneva, Switzerland, **2016**.
2. WHO; UNICEF. Declaration of Astana: From Alma-Ata towards Universal Health Coverage and the Sustainable Development Goals; World Health Organization (WHO) and United Nations Children's Fund (UNICEF): Astana, Kazakhstan, **2018**.
3. Aiken, L.H.; Buchan, J.; Sochalski, J.; Nichols, B.; Powell, M. Trends in International Nurse Migration. *Health Aff.* **2004**, *23*, 69–77.
4. Connell, J.; Zurn, P.; Stilwell, B.; Awases, M.; Braichet, J.-M. Sub-Saharan Africa: Beyond the Health Worker Migration Crisis? *Soc. Sci. Med.* **2007**, *64*, 1876–1891.
5. Dovlo, D. Wastage in the Health Workforce: Some Perspectives from African Countries. *Hum. Resour. Health* **2005**, *3*, 6.
6. Scheffler, R.M.; Campbell, J.; Cometto, G.; Maeda, A.; Liu, J.; Bruckner, T.A.; Arnold, D.R.; Evans, T. Forecasting Imbalances in the Global Health Labor Market and Devising Policy Responses. *Hum. Resour. Health* **2018**, *16*, 5.
7. Stenberg, K.; Hanssen, O.; Edejer, T.T.-T.; Bertram, M.; Brindley, C.; Meshreky, A.; Rosen, J.E.; Stover, J.; Verboom, P.; Sanders, R.; et al. Financing Transformative Health Systems towards Achievement of the Health Sustainable Development Goals: A Model for Projected Resource Needs in 67 Low-Income and Middle-Income Countries. *Lancet Glob. Health* **2017**, *5*, e875–e887, doi:10.1016/S2214-109X(17)30263-2.
8. Afriyie, D.O.; Nyoni, J.; Ahmat, A. The State of Strategic Plans for the Health Workforce in Africa. *BMJ Glob. Health* **2019**, *4*, e001115, doi:10.1136/bmjgh-2018-001115.
9. Asamani, J.A.; Amertil, N.P.; Ismaila, H.; Akugri, F.A.; Nabyonga-Orem, J. The Imperative of Evidence-Based Health Workforce Planning and Implementation: Lessons from Nurses and Midwives Unemployment Crisis in Ghana. *Hum Resour Health* **2020**, *18*, 16, doi:10.1186/s12960-020-0462-5.
10. Tomblin Murphy, G.; Kephart, G.; Lethbridge, L.; O'Brien-Pallas, L.; Birch, S. Planning for What? Challenging the Assumptions of Health Human Resources Planning. *Health Policy* **2009**, *92*, 225–233, doi:10.1016/j.healthpol.2009.04.001.
11. Ono, T.; Lafortune, G.; Schoenstein, M. Health Workforce Planning in OECD Countries: A Review of 26 Projection Models from 18 Countries. *OECD Health Work. Pap.* **2013**, doi:10.1787/5k44t787zcwb-en.

12. Roberfroid, D.; Leonard, C.; Stordeur, S. Physician Supply Forecast: Better than Peering in a Crystal Ball? *Hum. Resour. Health* **2009**, *7*, 1–13, doi:10.1186/1478-4491-7-10.
13. Castro Lopes, S.; Guerra-Arias, M.; Buchan, J.; Pozo-Martin, F.; Nove, A. A Rapid Review of the Rate of Attrition from the Health Workforce. *Hum. Resour. Health* **2017**, *15*, 21, doi:10.1186/s12960-017-0195-2.
14. Lopes, M.A.; Almeida, Á.S.; Almada-Lobo, B. Handling Healthcare Workforce Planning with Care: Where Do We Stand? *Hum. Resour. Health* **2015**, *13*, 38.
15. Hooker, R.S.; Muchow, A.N. Supply of Physician Assistants: 2013–2026. *J. Am. Acad. Pas* **2014**, *27*, 39–45.
16. Van Greuningen, M.; Batenburg, R.S.; Van der Velden, L.F. The Accuracy of General Practitioner Workforce Projections. *Hum. Resour. Health* **2013**, *11*, 31, doi:10.1186/1478-4491-11-31.
17. Murphy, G.T.; Birch, S.; MacKenzie, A.; Bradish, S.; Rose, A.E. A Synthesis of Recent Analyses of Human Resources for Health Requirements and Labour Market Dynamics in High-Income OECD Countries. *Hum. Resour. Health* **2016**, *14*, 59.
18. Castillo-Laborde, C. Human Resources for Health and Burden of Disease: An Econometric Approach. *Hum Resour Health* **2011**, *9*, 1–11.
19. Hall, T.L.; Mejia, A. *Health Manpower Planning: Principles, Method, and Issue*; World Health Organization: Geneva, Switzerland, **1978**.
20. Hornby, P.; Ray, D.K.; Shipp, P.J.; Hall, T.L. *Guidelines for Health Manpower Planning: A Course Book.*; World Health Organization: Geneva, Switzerland, **1980**.
21. Kavya, S.; Sanjay, P.Z.; Abhay, G.; Syed, Z.Q. Methodological Issues in Estimating and Forecasting Health Manpower Requirement. *J. Public Adm. Policy Res.* **2014**, *6*, 25–33, doi:10.5897/JPAPR2011.067.
22. Kolehmainen-Aitken, R.-L. *Human Resources Planning: Issues and Methods*; Data for Decision Making Project; Department of Population and International Health, Harvard School of Public Health: Boston, MA, USA, **1993**.
23. O'Brien-Pallas, L.; Baumann, A.; Donner, G.; Murphy, G.T.; Lochhaas-Gerlach, J.; Luba, M. Forecasting Models for Human Resources in Health Care. *J. Adv. Nurs.* **2001**, *33*, 120–129, doi:10.1046/j.1365-2648.2001.01645.x.
24. Dal Poz, M.R.; Dreesch, N.; Fletcher, S.; Gedik, G.; Gupta, N.; Hornby, P. *Models and Tools for Health Workforce Planning and Projections*; Human Resources for Health Observer; World Health Organization: Geneva, Switzerland, **2010**; pp. 1–19.

25. Tomblin Murphy, G.; Birch, S.; MacKenzie, A.; Alder, R.; Lethbridge, L.; Little, L. Eliminating the Shortage of Registered Nurses in Canada: An Exercise in Applied Needs-Based Planning. *Health Policy* **2012**, *105*, 192–202, doi:10.1016/j.healthpol.2011.11.009.
26. Ahern, S.; Woods, N.; Kalmus, O.; Birch, S.; Listl, S. Needs-Based Planning for the Oral Health Workforce—Development and Application of a Simulation Model. *Hum. Resour. Health* **2019**, *17*, doi:10.1186/s12960-019-0394-0.
27. Birch, S.; Gibson, J.; McBride, A.; Munros, team Opportunities for, and Implications of, Skill Mix Changes in Health Care Pathways: Pay, Productivity and Practice Variations in a Needs-Based Planning Framework. *Soc. Sci. Med.* **2020**, *250*, doi:10.1016/j.socscimed.2020.112863.
28. Birch, S.; Kephart, G.; Tomblin-Murphy, G.; O'Brien-Pallas, L.; Alder, R.; MacKenzie, A. Human Resources Planning and the Production of Health: A Needs-Based Analytical Framework. *Can. Public Policy* **2007**, *33*, S1–S16, doi:10.3138/9R62-Q0V1-L188-1406.
29. MacKenzie, A.; Tomblin Murphy, G.; Audas, R. A Dynamic, Multi-Professional, Needs-Based Simulation Model to Inform Human Resources for Health Planning. *Hum. Resour. Health* **2019**, *17*, doi:10.1186/s12960-019-0376-2.
30. Segal, L.; Guy, S.; Leach, M.; Groves, A.; Turnbull, C.; Furber, G. A Needs-Based Workforce Model to Deliver Tertiary-Level Community Mental Health Care for Distressed Infants, Children, and Adolescents in South Australia: A Mixed-Methods Study. *Lancet Public Health* **2018**, *3*, e296–e303, doi:10.1016/S2468-2667(18)30075-6.
31. Segal, L.; Leach, M.J. An Evidence-Based Health Workforce Model for Primary and Community Care. *Implement. Sci.* **2011**, *6*, doi:10.1186/1748-5908-6-93.
32. Asamani, J.A.; Christmals, C.D.; Reitsma, G.M. The Needs-Based Health Workforce Planning Method: A Systematic Scoping Review of Analytical Applications. *Health Policy Plan.* **2021**, doi:10.1093/heapol/czab022.
33. Murphy, G.T.; Birch, S.; Mackenzie, A.; Rigby, J.; Langley, J. An Integrated Needs-Based Approach to Health Service and Health Workforce Planning: Applications for Pandemic Influenza. *Healthc. Policy* **2017**, *13*, 28–42, doi:10.12927/hcpol.2017.25193.
34. Grossman, M. On the Concept of Health Capital and the Demand for Health. *J. Political Econ.* **1972**, *80*, 223–255.
35. Birch, S.; Kephart, G.; Murphy, G.T.; O'Brien-Pallas, L.; Alder, R.; MacKenzie, A. Health Human Resources Planning and the Production of Health: Development of an Extended Analytical Framework for Needs-Based Health Human Resources Planning. *J. Public Health Manag. Pract.* **2009**, *15*, S56–S61.

36. Murphy, G.T.; MacKenzie, A.; Guy-Walker, J.; Walker, C. Needs-Based Human Resources for Health Planning in Jamaica: Using Simulation Modelling to Inform Policy Options for Pharmacists in the Public Sector. *Hum. Resour. Health* **2014**, doi:10.1186/1478-4491-12-67.
37. World Health Organization. *Workload Indicators of Staffing Need—User Manual*; World Health Organization: Geneva, Switzerland, **2010**.
38. World Health Organization. *National Health Workforce Accounts: A Handbook*; World Health Organization: Geneva, Switzerland, **2017**.
39. McPake, B.; Scott, A.; Edoka, I. Analyzing Markets for Health Workers: Insights from Labor and Health Economics; The World Bank: Washington, DC, USA, **2014**; ISBN 978-1-4648-0224-9.
40. Hagopian, A.; Mohanty, M.K.; Das, A.; House, P.J. Applying WHO's 'Workforce Indicators of Staffing Need'(WISN) Method to Calculate the Health Worker Requirements for India's Maternal and Child Health Service Guarantees in Orissa State. *Health Policy Plan.* **2011**, *27*, czr007.
41. McQuide, P.A.; Kolehmainen-Aitken, R.-L.; Forster, N. Applying the Workload Indicators of Staffing Need (WISN) Method in Namibia: Challenges and Implications for Human Resources for Health Policy. *Hum. Resour. Health* **2013**, *11*, 64.
42. *Health Labor Market Analyses in Low- and Middle-Income Countries: An Evidence-Based Approach*; Scheffler, R.M., Herbst, C.H., Lemiere, C., Campbell, J., Eds.; The World Bank: Washington, DC, USA, **2016**; ISBN 978-1-4648-0931-6.
43. GSS Demography: Population Projection. Available online: https://statsghana.gov.gh/gssdatadownloadspage.php (accessed on 14 November 2020).
44. GSS; GHS. *ICF Ghana Maternal Health Survey 2007*; Ghana Health Service: Accra, Ghana, 2008.
45. GSS; GHS. *ICF Ghana Maternal Health Survey 2017*; Ghana Health Service: Accra, Ghana, 2018.
46. MOH. *Staffing Norms for the Health Sector*; Ministry of Health: Accra, Ghana, 2018.
47. GHS. *Human Resource Annual Report—2017*; Ghana Health Service: Accra, Ghana, 2017.
48. GHS. *Human Resource Annual Report—2018*; Ghana Health Service: Accra, Ghana, 2019.
49. GHS. *Human Resource Annual Report—2019*; Ghana Health Service: Accra, Ghana, 2020.
50. MOH. Holistic Assessment of the Health Sector Programme of Work 2013; Ministry of Health: Accra, Ghana, 2014.

51. MOH. Holistic Assessment of the Health Sector Programme of Work 2015; Ministry of Health: Accra, Ghana, 2016.
52. MOH. Health Sector Holistic Assessment of the Health Sector Performance—2015; Ministry of Health: Accra, Ghana, 2016.
53. MOH. Health Sector Holistic Assessment of the Health Sector Performance—2017; Ministry of Health: Accra, Ghana, 2018.
54. MDC Medical and Dental Council—Official Website. Available online: https://www.mdcghana.org/gazette/ (accessed on 14 November 2020).
55. Tomblin Murphy, G.; Birch, S.; MacKenzie, A.; Rigby, J.; Murphy, G.T.; Birch, S.; MacKenzie, A.; Rigby, J.; Tomblin Murphy, G.; Birch, S.; et al. Simulating Future Supply of and Requirements for Human Resources for Health in High-Income OECD Countries. *Hum. Resour. Health* **2016**, *14*, 77, doi:10.1186/s12960-016-0168-x.
56. MOH. Staffing Norms for the Health Sector of Ghana (Volume 1); Ministry of Health: Accra, Ghana, 2015.
57. GHS. *Health Sector Facts and Figures—2017*; Ghana Health Service, Policy, Planning Monitoring and Evaluation Division: Accra, Ghana, 2018.
58. Elisha, D.; Levinson, D.; Grinshpoon, A. A Need-Based Model for Determining Staffing Needs for the Public Sector Outpatient Mental Health Service System. *J. Behav. Health Serv. Res.* **2004**, *31*, 324–333, doi:10.1007/bf02287294.
59. Laurence, C.O.; Heywood, T.; Bell, J.; Atkinson, K.; Karnon, J. The Never Ending Road: Improving, Adapting and Refining a Needs-Based Model to Estimate Future General Practitioner Requirements in Two Australian States. *Fam. Pract.* **2018**, *35*, 193–198, doi:10.1093/fampra/cmx087.
60. O'Brien-Pallas, L.; Baumann, A.; Birch, S.; Murphy, G.T. Health Human Resource Planning in Home Care: How to Approach It–That Is the Question. *HealthcarePapers* **2000**, *1*, 53–59, discussion 109-112.
61. Asamani, J.A.; Chebere, M.M.; Barton, P.M.; D'Almeida, S.A.; Odame, E.A.; Oppong, R. Forecast of Healthcare Facilities and Health Workforce Requirements for the Public Sector in Ghana, 2016–2026. *Int. J. Health Policy Manag.* **2018**, *7*, 1040.
62. GHS, Health Workforce Gaps and Cost-Benefit Analysis of Proposed Staff Redistribution in the Ghana Health Service; Ghana Health Service: Accra, Ghana, 2018.
63. Birch, S.; Tomblin Murphy, G.; MacKenzie, A.; Whittaker, W.; Mason, T. Will the Need-Based Planning of Health Human Resources Currently Undertaken in Several Countries Lead

to Excess Supply and Inefficiency? A Comment on Basu and Pak. *Health Econ.* **2017**, *26*, 818–821, doi:10.1002/hec.3370.

64. Cometto, G.; Buchan, J.; Dussault, G. Developing the Health Workforce for Universal Health Coverage. *Bull. World Health Organ.* **2020**, *98*, 109.
65. WHO. National Health Workforce Accounts—Implementation Guide; World Health Organization: Geneva, Switzerland, 2017.

Supplementary material 2: Additional formulae

1. ATTRITION

The attrition, ***a*** of health professionals of category ***n***, in the analytical model (in equation 1) is defined as:

$$a_n = \frac{\sum(d, r, i, e)}{S_{n,t-1}} \quad \text{… supp. equation 1}$$

Where:

- ***d*** is the number of deaths in health professional of category ***n*** in time ***t-1***
- ***r*** is the number of retirements amongst health worker type n in time ***t-1***
- ***i*** is the number of health professionals of category ***n*** that permanently went out of the labour market due to ill-health in time ***t-1***
- ***e*** is the number of out-migration from the jurisdiction amongst health worker category ***n*** in time ***t-1***

2. HWF INFLOWS

The inflows, ***I*** for a health professional of category ***n***, in the analytical model (in equation 1) is also defined as:

$$I_n = [E_n(1 - U_n) + \mathrm{Im}_n] \times pr_n \quad \text{… supp. equation 2}$$

Where:

- I_n is the inflows of health professionals of category ***n***
- E_n is the number of enrolments in the health professions education institutions for health professionals of category ***n***.

- U_n is the program dropout rate (proportion of a year's cohort that does not complete the course of training).
- Im_n is the number of health professionals of category ***n*** that migrates into the jurisdiction per year.
- pr_n is the pass rate of trained health professionals of category ***n*** from the licensing examination.

3. RATE OF CHANGE IN LEVEL OF HEALTH

We adopted the standard formulae for instantaneous rate of change [36] which is mathematically expressed as follows:

$$R_h = \frac{-[\text{Ln}\,(1-P_h)]}{d} \qquad \textbf{… supp. equation 3}$$

Where:

- ***Ln*** is the natural log
- P_h is the proportional change of health status ***h*** over the duration between two timepoint ***d***.
- ***d*** is the duration in years within which the proportional change in health status ***h*** occurred. `

4. AVAILABLE WORKING TIME

$$AWT_n = [\text{A} - (\text{B} + \text{C} + \text{D} + \text{E})] \times \text{F} \qquad \text{… supp. equation 4}$$

- AWT_n is the total available working time in a year for a health professional of category ***n***
- ***A*** is the number of possible working days in a year
- ***B*** is the number of public holidays in a year
- ***C*** is the number of annual leave days in a year
- ***D*** is the number to sick leave days entitled by the health professional in a year

- ***E*** is the number of days off due to other leave, such as training in a year.

- ***F*** is the number of working hours in one day.

CHAPTER 4:
ARTICLE 3: HEALTH SERVICE ACTIVITY STANDARDS AND STANDARD WORKLOADS FOR PRIMARY HEALTHCARE IN GHANA: A CROSS-SECTIONAL SURVEY OF HEALTH PROFESSIONALS

James Avoka Asamani [1,2], Christmal Dela Christmals [2,*] and Gerda Marie Reitsma [2]

[1] Centre for Health Professions Education, Faculty of Health Sciences, North-West University, Potchefstroom Campus, Building PC-G16, Office 101,11 Hoffman St., Potchefstroom 2520, South Africa; asamanij@who.int (J.A.A.); christmal.christmals@nwu.ac.za (C.D.C); gerda.reitsma@nwu.ac.za (G.M.R.)

[2] Intercountry Support Team for Eastern and Southern Africa, Health Workforce Unit, Regional Office for Africa, World Health Organisation, 82-86 Cnr Enterprise/Glenara Roads, Harare CY 348, Zimbabwe

* Correspondence: christmal.christmals@nwu.ac.za; Tel.: +27-642379552

This article was published in the Health Policy Section of the Healthcare, an international peer-reviewed journal with an impact factor of 2.645 based on the 2021 Journal Citation Report (JCR). (Link to the publication https://doi.org/10.3390/healthcare9030332). The chapter is presented in accordance with the journal's guidelines which are available at https://www.mdpi.com/journal/healthcare/instructions. Exceptions were made for the prescribed margins, line-spacing, fonts, table formatting and also presented in one column per page instead of two columns per page by the journal. These modifications were to adhere to the North-West University guidelines and to maintain uniformity of the thesis. Tables and figures are included with the text to facilitate easier reading and comprehension.

4.1 ABSTRACT

The attainment of health system goals is largely hinged on the health workforce availability and performance; hence, health workforce planning is central to the health policy agenda. This study sought to estimate health service activity standards and standard workloads at the primary health care level in Ghana and explore any differences across health facility types. A nationally representative cross-sectional survey was conducted amongst 503 health professionals across eight health professions who provided estimates of health service activity standards in Ghana's PHC settings. Outpatient consultation time was 16 min, translating into an annual standard workload of 6030 consultations per year for General Practitioners. Routine nursing care activities take an average of 40 min (95% CI: 38–42 min) for low acuity patients; and 135 min (95% CI: 127–144 min) for high dependency patients per inpatient day. Availability of tools/equipment correlated with reduced time on clinical procedure. Physician Assistants in health centres spend more time with patients than in district hospitals. Midwives spend 78 min more during vaginal delivery in health centres/polyclinics than in district/primary hospital settings. We identified 18.9% (12 out of 67) of health service activities performed across eight health professional groups to differ between health centres/polyclinics and district/primary hospitals settings. The workload in the health facilities was rated 78.2%, but as the workload increased, and without a commensurate increase in staffing, health professionals reduced the time spent on individual patient care, which could have consequences for the quality of care and patient safety. Availability of tools and equipment at PHC was rated 56.6%, which suggests the need to retool these health facilities. The estimated standard workloads lay a foundation for evidence-based planning for the optimal number of health professionals needed in Ghana's PHC system and the consequent adjustments necessary in both health professions education and the budgetary allocation for their employment. Finally, given the similarity in results with Workload Indicators of Staffing Need (WISN) methodology used in Ghana, this study demonstrates that cross-sectional surveys can estimate health service activity standards that are suitable for health workforce planning just as the consensus-based estimates advocated in WISN.

Keywords: health service standards; standard workload; activity standards; primary health care; health workforce planning; human resources for health; workload indicators of staffing need (WISN)

4.2 INTRODUCTION

The extent of health service coverage and its quality anywhere is primarily hinged on the health workforce's availability and quality [1,2]. Therefore, as countries continue to push for Universal Health Coverage (UHC) and the Sustainable Development Goals (SDGs), planning for the health workforce has become a central part of the health policy agenda. One component of the health workforce planning process involves determining the optimal number and mix of health workers required to serve a given population. Three broad approaches, population ratios, service demand/utilisation-based, and population needs-based approaches, have been used in planning the health workforce. Underlying each of these approaches is an explicit (as in needs-based and utilisation-based approaches) or implicit (as in population ratios) assumption about some measures of health worker productivity [3,4]. The Workload Indicators of Staffing Needs (WISN) tool, which is part of the service demand/utilisation-based approaches, is developed by the World Health Organisation (WHO) and is widely used [5–7]. In the WISN manual, WHO defined standard workload as the amount of work of a particular service delivery activity that one health professional who is well trained and reasonably motivated could perform in a year if the health professional dedicated all his/her working time to delivering that service [5–7]. This depends on how much time a health professional has available in a year, and the professional standard time required to deliver one unit of his/her health service tasks (see equations 2 and 3). In the WISN methodology, staffing requirements to cover a health service activity are derived by dividing the observed workload (or count of service utilisation) for that activity by its standard workload [8–10]. Similarly, in the population needs-based methodology for health workforce requirements, estimates of anticipated workload (based on population size, demographics, health status indicators and planned or otherwise required type of services) are divided by the health worker productivity standard to derive the staffing requirement. Thus, both the service demand/utilisation-based approach and the needs-based approach have a similarity in the denominator; they use some measure of productivity or standard workload but only differ in whether anticipated workload (needs) or observed workload levels (service utilisation) should be used as the numerator. Additionally, there is an emerging approach in predicting health professionals' workload using health expenditure and budgets [11]. With the standard workloads for health professionals established, it would also be feasible to estimate the required health professionals using the predicted workloads from this emerging approach.

Proponents of the needs-based approach have not had consensus on the best proxy measure of health worker productivity; hence different measures have been used in previous estimates, mostly with validity concerns [12–14]. Asamani et al. [15] have argued that the concept of standard workload used in the WISN methodology appears to be a reasonably valid measure of a productivity standard that could be applied in a needs-based framework for health workforce planning. This will also allow for a concurrent application and comparability of results between the two approaches since the only divergent variable will be the measure of workload (i.e., observed workload versus predicted/anticipated workload).

Although all WISN studies have inherently elicited service (activity) standards and determined the standard workloads, most papers have focused on reporting the staffing estimates and gaps, which tend to be the WISN study outcome of policy interest. Thus, it has become necessary to systematically elicit and document the service standards and standard workloads of various health workers, which becomes an important reference standard for health workforce planning and management.

Ghana operates a multi-tier gatekeeper health system where community-based health planning and service (CHPS) compounds/zones serve as the first contact of the health system. CHPS are mainly manned by nurses who live within the communities to serve a population of 5000 or 750 households in sparsely populated areas [16]. At this level, the main services provided are preventive, treatment of minor illnesses and maternal care, including deliveries where there is a midwife available. The next level of the health system is health centres that serve as the first referral level health facility at the sub-district level for populations up to 200,000 but can be enhanced in urban areas to serve larger populations, in which case they are designated as polyclinics [17]. At these levels, a wide range of services are provided on an outpatient basis and with facilities for short-term admission for observation (not more than 24–48 h). Most health centres are headed by physician assistants, while polyclinics usually have a medical officer (general practitioner). District (primary) hospitals are established in administrative district capitals or for populations between 100,000 and 200,000, where they provide a range of outpatient and inpatient services. Administrative regions have regional hospitals that are equipped with specialist facilities for the secondary level of care. However, in large regions and metropolis, secondary hospitals may be designated for populations of at least 1.2 million. At the health system’s apex are tertiary hospitals (usually teaching hospitals affiliated with universities) that provide super-specialised health services and have a mandate for teaching and cutting-edge research [17].

Over the years, Ghana's health workforce situation dramatically improved from 1.07 doctors, nurses, and midwives per 1000 population in 2005 to 2.56 per 1000 population in 2018 [18], and with a capacity to produce more than 25,000 health professionals of various categories per year. However, various reports have shown that Ghana's health workforce situation is still sub-optimal and plagued with inequitable geographical distribution, sub-optimal productivity, and inefficiencies [19,20]. Determining the optimal need for health professionals and using the same to plan health service delivery, the production, recruitment, and distribution of health professionals has been a delicate issue with vested interests recently [21,22].

Ghana completed a WISN study in 2018 in which the activity standards were elicited using an open-ended questionnaire in which conveniently selected health professionals across health facilities provided information on their main activities and the corresponding time for accomplishing each of them [23]. Aimed to achieve a technical consensus, an initial group of health professionals provided a list of health service activities they perform, and the corresponding time spent on each patient. These were then collected and sent to the next health facility, where the completed tool was given to another batch of health professionals (in the same category) to indicate if they agreed with the previous batch of health professionals' proposal. The process continued until a near consensus was achieved where no new issues were raised by the subsequent batches of health professionals [24]. Although some of the established standards were cross-validated with time-motion observations, the approach arguably inhibited divergent views in the setting of standards. With the consensus-based approach adopted then, it was not possible to measure the level of uncertainty or practice variations that may be inherent across rural and urban areas, and the different types of health facilities. To address this concern, we undertook a cross-sectional study to elicit the activity standards of eight categories of health professionals at primary health care settings in Ghana. This study was, therefore, aimed at (a) systematically estimating service standards (the mean estimates of time spent on health service activities) alongside the level of uncertainties or practice variation (at 95% confidence interval); (b) the resulting standard workload per year and examined any differences across health facility types and other characteristics; and (c) explore the relationship between health service activity standards, and workload levels and availability of tools/equipment.

4.3 METHODS

4.3.1 Study Design

A cross-sectional survey design was adopted for this study to obtain information on the prevailing practice of health professionals under the given circumstances of their health facilities.

4.3.2 Population

The target population in this study included health professionals (general practitioners, nurses, midwives, physician assistants, biomedical scientists, pharmacists, pharmacy technicians and nutritionists/dieticians) working in Primary Health Care (PHC) settings (primary hospitals, health centres and CHPS compounds/zones) in Ghana.

The inclusion criteria were full-time health professionals of the GHS with the requisite practicing license from the relevant professional regulatory council who were working in either a primary/district hospital, or a health centre/polyclinic or a CHPS zone/compound and with a minimum of one-year post-qualification working experience in their duty post at the time of the study. Professionals with less than one year post-qualification working experience were assumed to be less proficient in the performance of key tasks [25] and could bias the standard time estimation if they were included. Health professionals who were on internship or relief duty (not their permanent post) were excluded, same for health professionals who were performing managerial or other duties different from their core professional training for more than 50% of their time.

4.3.3 Sample Size and Sampling Technique

4.3.3.1 Sample Size

Available data from the GHS [26] showed that in April 2020, the three (3) sampled regions had about 58,984 of the health professionals of interest in this study (general practitioners, nurses, midwives, physician assistants, biomedical scientists, pharmacists, and nutritionists/dieticians) working at the PHC level. Using this total number as the accessible population and an alpha level of 0.05, the minimum sample size was estimated to be 397 using the simplified Yamane's sample size formula [27]. To account for anticipated non-response, an assumed rate of 15% was added based on previous experiences with surveys involving health professionals in Ghana [28]. The adjusted sample size was a minimum of 456 health professionals to have sufficient representation of each health professional category to allow for inference [29]. An all-inclusive sample was used for the health professional categories with a total staff of thirty (30) or less in any of the three regions. Thus, the overall nationally representative sample was estimated to be at least 612 health professionals across the three (3) regions.

Box 1. Sample size determination.

$$\boldsymbol{n = \frac{N}{1 + N(e)^2}} \qquad (1)$$

where: *n* = required sample size

N= Accessible population

e = alpha level or significance level

Thus,

$$n = \frac{58984}{1+58984(0.05)^2} \approx 397$$

Adjusted sample size = 612

Source: Yamane (1967) [27].

4.3.3.2 Sampling Technique

A multistage stratified sampling approach was used to recruit a nationally representative sample [30]. First, the sixteen (16) regions of Ghana were geographically divided into three (3) main clusters: southern, middle, and northern zones. One region from each of these clusters was randomly selected through balloting in which the Greater Accra region in the southern zone, Bono East region in the middle zone, and Upper East region in the northern zone were selected for the study.

Each geographical stratum (represented by the regions) was allocated a sample proportional to its share of the national stock of the respective occupational groups of health professionals of interest (see Table 1). Similarly, in each stratum (region), the allocated sample was further proportionally allocated to the health facility types (primary/district hospital, health centre and CHPS zone). The health facilities were then randomly selected using Microsoft® Excel random numbers. In each health facility, the proportionally allocated sample size was further divided proportionally for the various health professional categories of interest in that health facility. For the health professionals, a simple random sampling using Microsoft® Excel was used to select those to contact from the facility's staff list (nominal roll). Whenever a health professional who has been randomly selected was contacted and he/she declined to participate in the study, others of similar health professional category in the facility (if available) were randomly sampled as a replacement until the required sample from that facility was exhausted.

Table 1: Sample size and sample allocation

Category of Staff	Greater Accra Region				Bono East Region				Upper East Region				Overall Sample
	PH	HC/ PolyC	CHPS	Regional Sample	PH	HC/ PolyC	CHPS	Regional Sample	PH	HC/ PolyC	CHPS	Regional Sample	
Medical officers (general practitioners)	24	12	0	36	9	1	0	10	14	1	0	15	61
Professional nurses	30	29	1	60	7	3	10	20	13	12	4	29	109
Enrolled nurses	20	31	3	54	5	9	4	18	10	14	9	33	105
Community health nurses	9	26	18	53	10	6	8	24	1	11	20	32	109
Midwives	15	23	1	39	2	3	1	6	4	5	4	13	58
Pharmacists and pharmacy technicians	15	6	0	21	5	1	0	6	7	1	0	8	35
Dieticians and Nutritionists	10	11	0	21	1	0	0	1	0	1	0	1	23
Physician assistants	2	4	1	7	15	20	1	36	14	1	7	22	65
Laboratory scientists and technicians	20	5	0	25	4	2	0	6	16	0	0	16	47
Total	92	127	25	316	54	44	25	127	63	46	44	169	612

PH = Primary hospital; HC = Health centre; PolyC = Polyclinic; CHPS = Community-Based Health Planning and Services.

4.3.4 Recruitment of Participants

Following ethical approval from the ethics review committees, permission was sought from the Director-General of GHS, which was granted, and an introductory letter was written from the office of the Director-General to the respective Regional Directors of Health Services (RDHS) to allow the study to proceed and serve as regional gatekeepers. The RDHS, in turn, informed the selected health facilities of the study to grant access to the participants.

In each hospital, the facility quality assurance or research coordinator served as mediators to facilitate the identification and access to potential participants. A research information sheet was handed out to prospective participants individually at their various units or wards by the research coordinator or the facility's quality assurance coordinator. However, in health centres and CHPS compounds, the staff are usually very few and with no quality assurance or research coordinators. In these settings, the researchers approached the team leader in the facility to identify one of the staff who was not within the study's inclusion criteria and had no power relationship with the other staff to serve as a mediator. The mediator supported the researchers to contact the rest of the staff to hand out the information sheet. Health professionals who met the inclusion criteria and voluntarily agreed to participate in the study were given a voluntary consent form to carefully study, ask the necessary questions and sign if they were willing to take part in the study.

Upon signing informed consent, willing participants were given the questionnaire and guided as needed to complete it via Data Analytics®, an online data collection platform with end-to-end encryption widely used for survey data collection. The geographical coordinates of the location where the participant completed the data collection tool were automatically recorded and linked to the data to enable audit. The data collection was conducted from 21 September 2020 to 21 December 2020.

4.3.5 Data Collection Tool

The data collection tool was adapted from the job components tool used for data collection in the Workload Indicators of Staffing Needs (WISN) study in Ghana [31,32]. The tool collected background information on the health facilities in which the health professionals work and that of the health professionals themselves, and the average time it takes health professionals to perform their main health service delivery activities. As the data collection tool was intended to measure the amount of time health workers spend in undertaking different health service delivery tasks, the data collection tool was designed to reflect the job description of the various health professionals and was scrutinised by peers and subject matter experts (SME) in the health professions whose feedback was used to make adjustments to address the objectives of the study better and ensure content validity.

4.3.6 Ethical Considerations

The study was reviewed and approved by the North-West University's Health Research Ethics Committee (NWU-00416-20-A1) and the GHS Ethics Review Committee (GHS-ER17/07/20) before the commencement of the study. Following ethical approval from both institutions, permission and introductory letters were obtained from the Director-General of GHS to the Regional Directors of Health Services (RDHS) and heads of health facilities to access participants. Participation was entirely voluntary, and the informed consent was obtained by an independent person who had no power relation with the participants. No individual information of health professionals or the facility they work in has been reported; instead, aggregate data is analysed and reported.

4.3.7 Data Processing and Analysis

The raw data was downloaded from the online Survey Analytics® Software to Microsoft Excel® for cleaning, after which it was imported into SPSS® version 26 for analysis. Descriptive analysis with estimates of uncertainty was undertaken mainly to estimate the average time taken by various health professionals to perform their service delivery activities and the 95% confidence interval around the point estimates. Inferential analysis in the form of an independent *t*-test [29,33] was conducted to examine if there were significant differences between district/primary hospitals' activity standards and those of the health centres/polyclinics. Pearson's correlation analysis [29,33] was also conducted to examine any association between self-reported workload levels and the estimated activity standards. The independent variables were measured at interval level using a scale of 0-5 while the dependent variable was measured at ratio level (unit of time in minutes).

4.3.8 Computing Standard Workload from Service Standards and Available Working Time

As defined in the WISN manual [7], the standard workload is a function of two components: (a) the Service Standard (SS) for the activity to be performed, which is defined as the average time that it will take a well-trained and motivated health professional to complete the health service activity to acceptable professional standards within the context of the jurisdiction and (b) the Available Working Time (AWT)—the time a health worker has available in one year to do his/her work, taking into account all absences (Equation (2)).

$$AWT = A - (B + C + D + E + F) \quad (2)$$

where:

- AWT is the total available working time
- A is the number of days in a year = 365
- B is the number of days off for public holidays in a year
- C is the number of days off for annual leave in a year
- D is the number of days off due to sick leave in a year
- E is the number of days off due to other leave, such as training, etc., in a year.
- F is the number of weekend days or off-duty days

$$SW_{n,y} = \frac{AWT_n}{SS_{y,n}} \quad (3)$$

where:

- $SW_{n,y}$ is the standard workload for health professional category n when performing health service activity y.
- AWT_n is the available working time of the health professional category n.
- $SS_{y,n}$ is the Service Standard or the time it takes a well-trained health professional of type n to deliver the service activity, y.

4.4 FINDINGS

4.4.1 Demographic Characteristics of the Participants and Health Facilities in Which They Work

A total of 503 valid questionnaires were received from participants out of the estimated sample size of 612, representing a response rate of 82.2%. The participants' ages ranged from 20–60 years, with an average of 33 years (±7.02 years). The majority of the health professionals (*n* = 267, 53%) were between the ages of 30–39 years, followed by those in the 20–29 years' age group (n = 166, 33%). About 86% of the health professionals were below 40 years which signifies the youthful nature of the health professionals. Only 4.2% (n = 21) were 50 years or older (Table 2).

Table 2: Age and gender distribution of health professionals

Age Bracket	Frequency	Percentage
20–29 Years	166	33.0%
30–39 Years	267	53.1%
40–49 years	49	9.7%
50–59 Years	20	4.0%
60 Years or more	1	0.2%
Total	503	100.0%
Gender		
Male	185	36.8%
Female	318	63.2%
Total	503	100.0%

Most participants were clinical nurses—Registered General Nurses and Enrolled Nurses (n = 219, 43.5%) followed by Community Health Nurses (n = 65, 12.9%) and Laboratory Scientist/Technicians (n = 56, 11.1%) while Nutritionist/Dietician were the least (n = 6, 1.2%). Almost one (1) in three (3) of the health professionals (n = 158, 31.4%) had post-secondary school certificate qualification in their respective professions, a similar proportion (n = 158, 31.4%) had either a university degree or post-graduate qualification. About 26% (n = 133) had diploma qualifications and nearly 5% (n = 24) indicated having other qualifications which included fellowship with medical colleges, higher national diplomas, and doctorate degrees.

The health professionals had diverse working experience ranging from one (1) to forty-four (44) years, with the average being about 7 years (mean = 6.8 years, SD = 3.41 years). Additionally, at the time of the study, the health professionals, on average, had been working in their health facilities for nearly 4 years (mean = 3.6 years, 95% CI: 3.4–4.0 years (Table 3).

Table 3: The professional background of participants

Variable	Dimension	Frequency	Percent
Type of Health Professional	General Practitioner (Generalist Doctor)	30	6.0%
	Physician Assistant	47	9.3%
	Midwife	47	9.3%
	Clinical Nurse (General Nurse/Enrolled Nurse)	219	43.5%
	Preventive Nurse (Community Health Nurse)	65	12.9%
	Nutritionist/ Dietician	6	1.2%
	Laboratory Scientist/Technician	56	11.1%
	Pharmacist/Pharmacy Technician	33	6.6%
Total		503	100.0%
Highest qualification of the Health Professional	Certificate	158	31.4%
	Diploma	133	26.4%
	Post-Basic (Advanced) Diploma	30	6.0%
	First Degree	132	26.2%
	Masters/post-graduate specialisation	26	5.2%
	Other	24	4.8%
Total		503	100.0%

Variable	Min.	Max.	Mean (Years)	Std. Error	SD	95% CI	
						Lower	Upper
Years of experience in the profession	1.0	44.0	6.8	0.29	6.57	6.3	7.4
Years of experience in the current health facility	1.0	23.0	3.7	0.15	3.41	3.4	4.0

Consistent with the distribution of the health workers in the country, most of the participants were from the Greater Accra region (n = 235, 46.7%), followed by the Upper East region (n = 170, 33.8%) and the rest from Bono East region (n = 98, 19.5%). Additionally, more than half were based in primary/district hospitals (which are usually in the urban parts of the districts), whereas the health centres/polyclinics and CHPS had 37% (n = 186) and 10.1% (n = 51), respectively. The vast majority (61.2%, n = 308) considered the location of their health facilities to be urban areas, while 38.7% thought they were either working in a rural (12.3%) or semi-urban (26.4%) area.

4.4.2 Estimated Health Service Activity Standards

We summarised the average time spent by the different health professionals on their respective health service activities and reported the level of uncertainty in the estimated time using standard deviation, standard errors, and the 95% confidence interval (CI) around the mean. The activity standards are presented in more detail in Table 4.

Table 4: Health service activity standards estimated by health professionals in primary health care settings.

Category of Health Professional	Descriptive Statistics	Unit of Measurement	Service Standard Time (Mean)	Std. Error of the Mean	Std. Deviation	95% Confidence Interval	
						Lower	Upper
General Practitioner (Generalist Doctor)	Assessment, diagnosis and treatment of a new out-patient case	Minutes per patient	16	1.63	8.75	13	19
	Review of a follow-up out-patient case (old cases)	Minutes per patient per visit	9	0.93	5.00	7	11
	Review of inpatient per patient day (daily ward rounds)	Minutes per patient per inpatient day	15	1.55	8.19	12	18
	Referral of a patient	Minutes per patient	14	1.84	9.58	10	17
	Minor surgical procedures (e.g., suturing lacerations, incision and drainage)	Minutes per case	19	1.74	9.02	16	23
	Major surgical procedures	Minutes per case	64	10.13	49.61	44	84
	Patient education and counselling	Minutes per patient	14	1.54	8.29	11	17
	Interventions for minor (simple) medical emergencies	Minutes per case	12	1.37	7.23	10	15
	Interventions for moderate-to-severe medical emergencies	Minutes per case	25	3.17	17.09	19	31
	Interventions for critically ill medical emergencies	Minutes per case	35	3.74	19.81	28	42
	Clinical meetings	Hours per week	3	0.31	1.59	2	3
Physician Assistant (Medical)	Assessment, diagnosis and treatment of a new out-patient case	Minutes per patient	16	1.28	8.59	13	18
	Review of a follow-up out-patient case (old cases)	Minutes per patient per visit	10	0.83	5.59	8	11
	Review of inpatient per patient day (daily ward rounds)	Minutes per patient per inpatient day	14	1.27	7.39	12	16
	Referral of a patient	Minutes per patient	13	1.15	7.72	10	15

Category of Health Professional	Descriptive Statistics	Unit of Measurement	Service Standard Time (Mean)	Std. Error of the Mean	Std. Deviation	95% Confidence Interval	
						Lower	Upper
	Minor surgical procedures (e.g., suturing lacerations, incision and drainage)	Minutes per case	25	1.48	9.94	22	28
	Patient education and counselling	Minutes per patient	11	0.99	6.64	9	12
	Interventions for minor (simple) medical emergencies	Minutes per case	17	1.68	11.24	14	20
	Interventions for moderate-to-severe medical emergencies	Minutes per case	25	2.71	18.18	20	31
	Interventions for critically ill medical emergencies	Minutes per case	27	2.76	17.02	21	32
	Clinical meetings	Hours per week	3	0.28	1.75	2	3
Midwife	Antenatal care (ANC) consultation	Minutes per patient per visit	22	2.03	13.63	18	26
	Postnatal care (PNC) consultation	Minutes per patient per visit	19	1.24	8.20	17	22
	Family planning service (non-invasive procedure)	Minutes per patient per visit	16	2.31	12.67	12	21
	Family planning service (invasive procedure)	Minutes per patient per visit	39	2.95	13.21	33	45
	Prevention of Mother-To-Child (PMTC) transmission of HIV during antenatal care visit	Minutes per patient per visit	17	1.30	8.52	14	19
	Vaginal delivery	Minutes per patient	131	15.18	97.23	101	160
	Inpatient care per patient day (routine care for mother)	Minutes per patient per inpatient day	30	2.83	16.51	24	36
	Inpatient care per patient day (routine care for new-born)	Minutes per patient per inpatient day	30	3.29	18.62	24	36
	Admission processes per patient	Minutes per patient	22	1.45	8.34	19	24
	Discharge processes per patient	Minutes per patient	21	1.54	8.83	18	24
	Preparing a patient for caesarean section	Minutes per case	32	3.23	14.06	26	38

Category of Health Professional	Descriptive Statistics	Unit of Measurement	Service Standard Time (Mean)	Std. Error of the Mean	Std. Deviation	95% Confidence Interval	
						Lower	Upper
	Patient education and counselling	Minutes per patient	23	1.00	6.45	21	25
	In-patient management of complications of pregnancy	Minutes per patient per inpatient day	44	2.24	12.86	40	49
	Daily report writing	Minutes per day	40	3.47	21.42	33	46
	Monthly reports	Hours per month	7	0.99	6.57	5	9
	Taking-over and handing-over	Minutes per day	31	2.94	17.42	25	36
	Clinical meetings	Hours per week	3	0.36	2.10	2	4
Clinical Nurse (Registered General Nurse & Enrolled Nurse)	Out-patient care (triaging, vital signs and history taking)	Minutes per patient per visit	10	0.26	3.85	9	10
	Out-patient consultation (where applicable)	Minutes per patient per visit	13	0.53	5.24	12	14
	Admission processes per patient	Minutes per patient	19	0.55	6.98	18	20
	Discharge processes per patient	Minutes per patient	16	0.75	9.37	14	17
	Pre-Operative preparation of patients	Minutes per case	26	1.50	16.65	23	28
	Post-operative management which is different from routine care	Minutes per case	42	2.11	23.35	38	46
	Inpatient care per patient day (routine care) for low dependent cases or mildly ill patients	Minutes per patient per inpatient day	40	1.06	14.82	38	42
	Inpatient care per patient day (routine care) for moderately dependent cases or patients with severe illness	Minutes per patient per inpatient day	43	1.54	21.29	40	46
	Inpatient care per patient day (routine care) for highly dependent cases or critically ill patients	Minutes per patient per inpatient day	135	4.27	55.64	127	144
	Discharge patient education and counselling	Minutes per patient	18	0.56	8.07	17	19

Category of Health Professional	Descriptive Statistics	Unit of Measurement	Service Standard Time (Mean)	Std. Error of the Mean	Std. Deviation	95% Confidence Interval	
						Lower	Upper
	Minor surgical procedures (suturing lacerations, incision and drainage, wound dressings)	Minutes per patient	27	1.20	16.74	24	29
	Daily report writing	Minutes per day	32	1.98	25.32	29	36
	Monthly reports	Hours per month	5	0.31	3.63	4	6
	Taking-over and handing-over	Minutes per day	25	1.15	16.20	23	28
	Clinical meetings	Hours per week	3	0.13	1.64	3	3
Preventive Nurse (Community Health Nurse)	Family planning	Minutes per patient per visit	14	1.18	8.93	12	17
	Out-patient consultation to manage minor ailments	Minutes per patient per visit	12	1.16	6.54	10	14
	Referral of patients	Minutes per patient	9	0.92	6.40	8	11
	Patient education and counselling	Minutes per patient	14	1.37	10.82	11	17
	Home visiting	Minutes per home visit	23	1.49	11.92	20	26
	School health	Minutes per patient	12	1.01	7.88	10	14
	Immunisation	Minutes per patient	6	0.44	3.56	5	7
	Growth monitoring	Minutes per patient	6	0.37	2.95	6	7
	Monthly reports	Hours per month	4	0.28	2.15	4	5
	Cold chain management	Minutes per day	17	1.47	11.20	14	19
	Clinical meetings	Hours per week	2	0.10	0.66	2	2
Nutritionist and Dietician	Nutritional Status Assessment	Minutes per patient	13	4.60	11.26	4	22
	Patient education and counselling	Minutes per patient	22	2.79	6.83	16	27
	Referral of patients	Minutes per patient	8	2.18	4.88	3	12
	Intervention including diet planning for patients	Minutes per patient per visit	27	7.84	17.54	12	42

Category of Health Professional	Descriptive Statistics	Unit of Measurement	Service Standard Time (Mean)	Std. Error of the Mean	Std. Deviation	95% Confidence Interval	
						Lower	Upper
	School health	Minutes per patient	20	5.77	10.00	9	31
	Follow-ups/home visits	Minutes per patient	23	10.93	18.93	2	45
	Monthly reports	Hours per month	47	28.01	68.62	−8	102
	Clinical meetings	Hours per week	3	0.88	1.53	1	4
Laboratory Scientist and Laboratory Technician	Sample taking and processing	Minutes per sample	9	0.67	4.75	8	11
	Full blood count (using an automated machine)	Minutes per sample	6	0.41	3.06	5	7
	Rapid diagnostic tests (Malaria, HIV, etc.)	Minutes per sample	17	0.53	3.89	16	18
	Malaria test using microscopy	Minutes per sample	27	1.53	11.15	24	30
	Urine routine examination	Minutes per sample	18	0.99	7.30	16	20
	Stool Urine routine examination	Minutes per sample	23	1.83	13.41	20	27
	Blood sugar test	Minutes per sample	14	1.39	10.30	11	16
	Blood donor bleeding	Minutes per patient	31	1.24	8.59	29	34
	Preparing blood for transfusion	Minutes per unit of blood	35	1.34	9.06	32	37
	Blood chemistry	Minutes per batch of samples	17	0.65	4.33	16	18
	Culture and sensitivity analysis	Minutes per sample	74	3.43	15.36	67	81
	Report writing	Minutes per day	11	0.74	4.98	10	13
	Blood donation campaign	Hours per month	6	0.84	4.26	5	8
	Clinical meetings	Hours per week	3	0.77	4.70	2	5
Pharmacist & Pharmacy Technician	Prescription auditing and dispensing for out-patient cases	Minutes per patient per visit	7	0.71	4.05	6	9
	Prescription auditing and dispensing for in-patient cases	Minutes per patient per inpatient day	7	0.52	2.96	6	8

Category of Health Professional	Descriptive Statistics	Unit of Measurement	Service Standard Time (Mean)	Std. Error of the Mean	Std. Deviation	95% Confidence Interval	
						Lower	Upper
	Prescription refilling for chronic conditions	Minutes per patient per visit	7	1.04	5.50	5	9
	Pharmaceutical interventions to correct prescription errors	Minutes per case	7	0.73	4.12	6	9
	Patient adherence counselling and education	Minutes per patient	13	0.90	5.19	11	15
	Report writing	Minutes per day	24	1.32	6.20	21	26
	Reconstitution of powdered preparations	Hours per week	3	0.40	1.77	2	4
	Clinical meetings	Hours per week	4	1.24	5.95	1	6
	Management of stocks	Hours per week	7	1.05	5.74	5	9
	Procurement activities	Hours per quarter	16	3.69	15.64	8	23
	Quality Assurance (QA), Drug and Therapeutics Committee (DTC) activities	Hours per quarter	4	1.04	3.90	2	6

4.4.2.1 General Practitioners (Generalist Doctors)

Across the primary health care (PHC) settings, General Practitioners spent an average of 16 min (95% CI: 13–19 min) on the assessment, diagnosis and treatment of new patients in the outpatient clinic but 9 min (95% CI: 8–11 min) for outpatients on follow-up visits. Reviewing patients who are on admission (i.e., daily ward rounds) took an average of 15 min (95% CI: 12 −18 min), while minor surgeries, including repair of lacerations, incisions and drainage, etc., took 19 min (95% CI: 16–23 min). Major surgeries within the PHC context, including caesarean section, laparotomy, herniorrhaphy, etc., took an average of 64 min. However, given wide variations in these procedures' complexity, there was also considerable uncertainty in the estimated time spent. Therefore, when the 95% confidence interval is considered, major surgeries at the PHC level could be done within 44 min or take as long as 84 min.

4.4.2.2 Physician Assistants (Medical)

The direct patient care activities performed by Physician Assistants (PAs) at the PHC settings closely mirrored those of the General Practitioners, except major surgeries, which they are, by law and job description, not mandated to undertake. PAs spent an average of 16 min (95% CI: 13–18 min) on the consultation of new outpatient but an average of 10 min (95% CI: 8–11 min) for follow-up/review of old outpatient cases. However, unlike the General Practitioners who spend about 19 min on minor surgical procedures, the PAs spent about 25 min (95% CI: 22–28 min). When the 95% confidence intervals are taken into consideration, there is no significant difference between them (as the confidence intervals overlap).

4.4.2.3 Midwives

For midwives, antenatal care consultation took an average of 22 min (95% CI: 18–26 min). For postnatal consultations, an average time of 19 min was spent on each patient by midwives (95% CI: 17–27 min); 16 min (95% CI: 12–21 min) for non-invasive family planning services; and 39 min (95% CI: 33–45 min) for invasive family planning procedures. Additionally, for each supervised vaginal delivery, midwives spend an average of 131 min which could be as short as 101 min or as long as 160 min, when the uncertainty in the estimate (95% confidence interval) is taken into account. For each day that a patient stays on admission after delivery, midwives spend about 30 min on each of the mother and the newborn for routine care but as much as 45 min if there is a pregnancy complication. Also, patients received roughly 23 min (95% CI: 21–25 min) of patient education and counselling from midwives. In addition to the direct patient care activities, midwives spent about 31 min (95% CI: 25–36 min) per day on handing over (and taking over) from one shift to another—this represents 6.5% of the daily working time of midwives.

4.4.2.4 Clinical Nurse (Registered General Nurse and Enrolled Nurse)

The survey revealed that clinical nurses spend up to 10 min on history taking and checking vital signs in out-patient clinics, but where they were conducting a full out-patient consultation, an average of 13 min (95% CI: 12–14 min) is spent on each outpatient. Patients requiring admission into inpatient wards consumed about 19 min (95% CI: 18–20 min) of nurses' time for the admission process while the process of discharging them also took about 16 min (95% CI: 14–17 min), in addition to an average of 18 min nurses spend on patient education and counselling. Preparing a patient for surgical procedures (which is considered not part of routine inpatient care) took an average of 26 min (95% CI: 23–28 min) of nurses' time, whereas the post-operative management of surgical patients (excluding routine nursing care) was estimated to be an average of 42 min (95% CI: 38–46 min) per patient per inpatient day.

Depending on the patient's acuity level, there is a substantial variation in the time nurses spend in routine nursing care activities, including monitoring vital signs, administering prescribed medications, and supporting patients in their daily living activities. Low dependent patients received an average of 40 min per inpatient day (95% CI: 38–42 min), while patients with moderate dependency required some 43 min (95% CI: 40–46 min) per inpatient day. Expectedly, high dependency patients required an average of 135 min per inpatient day at the primary care level, but the true estimate could be between 127 min and 144 min when the 95% confidence interval is taken into consideration. In addition to the various direct patient care activities, clinical nurses, on average, spend some 25 min each day on handing/taking over and another 32 min on writing daily reports. Thus, nearly 12% of nurses' daily working time could be spent on handing/taking over and report writing (not including the recording of nursing actions that are part of each nursing procedure).

4.4.2.5 Preventive Nurse (Community Health Nurse)

The average time to provide family planning services by Community Health Nurses (CHNs) at the PHC level was about 14 min (95% CI: 12–17 min). In line with national policy, CHNs at the CHPS compounds undertake consultation and treatment of minor ailments, which takes about 12 min

(95% CI: 10–14 min) per patient. A similar amount of time (an average of 12 min, 95% CI: 10–14 min) is spent per school child anytime when school health activities are conducted. Both immunisation and growth monitoring each took an average of 6 min, whilst home visits took about 23 min (95% CI: 20–26 min) per household visited (excluding travel time for the home visiting). Additionally, CHNs spend 17 min per day to check and report on the maintenance of the cold chain for their vaccines.

4.4.2.6 Nutritionists and Dieticians

With a limited sample, it is estimated that Nutritionists and Dieticians spend about 13 min per patient on nutritional status assessment, and patients requiring nutritional interventions receive about 27 min (95% CI: 12–42 min) per visit or inpatient day while an additional 22 min is spent on each patient for education and counselling. It is worth emphasising that due to the limited sub-sample of only 6 nutritionists/dieticians in the study, these estimates must be interpreted with caution.

4.4.2.7 Laboratory Scientist/Technicians

On average, obtaining and processing specimens (samples) for laboratory examination took 9 min (95% CI: 8–11 min) per patient. On actual tests, undertaking a full blood count using an automated analyser machine took about 6 min (95% CI: 5–7 min). Performing a rapid diagnostic test for malaria, HIV, and similar ones took an average of 17 min (95% CI: 16–18 min), the same for performing a batch of blood chemistry test using automated machines. Culture and sensitivity analysis, a procedure seldom performed at the PHC level, was estimated to take about 74 min but spread over a period of 2–4 days. When the uncertainty in the estimate is taken into account, culture and sensitivity analysis could take only 67 min or as much as 81 min. Besides the direct patient care activities performed on patients/samples, laboratory scientists/technicians spend roughly 10–13 min per day writing some summary reports and up to 8 h per month (upper confidence limit) on blood donation campaigns.

4.4.2.8 Pharmacists/Pharmacy Technicians

The time spent by Pharmacists/Pharmacy Technicians in auditing and dispensing prescribed medicines for outpatients (mean = 7, minutes 95% CI: 6–9 min) and inpatients (mean = 7 min, 95% CI: 6–8 min) were similar; same for the refilling of medications for patients with chronic illnesses. However, patient education and medication adherence counselling took 13 min (95% CI:

11–15 min). In addition to the direct individual patient care activities, Pharmacists/Pharmacy Technicians spend roughly 14 h per week or 35% of their working time reconstituting powdered preparations (3 h per week), managing pharmaceutical stock (7 h per week), and attending clinical meetings (4 h per week).

4.4.3 Estimated Standard Workload Per Year for the Health Service Activities

Using equation 2, we computed the available working time (AWT) for each health professional (supplementary material), which show that General Practitioners and PAs have 198 working days in a year (equivalent to 95,040 min) while the other categories have approximately 200 available working days per year which is equivalent to 96,000 min per year. Using the AWT in minutes as the numerator, we derived the standard workloads for each of the activity standards (see Equation (3)), which are crucial inputs for not only workforce planning but also productivity and efficiency management and analysis.

As shown in Table 5, if a General Practitioner is dedicated to only outpatient consultations, he/she could be reasonably expected to attend to 6030 new patients per year (or 10,444 follow-up cases per year). Given a marginal difference in the activity standard, PAs could see about 6108 new outpatients per year. The average number of deliveries that could be undertaken by a midwife in the PHC context of Ghana is estimated to be about 735, but the true value may lie somewhere between 598 and 951 per year. For patients with low-to-moderate dependency (as usually seen in PHC settings), a Clinical Nurse can be expected to nurse between 2078 and 2549 per year, which translates into a nurse-patient ratio of one nurse to 5–7 inpatients. A well-trained CHN could also provide roughly 16,000 (between 13,793 and 18,714) routine immunisations per year. A Laboratory Scientist/Technician could also perform some 5511 (or between 5199 and 5863) rapid diagnostic tests for Malaria, HIV or similar ones per year. Finally, a Pharmacist/Pharmacy Technician can audit and dispense 13,205 (or between 11,096 and 16,304) prescriptions in a year, while a Nutritionist/Dietician could undertake 7202 nutritional status assessments per year. Table 5 provides the details on the mean standard workloads with confidence intervals for all the health service activities included in the study.

Table 5: Estimated standard workload per year for health service activities.

Category of Health Professional	Descriptive Statistics	Standard Workload Per Year	95% Confidence Interval	
			Best Case Scenario (Using Lower Bound of the Service Standard)	Worst Case Scenario (Using the Upper Bound of the Service Standard)
General Practitioner (Generalist Doctor)	Assessment, diagnosis and treatment of a new out-patient case	6030	7558	5017
	Review of a follow-up out-patient case (old cases)	10,444	13,053	8704
	Review of inpatient per patient day (daily ward rounds)	6319	7915	5259
	Referral of a patient	6973	9489	5511
	Minor surgical procedures (e.g., suturing lacerations, incision and drainage)	4953	6020	4207
	Major surgical procedures	1488	2159	1135
	Patient education and counselling	6823	8708	5608
	Interventions for minor (simple) medical emergencies	7689	9817	6319
	Interventions for moderate-to-severe medical emergencies	3838	5126	3068
	Interventions for critically ill medical emergencies	2721	3444	2249
Physician Assistant (Medical)	Assessment, diagnosis and treatment of a new out-patient case	6108	7283	5259
	Review of a follow-up out-patient case (old cases)	9921	11,962	8475
	Review of inpatient per patient day (daily ward rounds)	6789	8254	5765
	Referral of a patient	7567	9224	6415
	Minor surgical procedures (e.g., suturing lacerations, incision and drainage)	3802	4301	3406
	Patient education and counselling	9043	11,088	7635
	Interventions for minor (simple) medical emergencies	5627	6985	4711
	Interventions for moderate-to-severe medical emergencies	3739	4726	3093
	Interventions for critically ill medical emergencies	3541	4435	2947

Category of Health Professional	**Descriptive Statistics**	**Standard Workload Per Year**	**95% Confidence Interval**	
			Best Case Scenario (Using Lower Bound of the Service Standard)	**Worst Case Scenario (Using the Upper Bound of the Service Standard)**
Midwife	Antenatal care (ANC) consultation	4449	5455	3755
	Postnatal care (PNC) consultation	5010	5735	4448
	Family planning service (non-invasive procedure)	5952	8280	4645
	Family planning service (invasive procedure)	2446	2869	2132
	Prevention of Mother-To-Child (PMTC) transmission of HIV during antenatal care visit	5694	6708	4946
	Vaginal delivery	735	951	598
	Inpatient care per patient day (routine care for mother)	3200	3926	2700
	Inpatient care per patient day (routine care for new-born)	3200	4077	2634
	Admission processes per patient	4436	5108	3921
	Discharge processes per patient	4533	5284	3968
	Preparing a patient for caesarean section	3015	3762	2515
	Patient education and counselling	6892	8796	5665
	In-patient management of complications of pregnancy	2163	2400	1968
Clinical Nurse (Registered General Nurse & Enrolled Nurse)	Out-patient care (triaging, vital signs and history taking)	9786	10,326	9299
	Out-patient consultation (where applicable)	7373	8009	6831
	Admission processes per patient	4436	5108	3921
	Discharge processes per patient	4533	5284	3968
	Pre-Operative preparation of patients	3763	4254	3374
	Post-operative management which is different from routine care	2285	2535	2080
	Inpatient care per patient day (routine care) for low dependent cases or mildly ill patients	2416	2549	2296

Category of Health Professional	Descriptive Statistics	Standard Workload Per Year	95% Confidence Interval	
			Best Case Scenario (Using Lower Bound of the Service Standard)	Worst Case Scenario (Using the Upper Bound of the Service Standard)
	Inpatient care per patient day (routine care) for moderately dependent cases or patients with severe illness	2224	2391	2078
	Inpatient care per patient day (routine care) for highly dependent cases or critically ill patients	709	756	668
	Discharge patient education and counselling	5324	5672	5017
	Minor surgical procedures (suturing lacerations, incision and drainage, wound dressings)	3586	3932	3296
Preventive Nurse (Community Health Nurse)	Family planning	6713	8012	5777
	Out-patient consultation to manage minor ailments	7895	9703	6655
	Referral of patients	10,289	12,768	8617
	Patient education and counselling	6892	8796	5665
	Home visiting	4237	4863	3753
	School health (assessment of pupil)	7799	9291	6719
	Immunisation	16,000	18,714	13,973
	Growth monitoring	15,335	17,320	13,759
Nutritionist and Dietician	Nutritional Status Assessment	7202	22,203	4298
	Patient education and counselling	6892	8796	5665
	Referral of patients	10,289	12,768	8617
	Intervention including diet planning for patients	3556	8255	2266
	School health	4800	11,056	3065
	Follow-ups/home visits	4115	50,284	2145
Laboratory Scientist and Laboratory Technician	Sample taking and processing	10,116	11,726	8894
	Full blood count (using an automated machine)	16,667	19,392	14,613

Category of Health Professional	Descriptive Statistics	Standard Workload Per Year	95% Confidence Interval	
			Best Case Scenario (Using Lower Bound of the Service Standard)	Worst Case Scenario (Using the Upper Bound of the Service Standard)
	Rapid diagnostic tests (Malaria, HIV, etc.)	5511	5863	5199
	Malaria test using microscopy)	3539	3979	3186
	Urine routine examination	5206	5820	4709
	Stool routine examination	4124	4872	3574
	Blood sugar test	7012	8753	5849
	Blood donor bleeding	3057	3314	2838
	Preparing blood for transfusion	2777	3004	2582
	Blood chemistry	5707	6171	5309
	Culture and sensitivity analysis	1297	1427	1189
Pharmacist & Pharmacy Technician	Prescription auditing and dispensing for out-patient cases	13,205	16,304	11,096
	Prescription auditing and dispensing for in-patient cases	13,953	16,396	12,144
	Prescription refilling for chronic conditions	13,994	19,910	10,788
	Pharmaceutical interventions to correct prescription errors	13,187	16,407	11,023
	Patient adherence counselling and education	7541	8761	6620

Note: The calculation for standard workload assumes that the health professional dedicates all his/her available working time to only a particular activity throughout the year.

4.4.4 Differences in Activity Standards between Health Centres/Polyclinics and District/Primary Hospitals

The services rendered at CHPS compounds are usually basic and performed by CHNs and some clinical nurses. However, all the cadres included in the study were available in the health centres/polyclinics and primary hospital/district hospitals. Hence, it was deemed appropriate to compare the activity standards between health centres/polyclinics and primary hospitals/district hospitals using an independent *t*-test (Table 6).

The analysis showed that out of 67 health service activities examined across eight health professional groups, there were statistically significant differences in 12 of the activity standards between health centres/polyclinics and district/primary hospitals. This represents significant practice variation across 18.9% of health service activities. The practice variations were much more pronounced amongst activities performed by PAs (7 out of 10 activities). PAs spend a significantly lower amount of time on patients at the district/primary hospitals compared to health centres for assessment, diagnosis and treatment of new cases ($MD = -9, p < 0.001$); review of follow-up patients ($MD = -5, P = 0.002$), minor surgical procedures ($MD = -7, P = 0.003$) as well as interventions for moderate-to-severe medical emergencies ($MD = -8, P = 0.035$). For General Practitioners, there was no statistically significant difference between the time spent on the various health service activities in health centres/polyclinics compared to the district/primary hospitals.

Similarly, no statistically significant difference was seen for activities performed by midwives except for time spent on supervised vaginal delivery. In health centres/polyclinics, midwives spend an average of 147 min on women during vaginal delivery as compared to an average of 70 min spent in the district/primary hospital settings. The mean difference of 78 min between health centres/polyclinics and district hospitals/primary hospitals is statistically significant ($t = -2.64, p = 0.013$). With regard to clinical nurses, the time spent on consultation (where they were permitted to do) varied between district hospitals and health centres/polyclinics (*15 min vs. 12 min*, $p = 0.011$). For CHNs, only the time spent on growth monitoring significantly varied between district hospitals and health centres (*8 min vs. 5 min*, $p = 0.009$). In the case of Laboratory Scientist/Technicians, the *t*-test shows a significant difference between the time taken to conduct blood sugar tests in the district/primary hospitals versus those of the health centres/polyclinics (*16 min vs. 9 min*, $p = 0.031$) as well as culture and sensitivity (*81 min vs. 64 min*, $P = 0.010$). Whereas no *t*-test was conducted in respect of activities performed by Nutritionists/Dieticians due to sample size limitation, those of the Pharmacist/Pharmacy Technician was not statistically significant.

Table 6: Test of differences in activity standards between health centres/polyclinics and primary/district hospitals.

Health Professional	Health Service Activities	Mean Time (Activity Standard)			*t*-Test for Equality of Means					
		Unit of Measurement	Primary/ District Hospital (a)	Health Centre/ Polyclinic (b)	Mean Difference (a-b)	Std. Error Difference	95% Confidence Interval of the Difference		t-Statistic	*p*-Value (2-tailed)
							Lower	Upper		
General Practitioner (Generalist Doctor)	Assessment, diagnosis and treatment of a new out-patient case	Minutes per patient	16	10	6	5.29	−4	17	1.21	0.235
	Review of a follow-up out-patient case (old cases)	Minutes per patient per visit	9	8	1	3.10	−5	7	0.28	0.784
	Review of inpatient per patient day (daily ward rounds)	Minutes per patient per inpatient day	15	15	0	6.12	−13	13	0.01	0.995
	Referral of a patient	Minutes per patient	13	18	−4	7.13	−19	11	−0.59	0.563
	Minor surgical procedures (e.g., suturing lacerations, incision and drainage)	Minutes per case	20	13	7	6.61	−6	21	1.09	0.285
	Major surgical procedures	Minutes per case	67	33	34	36.75	−42	110	0.93	0.362
	Patient education and counselling	Minutes per patient	14	12	3	5.12	−8	13	0.49	0.626
	Interventions for minor (simple) medical emergencies	Minutes per case	13	10	3	5.39	−9	14	0.47	0.641
	Interventions for moderate-to-severe medical emergencies	Minutes per case	27	8	18	10.01	−2	39	1.83	0.078
	Interventions for critically ill medical emergencies	Minutes per case	37	13	24	14.03	−5	53	1.72	0.097
Physician Assistant (Medical)	Assessment, diagnosis and treatment of a new out-patient case	Minutes per patient	11	19	−9	2.25	−13	−4	−3.85	0.000

Health Professional	Health Service Activities	Mean Time (Activity Standard)			*t*-Test for Equality of Means					
		Unit of Measurement	Primary/ District Hospital (a)	Health Centre/ Polyclinic (b)	Mean Difference (a-b)	Std. Error Difference	95% Confidence Interval of the Difference		t-Statistic	*p*-Value (2-tailed)
							Lower	Upper		
	Review of a follow-up out-patient case (old cases)	Minutes per patient per visit	7	12	−5	1.52	−8	−2	−3.30	0.002
	Review of inpatient per patient day (daily ward rounds)	Minutes per patient per inpatient day	10	17	−7	2.28	−12	−3	−3.20	0.003
	Referral of a patient	Minutes per patient	11	14	−4	2.28	−8	1	−1.63	0.111
	Minor surgical procedures (e.g., suturing lacerations, incision and drainage)	Minutes per case	21	28	−7	2.84	−12	−1	−2.38	0.022
	Patient education and counselling	Minutes per patient	8	12	−4	1.92	−8	0	−2.02	0.049
	Interventions for minor (simple) medical emergencies	Minutes per case	12	21	−8	3.17	−15	−2	−2.61	0.013
	Interventions for moderate-to-severe medical emergencies	Minutes per case	19	30	−11	5.24	−22	−1	−2.17	0.035
	Interventions for critically ill medical emergencies	Minutes per case	26	28	−2	5.59	−13	9	−0.38	0.709
Midwife	Antenatal care (ANC) consultation	Minutes per patient per visit	26	21	5	5.09	−5	15	0.95	0.347
	Postnatal care (PNC) consultation	Minutes per patient per visit	21	19	2	3.09	−4	8	0.59	0.556
	Family planning service (non-invasive procedure)	Minutes per patient per visit	23	15	8	6.04	−4	21	1.40	0.178
	Family planning service (invasive procedure)	Minutes per patient per visit	42	37	5	5.97	−8	17	0.75	0.461
	Prevention of Mother-To-Child (PMTC) transmission	Minutes per patient per visit	20	16	4	3.02	−2	10	1.29	0.205

Health Professional	Health Service Activities	Mean Time (Activity Standard)			*t*-Test for Equality of Means					
		Unit of Measurement	Primary/ District Hospital (a)	Health Centre/ Polyclinic (b)	Mean Difference (a-b)	Std. Error Difference	95% Confidence Interval of the Difference		t-Statistic	*p*-Value (2-tailed)
							Lower	Upper		
	of HIV during antenatal care visit									
	Vaginal delivery	Minutes per patient	70	147	−78	29.35	−137	−18	−2.64	0.013
	Inpatient care per patient day (routine care for mother)	Minutes per patient per inpatient day	28	31	−3	5.82	−15	9	−0.52	0.605
	Inpatient care per patient day (routine care for new-born)	Minutes per patient per inpatient day	34	27	8	6.60	−6	21	1.15	0.257
	Admission processes per patient	Minutes per patient	21	22	0	2.99	−6	6	−0.12	0.905
	Discharge processes per patient	Minutes per patient	22	20	2	3.15	−5	8	0.53	0.599
	Preparing a patient for caesarean section	Minutes per case	30	37	−7	7.35	−22	8	−0.95	0.354
	Patient education and counselling	Minutes per patient	24	23	1	2.43	−4	6	0.32	0.753
	In-patient management of complications of pregnancy	Minutes per patient per inpatient day	45	47	−3	5.09	−13	8	−0.49	0.627
Clinical Nurse (Registered General Nurse & Enrolled Nurse)	Out-patient care (triaging, vital signs and history taking)	Minutes per patient per visit	10	9	1	0.58	0	2	1.35	0.177
	Out-patient consultation (where applicable)	Minutes per patient per visit	15	12	3	1.29	1	6	2.61	0.011
	Admission processes per patient	Minutes per patient	19	19	0	1.29	−3	2	−0.24	0.812
	Discharge processes per patient	Minutes per patient	15	18	−3	1.75	−7	0	−1.75	0.082

Health Professional	Health Service Activities	Mean Time (Activity Standard)			*t*-Test for Equality of Means					
		Unit of Measurement	Primary/ District Hospital (a)	Health Centre/ Polyclinic (b)	Mean Difference (a-b)	Std. Error Difference	95% Confidence Interval of the Difference		t-Statistic	*p*-Value (2-tailed)
							Lower	Upper		
	Pre-Operative preparation of patients	Minutes per case	25	28	−2	3.86	−10	5	−0.64	0.523
	Post-operative management which is different from routine care	Minutes per case	41	49	−8	5.47	−19	3	−1.49	0.140
	Inpatient care per patient day (routine care) for low dependent cases or mildly ill patients	Minutes per patient per inpatient day	40	40	−1	2.19	−5	4	−0.28	0.782
	Inpatient care per patient day (routine care) for moderately dependent cases or patients with severe illness	Minutes per patient per inpatient day	43	43	1	3.19	−6	7	0.17	0.866
	Inpatient care per patient day (routine care) for highly dependent cases or critically ill patients	Minutes per patient per inpatient day	141	123	18	9.23	0	36	1.96	0.051
	Discharge patient education and counselling	Minutes per patient	19	17	2	1.20	−1	4	1.25	0.212
	Minor surgical procedures (suturing lacerations, incision and drainage, wound dressings)	Minutes per patient	29	25	4	2.53	−1	9	1.64	0.104
Community Health Nurse	Family planning	Minutes per patient per visit	13	15	−1	3.30	−8	5	−0.41	0.686
	Out-patient consultation to manage minor ailments	Minutes per patient per visit	14	12	2	3.86	−6	11	0.58	0.571
	Referral of patients	Minutes per patient	8	9	−1	2.78	−7	5	−0.33	0.745
	Patient education and counselling	Minutes per patient	13	17	−4	4.42	−13	5	−0.96	0.345

Health Professional	Health Service Activities	Mean Time (Activity Standard)			*t*-Test for Equality of Means					
		Unit of Measurement	Primary/ District Hospital (a)	Health Centre/ Polyclinic (b)	Mean Difference (a-b)	Std. Error Difference	95% Confidence Interval of the Difference		t-Statistic	*p*-Value (2-tailed)
							Lower	Upper		
	Home visiting	Minutes per home visit	25	21	4	4.01	−4	12	0.97	0.337
	School health	Minutes per patient	14	13	1	2.78	−5	6	0.28	0.784
	Immunisation	Minutes per patient	7	6	1	1.16	−1	3	0.90	0.375
	Growth monitoring	Minutes per patient	8	5	3	0.93	1	4	2.74	0.009
Laboratory Scientist/Technician	Sample taking and processing	Minutes per sample	10	9	1	1.47	−2	4	0.41	0.685
	Full blood count (using an automated machine)	Minutes per sample	6	5	0	0.90	−1	2	0.47	0.639
	Rapid diagnostic tests (Malaria, HIV, etc.)	Minutes per sample	17	18	−1	1.16	−4	1	−1.27	0.211
	Malaria test using microscopy)	Minutes per sample	29	24	5	3.30	−2	11	1.47	0.148
	Urine routine examination	Minutes per sample	18	20	−2	2.14	−6	2	−0.86	0.394
	Stool Urine routine examination	Minutes per sample	24	21	3	3.94	−4	11	0.89	0.379
	Blood sugar test	Minutes per sample	16	9	7	2.95	1	12	2.21	0.031
	Blood donor bleeding	Minutes per patient	32	29	3	2.77	−2	9	1.26	0.213
	Preparing blood for transfusion	Minutes per unit of blood	35	35	0	3.17	−6	6	0.01	0.993
	Blood chemistry	Minutes per batch of samples	17	18	−1	1.62	−4	2	−0.65	0.519
	Culture and sensitivity analysis	Minutes per sample	81	64	17	5.97	5	30	2.86	0.010
Pharmacist/ Pharmacy Technician	Prescription auditing and dispensing for out-patient cases	Minutes per patient per visit	8	6	2	1.44	−1	5	1.11	0.276

Health Professional	Health Service Activities	Mean Time (Activity Standard)			*t*-Test for Equality of Means					
		Unit of Measurement	Primary/ District Hospital (a)	Health Centre/ Polyclinic (b)	Mean Difference (a-b)	Std. Error Difference	95% Confidence Interval of the Difference		t-Statistic	*p*-Value (2-tailed)
							Lower	Upper		
	Prescription auditing and dispensing for in-patient cases Inpatient	Minutes per patient per inpatient day	7	7	0	1.10	−2	3	0.30	0.763
	Prescription refilling for chronic conditions	Minutes per patient per visit	8	5	4	2.10	−1	8	1.67	0.107
	Pharmaceutical interventions to correct prescription errors	Minutes per case	7	8	−1	1.52	−4	2	−0.67	0.508
	Patient adherence counselling and education	Minutes per patient	14	11	2	1.84	−2	6	1.21	0.237

4.4.5 Relationship between Health Service Activity Standards and Workload Levels and Availability of Tools/Equipment

Using a five-point Likert scale, health professionals were asked to self-rate the degree of workload in their health facility, workload level in their unit, and the availability of tools/equipment for work. The results show health facilities' workload was 3.91 out of 5, which represents 78.2% (95% CI: 76.8–79.6%); and 4.01 out of 5 at the unit level (80.2%, 95% CI: 78.7–81.7%). Also, the availability of equipment was self-rated as 2.83 out of 5, which represents only 56.6% (95% CI: 54.8–58.4%) availability of the requisite tools and equipment.

Using Pearson's correlation, we explored the relationship between the main health service activity standards on the one hand and self-rated health facility workload level, unit workload level and availability of tools/equipment on the other hand (Table 7). The analysis showed that for General Practitioners, none of the variables (i.e., self-rated health facility workload level, unit workload level and availability of tools/equipment) had a statistically significant association with the activity standards. However, health facilities' workload level had a moderate negative relationship with the time PAs spend on patient education/counselling ($r = -0.314, P < 0.05$). Similar moderate but statistically significant negative association are observed between workload at the unit level and PAs consultations for new outpatients ($r = -0.303, P < 0.05$); consultation for old outpatient cases ($r = -0.319, p < 0.05$) and review of inpatients ($r = -0.351, P <0.05$). Additionally, PAs time spent on minor surgical procedures significantly reduced with increasing workload level at the unit ($r = -0.348, P < 0.05$). Similarly, increasing availability of tools/equipment significantly reduced the time spent on minor surgical procedures ($r = -0.355, P < 0.05$) and referrals ($r = -0.444, P < 0.001$). On the other hand, the time PAs spent on interventions for critically ill medical emergencies rather increased with increasing levels of overall workload in the health facility ($r = 0.414, P < 0.05$).

For midwives, workload at the health facility moderately and positively correlated with the time spent on postnatal care consultations ($r = 0.313, p < 0.05$), family planning ($r = 0.434, p < 0.05$); inpatient care for the newborn ($r = 0.354, p < 0.05$); patient education/counselling ($r = 0.454, p < 0.05$) and management of complication of pregnancy ($r = 0.422, p < 0.05$). Availability of tools/equipment also had a moderate but statistically significant negative association with the time Clinical Nurses spend on the routine care of inpatients with moderate dependency ($r = -0.333, p < 0.001$). Noteworthy is also the Laboratory Scientists/Technicians spending more time on routine stool examination if there are tools/equipment and vice versa ($r = 0.288, p < 0.05$) but the time spent on full blood count being positively correlated with higher workload in the unit ($r = 0.289, p < 0.05$); same for blood sugar test ($r = 0.327, p < 0.05$) and blood chemistry analysis ($r = 0.294, p < 0.05$). Surprisingly, none of the health service activities performed by Pharmacists/Pharmacy Technicians had a statistically significant correlation with either self-rated workload levels or availability of the tools and equipment.

Table 7: Factors influencing the average time taken to accomplish health service activities.

Health Professional	Health Service Activities	Facility Workload Level	Unit Workload Level	Availability of Tools and Equipment
General Practitioner (Generalist Doctor)	Assessment, diagnosis and treatment of a new out-patient case	0.006	0.04	0.07
	Review of a follow-up out-patient case (old cases)	−0.192	−0.14	−0.15
	Review of inpatient per patient day (daily ward rounds)	0.043	0.33	−0.01
	Referral of a patient	0.068	0.14	−0.21
	Minor surgical procedures (e.g., suturing lacerations, incision and drainage)	0.349	0.33	−0.16
	Major surgical procedures	0.171	0.33	−0.12
	Patient education and counselling	0.095	0.14	0.10
	Interventions for minor (simple) medical emergencies	−0.069	−0.02	−0.03
	Interventions for moderate-to-severe medical emergencies	−0.065	−0.02	0.13
	Interventions for critically ill medical emergencies	0.165	0.24	0.18
Physician Assistant (Medical)	Assessment, diagnosis and treatment of a new out-patient case	−0.099	−0.303 *	−0.25
	Review of a follow-up out-patient case (old cases)	−0.129	−0.319 *	−0.17
	Review of inpatient per patient day (daily ward rounds)	−0.042	−0.351 *	−0.339 *
	Referral of a patient	−0.044	−0.14	−0.444 **
	Minor surgical procedures (e.g., suturing lacerations, incision and drainage)	−0.283	−0.0348 *	−0.355 *
	Patient education and counselling	−0.314*	−0.04	0.27
	Interventions for minor (simple) medical emergencies	0.072	−0.07	−0.13
	Interventions for moderate-to-severe medical emergencies	0.107	−0.04	−0.07
	Interventions for critically ill medical emergencies	0.414 **	0.25	−0.01
Midwife	Antenatal care (ANC) consultation	0.254	0.11	0.22
	Postnatal care (PNC) consultation	0.313 *	0.21	0.10
	Family planning service (non-invasive procedure)	0.434 *	0.29	−0.12
	Family planning service (invasive procedure)	0.549 *	0.37	−0.08
	Prevention of Mother-To-Child (PMTC) transmission of HIV during antenatal care visit	0.192	−0.16	−0.15

Health Professional	**Health Service Activities**	**Facility Workload Level**	**Unit Workload Level**	**Availability of Tools and Equipment**
	Vaginal delivery	−0.043	−0.19	−0.15
	Inpatient care per patient day (routine care for mother)	0.012	−0.21	−0.20
	Inpatient care per patient day (routine care for new-born)	0.354 *	0.07	−0.20
	Admission processes per patient	0.267	0.23	0.09
	Discharge processes per patient	0.319	0.33	0.02
	Preparing a patient for caesarean section	0.495 *	0.23	−0.09
	Patient education and counselling	0.454 **	0.06	0.14
	In-patient management of complications of pregnancy	0.422 *	0.22	0.26
Clinical Nurse (Registered General Nurse & Enrolled Nurse)	Out-patient care (triaging, vital signs and history taking)	0.056	−0.04	0.12
	Out-patient consultation	0.051	0.00	0.07
	Admission processes per patient	0.156 *	0.167*	0.00
	Discharge processes per patient	0.013	−0.02	0.05
	Pre-Operative preparation of patients	0.240 **	0.03	0.04
	Post-operative management which is different from routine care	0.169	0.268 **	−0.04
	Inpatient care per patient day (routine care) for low dependent cases or mildly ill patients	0.062	0.04	−0.02
	Inpatient care per patient day (routine care) for moderately dependent cases	−0.134	−0.03	−0.333 **
	Inpatient care per patient day (routine care) for highly dependent cases or critically ill patients	0.028	0.04	0.152 *
	Discharge patient education and counselling	−0.004	−0.01	−0.02
	Minor surgical procedures (suturing lacerations, incision and drainage, wound dressings)	0.181 *	0.10	0.03
Community Health Nurse	Family planning	0.227	0.24	0.16
	Out-patient consultation to manage minor ailments	−0.079	0.02	−0.14
	Referral of patients	−0.248	−0.26	0.09
	Patient education and counselling	0.157	0.19	−0.01
	Home visiting (minutes per each home visit)	−0.162	0.05	−0.03
	School health (minutes per each pupil)	0.175	0.04	0.18

Health Professional	Health Service Activities	Facility Workload Level	Unit Workload Level	Availability of Tools and Equipment
	Immunisation (minutes per child immunised)	0.073	0.24	0.19
	Growth monitoring (minutes per child)	−0.045	0.21	0.17
Laboratory Scientist/Technician	Sample taking and processing	−0.189	−0.03	0.26
	Full blood count (using an automated machine)	0.214	0.289 *	0.06
	Rapid diagnostic tests (Malaria, HIV, etc.)	−0.128	−0.04	−0.15
	Malaria test using microscopy	−0.014	0.02	0.12
	Urine routine examination	0.032	0.07	−0.15
	Stool routine examination	0.116	0.24	0.288 *
	Blood sugar test	0.308 *	0.327 *	0.23
	Blood donor bleeding	−0.017	−0.05	−0.01
	Preparing blood for transfusion	0.036	0.05	−0.21
	Blood chemistry (minutes per sample)	0.304 *	0.294 *	0.28
	Culture and sensitivity analysis (minutes per sample)	0.093	0.16	0.22
Pharmacist/Pharmacy Technician	Prescription auditing and dispensing for out-patient cases	−0.064	0.06	0.16
	Prescription auditing and dispensing for in-patient cases	−0.272	−0.25	0.05
	Prescription refilling for chronic conditions	0.072	0.11	−0.06
	Pharmaceutical interventions to correct prescription errors	−0.064	0.28	0.10
	Patient adherence counselling and education	−0.301	−0.15	0.02

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed). Facility workload level was measured on a scale of 0 to 5 (where 0 is no workload and 5 is the heaviest workload possible in any health facility); Unit workload level was measured on a scale of 0 to 5 (where 0 is no workload and 5 is the greatest workload possible in any Unit in the facility); Availability to tools and equipment was measured on a scale of 0 to 5 (where 0 is a situation all the tools/equipment are not available, and 5 is a situation that all tools/equipment are available

4.5 DISCUSSION

To the best of our knowledge, this study is the first attempt to use a cross-sectional survey to estimate activity standards of health service activities across multiple health professions. Previous studies [5,9,10,34–36] have either been focused on only a few cadres and activities or based on expert group consensus to determine the standard time which the statistical uncertainty in the estimates could not be ascertained. The findings of the study demonstrate that using a cross-sectional survey could yield fairly reliable activity standards suitable for health workforce planning, just as the consensus-based estimates advocated in the WISN methodology. The added advantage of using a more rigorous survey approach which allows for sensitivity analysis in the planning process using the estimates of uncertainty, cannot be overemphasised.

The study revealed that at the PHC settings, General Practitioners and Physician Assistants spent an average of 16 min, with the true estimate between 13 and 19 min for the assessment, diagnosis, and treatment of new patients in the outpatient clinic but 10 min (95% CI: 8–11 min) for patients on follow-up visits. The WISN study conducted in Ghana in 2015 [31] set a standard of 15 min for new outpatient cases at the primary hospitals and 8 min at the health centres/polyclinics for Physician Assistants, while that of the General Practitioners was 10 min in primary hospitals and 8 min in health centres/polyclinics. Comparing the result of the present study with the WISN results, there is no significant difference given that the WISN estimates fall within the confidence limits of the currents estimates. These do not only demonstrate the consistency of the results but also suggest that using a cross-sectional survey could (as in the case of the present study) be as reliable for health workforce planning as the consensus-based estimates advocated in the WISN methodology. Some studies have also found consultation time for doctors to be 18.21 min [37] which is also within the confidence limits of the present estimates. Patients have indicated in other studies that a minimum consultation time of 6.3 min (or 9 min depending on the complexity) is necessary to keep them satisfied [38]. However, while the 2015 Ghana WISN results suggested an average of 105 min for major surgical procedures at the PHC levels, the current study estimates 64 min (95% CI: 44–84 min). The lack of convergence between the two studies in this instance is attributable to the wide diversity in the complexity of major surgeries. This is also reflected in the wide confidence interval in the current estimate, in which the confidence width is about 62.5% of the mean estimate.

Although PAs spent about 6 min more on minor surgical procedures than General Practitioners, the difference between them is not statistically significant. When interpreted alongside the similarity in outpatient service time between these categories of health professionals, it appears that there may not be substantial variations in the quality of their services. Although previous studies [39,40] demonstrated that they do not necessarily differ in terms of the patient outcomes from their services, issues of subjective quality have not received much intellectual examination, and these findings may be one step towards that discourse. Furthermore, the analysis revealed a pronounced practice variation amongst PAs such that they spend more time on patients in health centres/polyclinics than district/primary hospitals. In health centres/polyclinics, PAs are at the helm of most clinical decision making where they need to spend more time for thorough assessment and procedures that they would otherwise easily refer (or pass on) to a physician in district/primary hospitals. The correlation analysis also revealed that improving the availability of tools/equipment significantly reduced the PAs time spent on minor surgical procedures by 35.5% ($p < 0.05$) and clinical nurses' time spent on moderate dependency patients by 33.3% ($p < 0.05$). This finding points to the potential benefit of improving the availability of tools/equipment, which was rated to be only 57% by the health professionals.

The present study found that midwives' antenatal care consultation took an average of 22 min (95% CI: 18–26 min) which is not significantly different from 25 min estimated from the previous WISN study in Ghana and 20–30 min estimated in a Namibian WISN study [35]. Additionally, whereas the current study shows that midwives spend 131 min (95% CI: 101–160 min) per supervised vaginal delivery, the WISN study in Ghana, which employed a time-motion observation for this activity, also estimated 152 min, which falls within the confidence limits of the present study. In the absence of well-conducted time-motion observations, the Namibian WISN study assumed 240 min per supervised vaginal delivery, but that is without considering the need to count only the direct patient care (or contact) time, not necessarily the entire length of the process of labour and delivery. In health centres/polyclinics, midwives spent an average of 78 min more on women during vaginal delivery as compared to district/primary hospital settings (p = 0.013). In the context of Ghana, there are very few women who deliver in health centres where they usually record one or two per day. As a result, midwives at health centres who usually reside within walking distance of the health centre seem to pay greater attention to the monitoring and psychosocial support to the pregnant in labour.

We found that routine nursing care activities (made up of patient monitoring, administration of prescribed medications and support for patients' activities of daily living) was an average of 40 min per inpatient day (95% CI: 38–42 min) for low acuity patients; 43 min (95% CI: 40–46 min) per inpatient day for moderate acuity patients and 135 min (95% CI: 127–144 min) per inpatient day for high dependency patients. These were, however, negatively correlated with the availability of tools/equipment, which suggests that clinical nurses would spend more time on direct routine care to inpatients if they had sufficient tools and equipment. Indeed, the resource constraints in the PHC setting, especially in health facilities and their effects on inpatient care, is well documented [17]. WISN studies in Kenya, Nigeria and Namibia [9,10,35] found lower estimates of time spent on routine nursing care, but the Ghana WISN study made similar or slightly higher estimates. The aforesaid further reinforces the point that health service activity standards cannot be universal but context-specific, taking into account models of care and mix of patient acuity levels [7].

Performing a full blood count analysis using an automated analyser machine is estimated to take 6 min (95% CI: 5–7 min), while it takes an average of 17 min (95% CI: 16–18 min) to conduct a rapid diagnostic test for malaria, HIV and similar ones routinely carried out in PHC settings. These estimates are not only consistent with the results of the Ghana WISN study but also similar to estimates from a Kenyan study [9], a similarity that may be a reflection of the highly standardised nature of laboratory processes and machines.

The correlation analysis revealed that a unit increase in perceived or actual workload was associated with a 31–44% reduction in the time PAs spend on the various health service activities; a similar finding was found for some activities undertaken by clinical nurses. These suggest that when workload increases, health professionals with the moral duty not to turn patients away rather reduces the time spent on patients to be able to attend to all the patients. This, however, have huge implications for quality of care and patient safety.

The analysis shows that General Practitioners (who are not heads of health facilities) spend at least 3 hours per week or 7.5% of their working time on clinical meetings, while nurses and midwives spend up to 14% on both clinical meetings and handing over (or taking over) from one shift to another. When blood donation campaigns are taken into account, laboratory scientist spends up to 22.5% of their time on catalytic or support activities while Pharmacist spends at least 35% of their time on activities that are essential but not measurable per patient. These underscore the need to factor support activities into all health workforce planning models, especially needs-based planning tools that are regarded as the most conceptually appropriate and intuitively consistent planning framework for the tenets of UHC [41–43].

4.6 LIMITATIONS

Although the study used a cross-sectional study design with a carefully selected nationally representative sample, only six nutritionists/dieticians (out of an all-inclusive target of 23) responded to the survey, which requires the exercise of caution when interpreting or using the results of that category of health professionals. Linked to the sampling, the study was based on public health facilities and hence, excluded the private sector, some of which is known for low standards of care in Ghana [17,44]. Besides, the study adopted a self-reported approach which undoubtedly, could have benefited from a follow-up time-motion observation to validate the estimated time provided by health professionals. However, as time-motion studies are quite expensive, its use in this study was constrained by logistical challenges coupled with restrictions occasioned by the COVID−19 pandemic.

4.7 CONCLUSIONS

The study systematically estimated the service standards (the mean estimates of time spent on health service activities), identifying statistically significant differences between health centres/polyclinics and district/primary hospitals in 18.9% (12 out of 67) of health service activities performed across eight health professional groups. For example, the standard workload for General Practitioners in PHC settings is 6030 new patients per year (or 10,444 follow-up cases per year); 6108 new outpatients per year for Physician Assistants, while midwives can conduct 735 spontaneous vaginal deliveries per year. In patients with low-to-moderate dependency, Clinical Nurses' standard workload is between 2078 and 2549 per year, or a nurse-patient ratio of one is to 5–7 inpatients; and a CHN could give roughly 16,000 immunisations per year.

The intensity of workload in health facilities was rated to be 3.91 out of 5 (78.2%) but as workload increases, and without a commensurate increase in staffing, health professionals reduced the time spent on individual patient care so as to be able to attend to all patients—a practice that could have adverse implications for quality of care and patient safety. Availability of tools and equipment at PHC was rated 2.83 out of 5 (56.6%) which a unit improvement is associated with a significant reduction in the time PAs spend on minor surgical procedures by 35.5% ($p < 0.05$) and clinical nurses time spent on moderate dependency patients by 33.3% ($p < 0.05$).

4.8 IMPLICATIONS FOR POLICIES, PLANNING AND FURTHER RESEARCH

With the estimated standard workloads, it would be imperative to use them for evidence-based planning by estimating the optimal number of health professionals needed in Ghana's PHC system and the consequent adjustments necessary in health professions educations to fill any gaps, and the budgetary requirements for their employment. The evidence also suggests that increasing workload levels were associated with reduced health professionals' contact time with patients in many health service activities, which may be an indicator of the quality of healthcare provided. It will be important to further explore the potential relationship between workload and both objective and subjective measures of primary healthcare quality.

The study partly demonstrates that improving the availability of tools and equipment could substantially improve staff efficiency, which ultimately lessens the need for additional staff. This provides some justification that can be used alongside other evidence for retooling the PHC system in Ghana. From a planning methodology perspective, the study revealed that health professionals spent between 7.5% and 35% of their time performing support activities that catalases the performance of direct patient care activities. These must be considered in all health workforce planning models, especially those that are founded on the needs-based framework - which has hitherto not taken support activities into account.

Based on the findings and the limitations identified, it is recommended that a similar study is executed in the private sector to establish homogeneity or otherwise in the service standards (and standard workloads) across the public and private sectors. Finally, a form of observation (preferably time-motion in nature) can be included as part of future data gathering process should the COVID-19 situation allow for direct observation, which was not feasible in this study due to COVID-19 restrictions and logistical challenges.

Supplementary Materials: A supplementary table is available online at:

https://www.mdpi.com/2227-9032/9/3/332/s1.

Author Contributions: J.A.A., C.D.C., and G.M.R. conceived and designed the study as part of J.A.A.'s doctoral research. J.A.A. undertook the data collection under the supervision of C.D.C. and G.M.R., J.A.A., with support from C.D.C., undertook the data analysis and drafted the manuscript under G.M.R.'s direction. All the authors read and approved the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: As part of a larger doctoral research project, the study received ethics approval from the Health Research Ethics Committee (HREC) of NWU (ethics approval number: NWU-00416-20-A1) and the Ghana Health Service Ethics Committee (ethics approval number: GHS-ER17/07/20).

Informed Consent Statement: Not applicable.

Data Availability Statement: The raw data is available with the authors and could be provided upon reasonable request, subject to the conditions of the ethics approval.

Acknowledgements: We express gratitude to the Ghana Health Service for granting permission for this study, especially to the Director-General, Patrick Kuma Aboagye, and the health professionals who took part in the study. We thank the Scientific and Ethics Committees of both NWU and GHS for the quality feedback and approval of the study. We are most grateful to Josephine Kyei for supervising the data collection and Jerry Kwame Asamoah, Richmond Sowah and Immaculate Bernice Avoka-Asamani for their support during the data collection and analysis. Hamza Ismaila and Samuel Alugsi are duly acknowledged for providing feedback on early drafts of the manuscript. Paula Jardim and Yolande Heymans of the CHPE, NWU, are acknowledged for their respective administrative and technical support during the process of scientific and ethics review of the study proposal.

Conflicts of Interest: The authors declare no conflict of interest.

4.9 REFERENCES

1. WHO. Global Strategy on Human Resources for Health: Workforce 2030; World Health Organisation: Geneva, Switzerland, 2016. Available online: https://www.who.int/hrh/resources/globstrathrh-2030/en/ (accessed on 21 December 2020).
2. WHO. State of the World's Nursing Report—2020; World Health Organization: Geneva, Switzerland, 2020. Available online: https://www.who.int/publications-detail/nursing-report-2020 (accessed on 21 December 2020).
3. Kavya, S.; Sanjay, P.Z.; Abhay, G.; Syed, Z.Q. Methodological issues in estimating and forecasting health manpower requirement. J. Public Adm. Policy Res. 2014, 6, 25–33.
4. Lopes, M.A.; Almeida, Á.S.; Almada-Lobo, B. Handling Healthcare Workforce Planning with Care: Where Do We Stand? Hum. Resour. Health 2015, 13. Available online: http://www.human-resources-health.com/content/13/1/38 (accessed on 21 December 2020).
5. Hagopian, A.; Mohanty, M.K.; Das, A.; House, P.J. Applying WHO's 'workforce indicators of staffing need'(WISN) method to calculate the health worker requirements for India's maternal and child health service guarantees in Orissa State. Health Policy Plan. 2011, czr007. Available online: http://heapol.oxfordjournals.org/content/early/2011/02/10/heapol.czr007.short (accessed on 21 December 2020).
6. McQuide, P.A.; Kolehmainen-Aitken, R.-L.; Forster, N. Applying the workload indicators of staffing need (WISN) method in Namibia: Challenges and implications for human resources for health policy. Hum. Resour. Health 2013, 11, 64. Available online: http://www.biomedcentral.com/content/pdf/1478-4491-11-64.pdf (accessed on 21 December 2020).
7. World Health Organization. Workload Indicators of Staffing Need—User Manual; World Health Organization: 2010. Available online: http://apps.who.int/iris/handle/10665/44414 (accessed on 21 December 2020).
8. Govule, P.; Mugisha, J.F.; Katongole, S.P.; Maniple, E.; Nanyingi, M.; Onzima, R.A.D. Application of Workload Indicators of Staffing Needs (WISN) in Determining Health Workers' Requirements for Mityana General Hospital, Uganda. Int. J. Public Health Res. 2015, 3, 254–263. Available online: http://www.opensciencenline.com/journal/ijphr (accessed on 21 December 2020).

9. Musau, P.; Nyongesa, P.; Shikhule, A.; Birech, E.; Kirui, D.; Njenga, M.; Kiilu, K. Workload Indicators of Staffing Need Method in determining optimal staffing levels at Moi Teaching and Referral Hospital. East Afr. Med. J. 2008, 8, 232–239.
10. Okoroafor, S.; Ngobua, S.; Titus, M.; Opubo, I. Applying the workload indicators of staffing needs method in determining frontline health workforce staffing for primary level facilities in Rivers state Nigeria. Glob. Health Res. Policy 2019, 4, 35. Available online: https://ghrp.biomedcentral.com/articles/10.1186/s41256-019-0125-z (accessed on 21 December 2020).
11. Quercioli, C.; Nisticò, F.; Troiano, G.; Maccari, M.; Messina, G.; Barducci, M.; Nante, N. Developing a new predictor of health expenditure: Preliminary results from a primary healthcare setting. Public Health 2018, 163, 121–127. Available online: https://www.sciencedirect.com/science/article/pii/S0033350618302324 (accessed on 21 December 2020).
12. Birch, S.; Gibson, J.; McBride, A. Opportunities for, and implications of, skill mix changes in health care pathways: Pay, productivity and practice variations in a needs-based planning framework. Soc. Sci. Med. 2020, 250, 112863. Available online: https://linkinghub.elsevier.com/retrieve/pii/S0277953620300824 (accessed on 21 December 2020).
13. Hollingsworth, B. The measurement of efficiency and productivity of health care delivery. Health Econ. 2008, 17, 1107–1128. Available online: https://onlinelibrary.wiley.com/doi/abs/10.1002/hec.1391 (accessed on 21 December 2020).
14. Laurence, C.O.; Karnon, J. Improving the planning of the GP workforce in Australia: A simulation model incorporating work transitions, health need and service usage. Hum. Resour. Health 2016, 14, 13.
15. Asamani, J.A.; Christmals, C.D.; Reitsma, G.M. Advancing the Population Needs-Based Health Workforce Planning Methodology: A Simulation Tool for Country Application. Int. J. Environ. Res. Public Health 2021, 18, 2113.
16. MOH. National Community-Based Health Planning and Services (CHPS) Policy: Accelerating Attainment of Universal Health Coverage and Bridging the Access Inequity Gap; Ministry of Health: Accra, Ghana, 2015.
17. Saleh, K. The Health Sector in Ghana: A Comprehensive Assessment; World Bank Publications: Washington D.C, USA, 2013; doi: 10.1596/978-0-8213-9599-8
18. GHS. Human Resource Annual Report—2018; Ghana Health Service: Accra, Ghana, 2019.

19. GHS. Health Workforce Gaps and Cost-Benefit Analysis of Proposed Staff Redistribution in the Ghana Health Service; Ghana Health Service: Accra, Ghana, 2018.
20. Asamani, J.A.; Ismaila, H.; Plange, A.; Ekey, V.F.; Ahmed, A.-M.; Chebere, M. The cost of health workforce gaps and inequitable distribution in the Ghana Health Service: An analysis towards evidence-based health workforce planning and management. Hum. Resour. Health 2020. Available online: https://www.researchsquare.com/article/rs-21946/v3 (accessed on 4 January 2021).
21. MOH. Holistic Assessment of the Health Sector Programme of Work 2015; Ministry of Health: Accra, Ghana, 2016. Available online: www.moh.gov.gh (accessed on 21 December 2020).
22. MOH. Holistic Assessment of the Health Sector Programme of Work 2013; Ministry of Health: Accra, Ghana, 2014. Available online: http://www.moh.gov.gh/wp-content/uploads/2016/02/Holistic-Assessment-Report-June-2014140811072318.pdf (accessed on 21 December 2020).
23. MOH. Staffing Norms for the Health Sector; Ministry of Health: Accra, Ghana, 2018.
24. Asamani, J. A., d'Almeida, S. A., Chebere, M., Yeboah, G., Asabir, K., Kyereboah, F., Hottordze, A. G., Ekey, F., Amankwa, G., Darko, S. Workload Indicators of Staffing Needs (WISN) Implementation in Ghana: Technical Report of Staffing Norms for the Health Sector of Ghana; Technical Reports; Ministry of Health: Accra, Ghana, 2014, doi:10.13140/2.1.3251.2806.
25. Thomas, C.M.; Kellgren, M. Benner's Novice to Expert Model: An Application for Simulation Facilitators. Nurs. Sci. Q. 2017, 30, 227–234, doi:10.1177/0894318417708410.
26. GHS. Human Resources Information and Management System (HRIMS); Ghana Health Service: Accra, Ghana, 2020. Available online: https://www.ghsnewhrims.org/Progress.php (accessed on 10 May 2020).
27. Yamane, T. Statistics: An Introductory Analysis, 2nd ed.; Harper & Row: New York, NY, USA, 1967. Available online: http://www.sidalc.net/cgi-bin/wxis.exe/?IsisScript=bac.xis&method=post&formato=2&cantidad=1&expresion=mfn=033304 (accessed on 12 February 2020).
28. Asamani, J.A.; Naab, F.; Ofei, A.M.A. Leadership styles in nursing management: Implications for staff outcomes. J. Health Sci. 2016, 6, 1–14. Available online: http://www.jhsci.ba/OJS/index.php/jhsci/article/view/266 (accessed on 21 December 2020).
29. Utts, J.M.; Heckard, R.F. Mind on Statistics; Cengage Learning: Standford, U.S.A. 2011.

30. Utts, J.M.; Heckard, R.F. Mind on Statistics, 2nd ed.; Thomson Learning: London, UK, 2004.
31. MOH. Staffing Norms for the Health Sector of Ghana; Ministry of Health: Accra, Ghana; 2015; Volume 1.
32. WHO. Workload Indicators of Staffing Need (WISN): Selected Country Implementation Experiences. Hum. Resour. Health Obs. Ser. 2016, 15. Available online: http://apps.who.int/iris/bitstream/10665/205943/1/9789241510059_eng.pdf (accessed on 21 December 2020).
33. Keller, G. Statistics for Management and Economics; Thompson Nelson Education: North-Western, Evanston, IL, USA, 2014.
34. Ly, A.; Kouanda, S.; Ridde, V. Nursing and midwife staffing needs in maternity wards in Burkina Faso referral hospitals. Hum. Resour. Health 2014, 12, S8. Available online: http://www.human-resources-health.com/content/12/S1/S8 (accessed on).
35. Mohamed, N.; Al-Qasmi, A.; Al-Lamki, S.; Bayoumi, M.; Al-Hinai, A. An estimation of staffing requirements in primary care in Oman using the Workload Indicators of Staffing Needs method. Eastern Mediterr. Health J. 2018, 24, 823–829. Available online: http://applications.emro.who.int/emhj/v24/09/EMHJ_2018_24_09_823_829.pdf (accessed on 21 December 2020).
36. Ahmad, B.; Khairatul, K.; Farnaza, A. An assessment of patient waiting and consultation time in a primary healthcare clinic. Malays Fam Physician 2017, 12, 14–21. Available online: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5420318/ (accessed on 21 December 2020).
37. Lee, C.H.; Lim, H.; Kim, Y.; Park, A.H.; Park, E.-C.; Kang, J.-G. Analysis of Appropriate Outpatient Consultation Time for Clinical Departments. Health Policy and Management. Korean Acad. Health Policy Manag. 2014, 24, 254–260. Available online: https://www.koreascience.or.kr/article/JAKO201431763840663.page (accessed on 21 December 2020).
38. Brentlinger, P.E.; Assan, A.; Mudender, F.; Ghee, A.E.; Torres, J.V.; Martínez, P.M. Task shifting in Mozambique: Cross-sectional evaluation of non-physician clinicians' performance in HIV/AIDS care. Hum. Resour. Health 2010, 8, 1. Available online: http://human-resources-health.biomedcentral.com/articles/10.1186/1478-4491-8-23 (accessed on 21 December 2020).

39. van Ginneken, N.; Tharyan, P.; Lewin, S.; Rao GN, Meera, S.; Pian, J. Non-specialist health worker interventions for the care of mental, neurological and substance-abuse disorders in low- and middle-income countries. In Cochrane Database of Systematic Reviews; John Wiley & Sons, Ltd: Hoboken, NJ, USA, 2013. Available online: http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD009149.pub2/abstract (accessed on 12 February 2020).
40. Birch, S.; Tomblin Murphy, G.; MacKenzie, A.; Whittaker, W.; Mason, T. Will the Need-Based Planning of Health Human Resources Currently Undertaken in Several Countries Lead to Excess Supply and Inefficiency? A Comment on Basu and Pak. Health Econ. 2017, 26, 818–821.
41. Segal, L.; Guy, S.; Leach, M.; Groves, A.; Turnbull, C.; Furber, G. A needs-based workforce model to deliver tertiary-level community mental health care for distressed infants, children, and adolescents in South Australia: A mixed-methods study. Lancet Public Health 2018, 3, e296–303.
42. Tomblin Murphy, G.; Birch, S.; MacKenzie, A.; Rigby, J. Simulating future supply of and requirements for human resources for health in high-income OECD countries. Hum. Resour. Health 2016, 14, 1–18.
43. Hutchinson, P.L.; Do, M.; Agha, S. Measuring Client Satisfaction and the Quality of Family Planning Services: A Comparative Analysis of Public and Private Health Facilities in Tanzania, Kenya and Ghana. BMC Health Serv. Res. 2011, 11, 1. Available online: http://bmchealthservres.biomedcentral.com/articles/10.1186/1472-6963-11-203 (accessed on 12 February 2020).

CHAPTER 5:

ARTICLE 4: MODELLING THE SUPPLY AND NEED FOR HEALTH PROFESSIONALS FOR PRIMARY HEALTH CARE IN GHANA: IMPLICATIONS FOR HEALTH PROFESSIONS EDUCATION AND EMPLOYMENT PLANNING

James Avoka Asamani [1,2], Christmal Dela Christmals [2,*] and Gerda Marie Reitsma [2]

[1] Centre for Health Professions Education, Faculty of Health Sciences, North-West University, Potchefstroom Campus, Building PC-G16, Office 101,11 Hoffman St, Potchefstroom 2520, South Africa; christmal.christmals@nwu.ac.za (J.A.A.); gerda.reitsma@nwu.ac.za (G.M.R.)

[2] Intercountry Support Team for Eastern and Southern Africa, Health Workforce Unit, Regional Office for Africa, World Health Organisation, 82-86 Cnr Enterprise/Glenara Roads, Harare CY 348, Zimbabwe; asamanij@who.int

* Correspondence: christmal.christmals@nwu.ac.za; Tel.: +27-642-379-552

This article was submitted to PLOS ONE, a journal with an impact factor of 3.240 based on the 2021 Journals' Citation Report (JCR). The manuscript was undergoing peer-review at the time of writing the thesis, hence the chapter is presented in accordance with the guidelines and style for the journal (available at https://journals.plos.org/plosone/s/submission-guidelines. Exceptions were made to comply with the prescribed NWU guidelines on margins, line-spacing fonts and table formatting. This was also necessary to maintain uniformity of the thesis.

5.1 ABSTRACT

Background: The health workforce is critical in developing responsive health systems to address population health needs and respond to health emergencies, but defective planning have arguably resulted in underinvestment in health professions education and decent employment. Primary Health Care (PHC) has been the anchor of Ghana's health system since 1980s . As Ghana's population increase and the disease burden doubles, it is imperative to estimate the potential supply and need for health professionals; and the level of investment in health professions education and employment that will be necessary to address population health needs and respond to health emergencies.

Methods: Using a need-based health workforce planning framework, we triangulated data from multiple sources and systematically applied a previously published Microsoft® Excel-based model to conduct a fifteen-year projection of the health workforce supply, needs, gaps and training requirements in the context of PHC in Ghana.

Results: The projections show that based on the population (size and demographics), disease burden, package of health services and the professional standards for delivering those services, Ghana needed about 221,593 health professionals across eleven categories in PHC in 2020. At a rate of change between 3.2% and 10.7% (average: 5.5%) per annum, the aggregate need for health professionals is likely to reach 495,273 by 2035. By comparison, the current (2020) stock is estimated to grow from 148,390 to about 333,770 by 2035 at an average growth rate of 5.6%. The health professional's stock is projected to meet 67% of the need but with huge supply imbalances. Specifically, the supply of six out of the 11 health professionals (~54.5%) cannot meet even 50% of the needs by 2035, but Midwives could potentially be overproduced by 32% in 2030.

Conclusion: Future health workforce strategy should endeavour to increase the intake of Pharmacy Technicians by more than seven-folds; General Practitioners by 110%; Registered General Nurses by 55% whilst Midwives scaled down by 15%. The role of Enrolled Nurses needs to be revaluated and their production adjusted accordingly. About US$ 480.39 million investment is required in health professions education to correct the need versus supply mismatches. Annually, US$1.762 billion (and up to US$ 2.374 billion in 2035) must be planned for the employment of those that would have to be trained to fill the needs-based shortages and for sustaining the employment of those currently available.

Keywords: Needs-based Modelling; Primary Health Care, Health Workforce Planning, Human Resources for Health; Health Workforce Modelling; Health Professions Education; Ghana

5.2 INTRODUCTION

Over the years, most health workforce (HWF) planning has been based on either population ratio approaches or currently observed health service utilisation [1,2]. However, in a context where the population still faces an unmet need for health services or large disparities in the need for health services, these approaches have been found to be of limited value [3–5]. Consequently, in 2016, the World Health Assembly (WHA) adopted resolution WHA69.19 (The Global Strategy on Health Workforce), urging countries to make a paradigm shift towards the use of population health needs as the basis for health workforce planning rather than the use of currently observed levels of health service utilisation, service targets, health facilities or simple population ratios. In furtherance of this, it called for health workforce investments to be based on matching "…the supply of health workers to population needs, now and in the future" [6]. This paradigm shift has been deemed necessary to uphold the tenets of UHC in ensuring that all persons have access to the health workers they will require based on their health needs and not their location, ability to pay, gender, race or other characteristics. Thus, it has become critical for countries to devise effective policies that respond to population needs and effectively plan the future training of health professionals by quantifying the needed health workforce based on the population health needs and their supply capacity [6].

Ghana faces a double burden of disease whereby non-communicable diseases and their risk factors are at alarming levels, whilst communicable diseases are still a public health threat [7,8]. With a universal health coverage (UHC) score estimated at 47% in 2019, Ghana does not only sub-optimally compares with Africa's average of 48% [9] but also has up to 53% of its population health needs (which are tracked by UHC tracer indicators) likely not to be met by the existing coverage of health services. Addressing the aforesaid and ever-changing pattern of the population's health needs requires investments across the different health system components, but critically aligning the health workforce production to the population health needs is imperative. Like many other low-and middle-income countries, Ghana faces a critical shortage of health workers, undermining health service coverage [10–13].

To address the severe health workforce shortages in the late 1990s, Ghana expanded its public and private-sector production of the health workforce, resulting in increasing the public sector health workforce by nearly three-folds between 2005 and 2019 [14], following which the country is being cited as one of the leading producers of physicians, nurses and midwives in sub-Saharan Africa [15]. Nonetheless, based on the national health facility staffing norms [16], Ghana is estimated to have at least a 42% shortfall of the health professionals needed [17]. On the one hand, the shortfall is more critical amongst highly trained health professionals, while on the other hand, some mid-level health workers appear to have been overproduced [17]. It is also worth noting that these challenges co-exist with several trained but unemployed health workers in the country, mainly due to inadequate investments in health sector employment [18]. Recent estimates show that there is a need for a public sector health workforce budgetary increase of 57% (~US$295.4 million) to meet minimum staffing requirements for primary and secondary level health services [19]. Such demands are becoming difficult to justify as some 22% (range: 14% – 50%) of prevailing wage bill have been spent on the inequitably distributed health workforce [19] in favour of specialised health facilities in large cities [12,20]. This has, thus, left significant staffing gaps at the PHC level, which provides about 95% of all outpatient services in Ghana [21]. Therefore, several policy questions continue to persist. These questions, amongst others, include: how many health professionals are needed at the PHC level based on the population health needs viz-a-viz potential supply and what level of investment in health professions education and employment will be required to avert any shortages?

To address these critical policy questions, we employed a population needs-based approach to model the requirements of eleven categories of health professionals at PHC level in Ghana, alongside their supply projections based on stock-and-flow approach. Together, these health professionals' categories constitute more than 80% of the total wage bill and are the main anchor of PHC interventions.

The Primary Health Care context in Ghana

Ghana is politically and administratively divided into sixteen (16) regions, further divided into 260 districts. Each district is also divided into health sub-districts and communities. The delivery of health services is operationally and administratively aligned with these structures. By a legislative Act (Act 525 of 1996), the public health service delivery is entrusted in semi-autonomous establishments, namely the Ghana Health Service (GHS) and Teachings Hospitals (THs). There are also several faith-based, private-for-profit and quasi-governmental institutions and mental health facilities. The Ministry of Health (MOH) supervises all these institutions regarding policy formulation, resource mobilisation and allocation, and monitoring and evaluation.

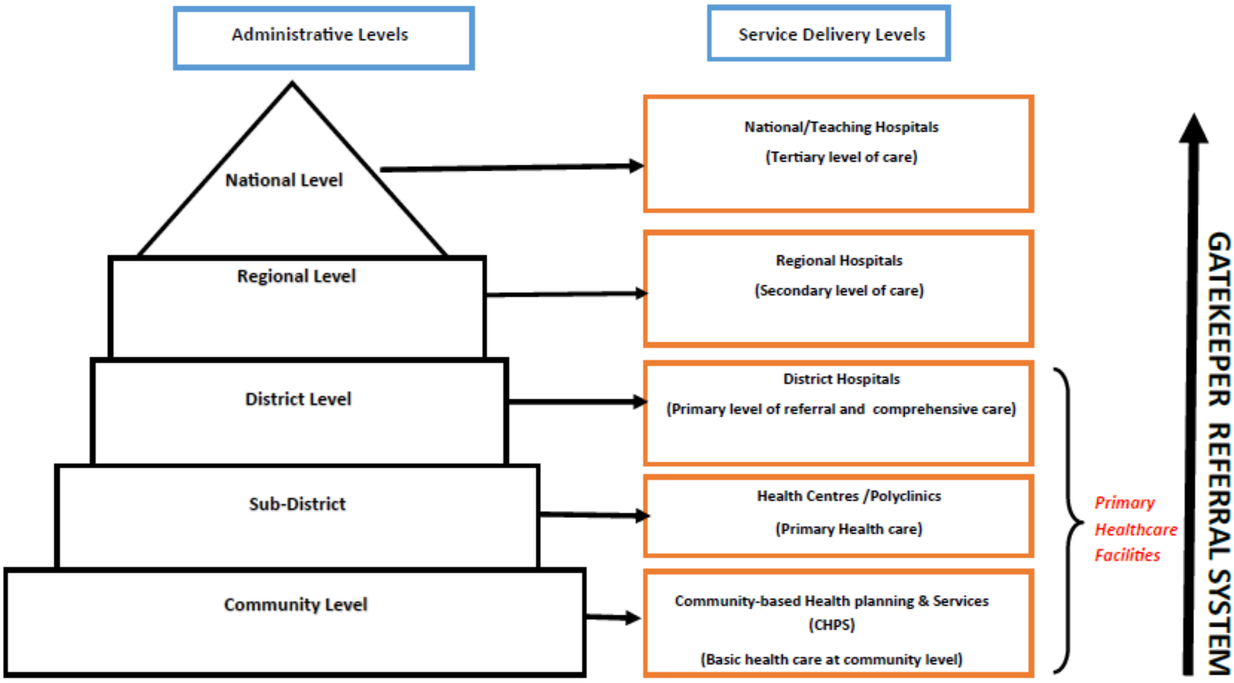

Figure 1: The health care system structure in Ghana [Source: Authors' construction]

As indicated in Figure 1, a pluralistic gatekeeper health service delivery system is established. At the bottom of the PHC hierarchy are community-based health planning and services (CHPS), the first point of contact of the health system, each serving a defined population of 5,000 people or 750 households, sometimes coterminous with electoral areas [22]. These are mandated to deliver preventive health services and to treat minor illnesses with over-the-counter medicines at the community level.

Health centres (HCs) serve people in the catchment area of a sub-district and are expected to provide basic curative and preventive health services. They are the first level of referral from the communities and CHPS. Although health centres are mandated to serve catchment populations of about 20,000 or less, in urban areas, they could be expanded (in size and staffing) and designated as polyclinics to serve larger populations. One report revealed that some urban polyclinics were even operating at the level of hospitals, beyond their designation, due to increased service demand from the population [19]. At the top of the PHC hierarchy are the district/primary hospitals intended to serve as district-level referral centres and provide preventive, curative, and emergency health care to populations between 100,000 and 200,000 people. However, it is estimated that at least half of the districts were without these primary/district hospitals, resulting in extra workload in other facilities, which operate beyond their capacity [12,19].

5.3 METHODOLOGY

5.3.1 Overview of Population Needs-based Simulation Model for Health Workforce Planning

Based on a scoping review of various analytical applications of needs-based health workforce planning approach [23], and building upon previous works [24–29], we developed a needs-based analytical health workforce planning model, built in Microsoft® Excel and suitable for health sector-wide application in any country [30]. The paper reports on how the model was applied to conduct health workforce projection in PHC in Ghana. As illustrated in Figure 2, the underpinning conceptual framework of the model consists of need analysis, supply analysis, gap analysis, and resource implications.

The need analysis assumes that the required calibre and quantity of health professionals are derived from the population's need for health services [31–34]; as the population in any jurisdiction at any given time have some need for health services, regardless of whether or not they have demanded such service or if it can even be afforded [33]. Therefore, forecasting the optimal requirement for health professionals in a health system must directly flow from an estimate of the population's need for health services which can be modelled as a function of (a) the size of the population and its demographic characteristics, (b) the state of health or level of health of the population and (c) the level of services (type and frequency) necessary to attain and maintain optimal health of the population. The aggregate need for health services can then be translated into the health workforce requirements if the category of health professional competent to deliver the service was identified [35] with clear work division [36], and an established measure of their standard workload (or productivity) [37,38]. Box 1 summarises the empirical formulae for estimating the need for health services and translating the same into health workforce requirements.

Box 1: Summary of formulae for estimating needs-based health workforce requirements

$$NHS_t = \sum P_{i,j,g,t} \times [H_{h,i,j,t-1} \times (1 + R_h)] \times L_{y,h,i,j,t} \quad \textbf{… equation 1}$$

Where:

- NHS_t represents the 'Needed Health Services' by a given population under a given service model, $L_{i,j,t}$ over a period of time t.
- $P_{i,j,g,t}$ represents the size of the given population of age cohort i, gender j in location (rural or urban) g at time t in a given jurisdiction (this represents the population and its demographic characteristics).
- $H_{h,i,j,g,t}$ represents the proportion of the given population with health status h, of age cohort i, gender j in location g at time t (this represents the level of health of the population).
- $L_{y,h,i,j,g,t}$ represents the frequency of health services of type y planned or otherwise required, under a specified service model, to address the needs of individuals of health status h among age cohort i, gender j in location g over time t (this represents the level of service required by the population).
- R_h is the instantaneous rate of change of the health status, h.

$$SW_{n,y} = \frac{AWT_n}{SS_{y,n}} \quad \textit{… equation 2}$$

Where:

- $SW_{n,y}$ is the standard workload for health professional of category n when performing health service activity y.
- AWT_n is the annual available working time of the health professional of category n
- $SS_{y,n}$ is the Service Standard or the time it takes a well-trained health professional of category n to deliver the service activity, y.

$$N_{n,t} = \Sigma \frac{NHS_{n,y,t}}{SW_{n,y}} \quad \textit{… equation 3}$$

Where:

- $N_{n,t}$ is the needs-based requirements of a health professional of category n at time point t
- NHS_t represents the number of needed health service activity y, delivered by a health professional of category n at time t.
- $SW_{n,y}$ is the standard workload for health professional of category n when performing health service activity y.

Sources: [30,39]

Building on existing stock and distribution of the health workforce, the model uses the stock and flow approach to estimate health professionals' future supply. It comprises determining the inflow or entry in the current workforce and the outflow or attrition from the current workforce. While the inflow depends on the training capacity and immigration, the outflow/attrition is influenced by natural and unnatural disengagements such as retirements, emigration, deaths, resignations and dismissals. Box 2 presents the supply projection formula, explained in detail in a prior publication [30].

Box 2: Stock and flow formulae for health professionals' supply estimation

$\boldsymbol{S_{n,t}} = \left[\boldsymbol{T_{n,t-1}} \times (\boldsymbol{1} - \boldsymbol{a_n}) + \boldsymbol{I_n}\right] \times \mathbf{P}$ … equation 4

Where:

- $\boldsymbol{S_{n,t}}$ is the effective supply of health professional of category $\boldsymbol{n}$, at time $\boldsymbol{t}$.
- $\boldsymbol{T_{n,t}}$ is the overall stock of health professionals (number registered) category $\boldsymbol{n}$ at time $\boldsymbol{t}$.
- $\boldsymbol{a_n}$ is the rate of attrition (the proportion of the stock, $\boldsymbol{T_{n,t-1}}$ that died, retired, could not work due to ill-health or migrated out) which adjusts the overall stock to get the professionally active health professional of category $\boldsymbol{n}$.
- $\boldsymbol{I_n}$ is the inflows of the health professional of category $\boldsymbol{n}$ from both domestic and foreign sources.
- $\boldsymbol{P}$ is the rate of labour participation that reflects the proportion of the professionally active health professionals engaged in direct health service delivery.

Sources: [30,39]

The gap analysis compares the need analysis and the supply analysis to determine if there were a potential shortage or oversupply of health professionals [40]. Absolute gaps are presented in the form of the actual deficit or surplus of health professionals, whilst relative gaps were presented in the form of the proportion of the needs-based requirements that the anticipated levels of supply could potentially meet. While absolute gaps are essential for planning the number of additional health professionals to train, relative gaps are significant in prioritising the health professional group that required immediate attention. It also has implications for quality of care as it could be interpreted to mean the degree to which professionals standards will be met [41]. Finally, the resource implications are computed in terms of the investment required to sustain jobs for the anticipated supply can be compared with the investment needed to employ to fill the needs-based requirement, assuming there were no supply-side barriers (see box 3 for formulae). Where there are needs-based shortages, the required investment in health professions education to fill the gaps are estimated. All these cost implications are then compared with budgetary allocations or potential financial space to examine their feasibility.

Box 3: Formulae for gap analysis and cost implications

$$\boldsymbol{Absolute\ Gap_{n,t} = S_{n,t} - N_{n,t}} \quad \textbf{… equation 5}$$

$$\boldsymbol{SAR_{n,t} = \frac{S_{n,t}}{N_{n,t}}} \quad \textbf{… equation 6}$$

- ***Absolute Gap**$_{n,t}$* is the absolute gap for health professional of type ***n*** at time ***t***.
- ***S**$_{n,t}$* is the supply of health professional of category ***n*** at time ***t.***
- ***N**$_{n,t}$* is the needs-based requirements of a health professional of category ***n*** at time ***t.***

$$\boldsymbol{TCS_{n,t} = \sum (S_{n,t} \times K_{n,t})} \quad \textit{… equation 7}$$

Where:

- ***TCS**$_{n,t}$* is the total wage bill cost of the anticipated supply of health professional category ***n*** at time point ***t***.
- ***S**$_{n,t}$* is the anticipated supply of health worker category ***n*** at time point ***t***.
- ***K**$_{n,t}$* is the average income (made up of salaries, allowances and monetary benefits and adjusted for inflation) for health professional of category ***n*** at time point ***t***.

$$\boldsymbol{TCN_{n,t} = \sum (N_{n,t} \times K_{n,t})} \quad \textit{… equation 8}$$

- ***TCN**$_{n,t}$* is the total wage bill cost of needs-based requirements of a health professional of category ***n*** at time point ***t***.
- ***N**$_{n,t}$* is the needs-based requirements of a health professional of category ***n*** at time point ***t***.
- ***K**$_{n,t}$* is the average income (made up of salaries, allowances and monetary benefits and adjusted for inflation) for health professional of category ***n*** at time point ***t***.

Source: [30]

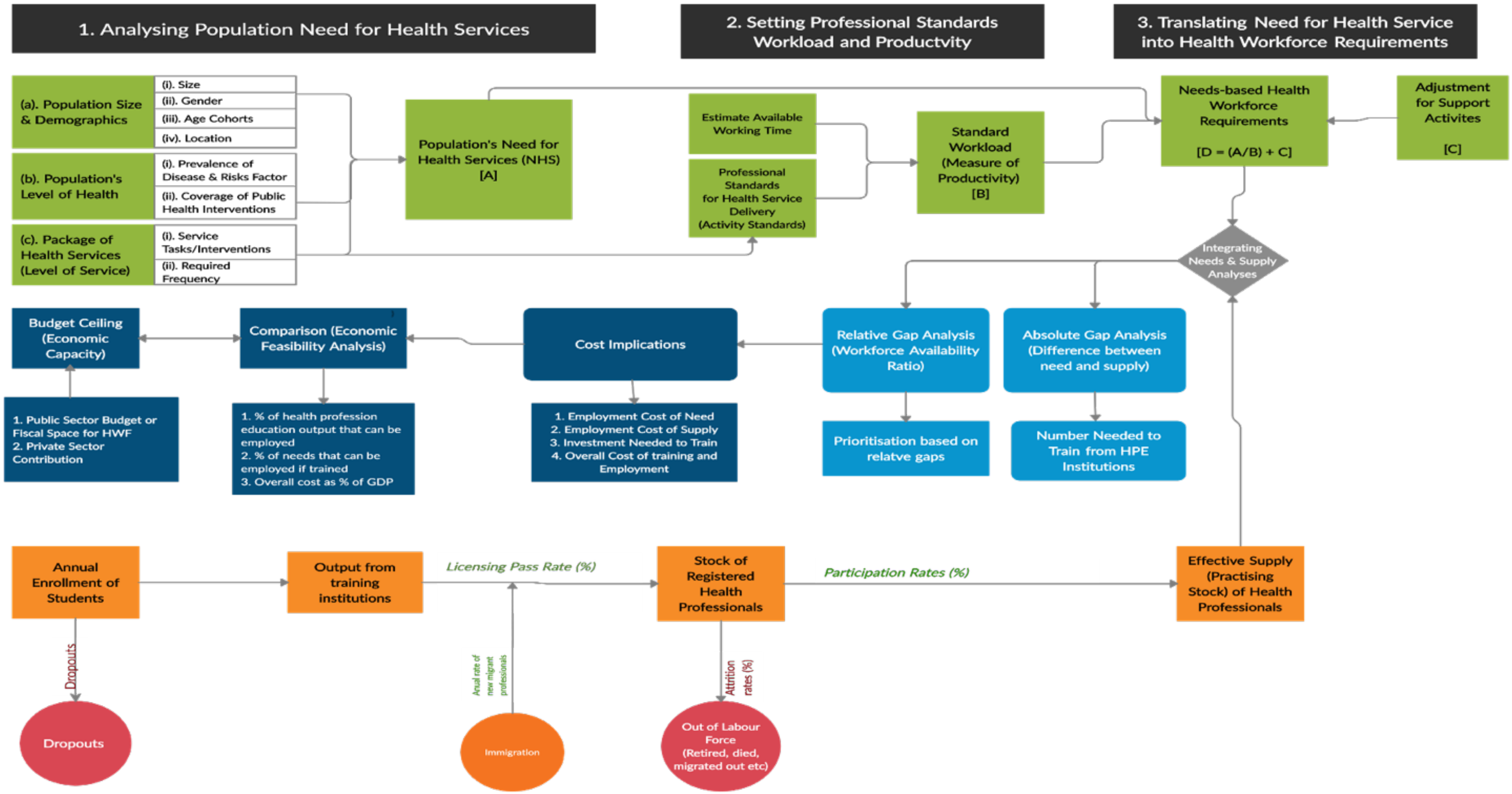

Figure 2: A conceptual framework for the Population Needs-based Simulation Model for Health Workforce Planning Source: [30]

5.3.2 The empirical application of the model: data sources and assumptions

Input data for the model application (equations 1 – 8) were triangulated from multiple sources. This section highlights the nature and process of data acquisition and data validation procedure and limitations.

5.3.3 Data sources for the need analysis

Population size and characteristics: The population size, gender, age composition (age cohorts) and distribution by geographical regions and rural and urban distribution were taken from the Ghana Statistical Service projections [42].

Level of health (disease burden)*:* The list of diseases and risk factors that accounted for 98% of the burden of mortalities, outpatient attendance and hospital admissions were profiled from the Global Burden of Disease Study [43] and the Facts and Figures report of the Health Sector in Ghana [44,45]. We then conducted a desk review of survey reports, analytical reports and peer-reviewed publications to map the prevalence or incidence (as appropriate) of the diseases and risk factors identified and the coverage rates of essential public health interventions. The notable sources of the data included the Ghana Demographic and Health Surveys [46,47], Ghana Maternal Health Surveys [48,49], the Facts and Figures report of the health sector in Ghana [44,45], Ministry of Health annual holistic assessment report of the health sector [21,50,51], and several peer-reviewed publications (see supplementary material 1 for the details of diseases and risk factors with their prevalence or incidence rate as well as the data sources).

Level of service*:* The main health services that were being provided or were otherwise necessary at the PHC level to address the diseases and risk factors identified above were extracted from various sources, including the Ghana Standard Treatment Guidelines 2017 [52]; CHPS Policy [22]; National Reproductive Health Service Policy and Standards [53]; the Non-Communicable Disease Strategy [54]; Ghana National HIV and AIDS Strategic Plan [55]; and Clinical Management Guidelines for TB and HIV Infection [56]. The health service activities were matched to the job description of the health professionals being studied.

Activity standards and standard workloads*:* The list of tasks performed by health professionals (matched with the services required to address the disease burden identified above) was extracted from the job descriptions of the respective health professionals and those of a previous WISN study [57]. The standard time it would take the individual health professionals to perform these health service tasks were elicited through a nationally representative cross-sectional survey completed by 503 health professionals. The detailed methodology and results of the survey have been reported in a separate piece [58].

Workload division: We adopted a workload division established by the Technical Working Group (TWG) on Staffing Norms of the Ministry of Health in 2014 [16,57]. The TWG adopted a workload division of 25% of medical laboratory workload for the Biomedical Scientist and 75% for Laboratory Technicians, noting that most laboratory examinations, especially at PHC level, were not complex and hence the role of the Biomedical Scientist was for quality assurance undertaking the 25% of the workload which may require a higher level of technical knowledge or skill. Based on similar logic, pharmacy-related workload division of 20% for Pharmacists and 80% for Pharmacy Technicians was also adopted by the TWG. Based on observed data, the TWG also concluded that Physician Assistants covered 20% of the workload in terms of outpatient consultations in primary/district hospitals and polyclinics, leaving 80% for General Practitioners. However, the Physician Assistant covered 80% of outpatient consultations at health centres, with the remaining 20% taken care of by nurses. We also adopted the workload ratio of 70% for professional nurses (Registered General Nurses) and 30% for auxiliary nurses (Enrolled Nurses) for clinical nursing care. For Midwives, Community Health Nurses, Nutritionists and Dieticians, their functions at the PHC level are usually not shared with other professionals; hence, we made no workload division assumptions.

Data from the health sector holistic assessment by the MOH show that between 2014 and 2017, on average, about 20% of outpatient consultations were provided by health professionals at CHPS compounds/zones; 26% at health centres/polyclinics; 49% at primary (and district) hospitals while the rest of 5% was provided in either secondary or tertiary health facilities [21]. We applied the above-mentioned observed trends to the modelled need for health services for the division of service delivery at the various levels of PHC.

5.3.4 Data sources for the supply analysis and costing

The existing stock of health professionals, the rate of labour flow (attrition), the education pipeline (number of admissions into health professions education institutions and pass rates) were obtained from the respective professional regulatory bodies of the health professions (as indicated in Table 1). The health professionals' average income level was taken from the public sector Single Spine

Salary (SSS) scale obtained from the Ghana Health Service. In the absence of comprehensive data on the cost of training of health professionals, we used the average of annual fees paid by fee-paying students as published by two public universities (the University of Ghana's College of Health Sciences and the University of Health and Allied Sciences) and one private university (the Central University). Since fee-paying students in public and private universities do not benefit from government subsidies and are usually charged at least for full cost recovery for tuition and other costs of training, we assumed that it better reflected the 'true cost' of training as compared with the regular student fees which the government substantially subsides. However, the estimated cost of training per student per year excluded boarding and lodging, which enormously varies depending on the cities and lifestyles of individual students.

5.3.5 Data validation and quality assurance

Data extracted from official reports and websites of MoH, GHS and the respective health professions regulatory bodies were sent to focal persons in the respective institutions to confirm the validity of the data and an explanation was provided for any inconsistencies observed. They also indicated whether or not any subsequent update to the data or report was made and available. Where there was unexplained data inconsistency, a comparison was made with international datasets (if available) such as the World Development Indicators of the World Bank, WHO's Global Health Observatory (GHO), and the National Health Workforce Account (NHWA) database. Data obtained from peer-reviewed publications were also compared with papers of similar methodology to ensure consistency of estimates. Whenever there was wide variation in estimation between two publications, additional papers were sought for further comparison, and closest of the estimates was used. Two of the authors systematically and consistently scrutinised the data before analysis.

Table 1: Baseline stock, labour flows, training outputs, average income levels and cost of training

No.	List of cadres	Active Baseline Stock	Rate of Annual Retirements/ Death (%)	Rate of other forms of attrition	Overall Annual Attrition Rate (%)	Duration of training (Years)	Average Number of Annual Enrolments	Averag e Pass Rate (%)	Average Annual Income (GH¢)	Cost of Training Per Year (GH¢)	Sources of Data
1	General Practitioner (Generalist Doctor)	6,173	1.9%	5.2%	7.1%	6	1,566	70.0%	68,182.3	8,242.0	MDC; GHS; MoH; UG; UHAS
2	Physician Assistant (Medical)	3,118	1.9%	0.0%	1.9%	3	638	80.5%	35,821.4	10,712.5	MDC; GHS; MoH; UG; CU
3	Midwife	12,786	7.6%	0.3%	7.9%	3	4,827	79.0%	28,290.1	8,910.5	NMC; GHS; MoH; UHAS; UG
4	Registered General Nurse	60,530	2.8%	0.4%	3.2%	3	7,353	73.0%	28,290.1	8,910.5	NMC; GHS; MoH; UHAS; UG; CU
5	Enrolled Nurse	40,000	1.6%	3.9%	5.5%	2	8,379	86.0%	18,260.4	8,910.5	NMC; GHS; MoH; UHAS
6	Community Health Nurse	24,494	0.8%	3.9%	4.7%	2	4,184	92.0%	18,260.4	8,910.5	NMC; GHS; MoH; UHAS
7	Nutritionist and Dietician	334	2.1%	0.0%	2.1%	3	429	92.8%	35,821.4	8,089.0	AHPC; GHS; MoH; UHAS; UG
8	Biomedical Scientist*	1,355	2%	0.0%	2%	4	396	92.8%	35,821.4	8,089.0	AHPC; GHS; MoH; UHAS; UG
9	Laboratory Technician	855	2.1%	0.0%	2.1%	3	682	92.8%	28,290.1	8,089.0	AHPC; GHS; MoH; UHAS; UG
10	Pharmacist**	1,052	0.8%	0.1%	0.9%	4	343	81.6%	38,317.4	7,594.0	PCG; GHS; MoH; UHAS; UG
11	Pharmacy Technician	1,055	2.1%	0.0%	2.1%	3	173	81.6%	26,007.8	7,594.0	PCG; GHS; MoH; UHAS; UG

**a six-year Doctor of Medical Laboratory programme has been introduced by some universities*
***a six-year Doctor of Pharmacy programme is being introduced by universities, but the 4-year Bachelor of Pharmacy degree is still the basic requirement to be a Pharmacist in the country.*

AHPC – Allied Health Professions Council; CU – Central University; GHS – Ghana health Service; MDC – Medical and Dental Council; MoH – Ministry of Health; NMC – Nursing and Midwifery Council; PCG – Pharmacy Council of Ghana; UG – University of Ghana; UHAS – the University of Health and Allied Sciences

5.4 FINDINGS

5.4.1 Projected supply of health professionals, 2020 - 2035

In aggregate, the current stock of 11 health professionals considered in this analysis was estimated to be 148,390 across public and private sectors, with the projection showing a progressive increase over the next 15 years. Overall, the average net annual growth rate is estimated to be 5.6% resulting in a rise of 51.9% from the current stock to 225,454 by 2025 and a further 26.8% increase to 285,900 by 2030, which could reach 333,770 by 2035. Thus, by 2035, holding the current rate of production and attrition constant, the size of the 11 categories of health professionals considered in this analysis is likely to be two and a half folds that of the bassline stock in 2020.

General Practitioners' stock is expected to increase by 46.2% from 6,173 in 2020 to 9,027 by 2025, with a further increase of 12.19% by 2030 and capping at about 12,369 by 2035 (an increase of 12.4% from the stock expected in 2030). Similarly, the supply of Physician Assistants is anticipated to increase by almost 70% from 3,118 in 2020 to 5,305 in 2025 and 37.5% and 24.8% by 2030 and 2035, respectively. Also, with the double streams of producing Midwives via direct entry and post-basic training, the stock of Midwives is likely to almost double (93.6% increase) from 12,786 in 2020 to 24,756 in 2025, and a further expansion of 53.3% could be reached by 2030 if the prevailing rate of production and attrition were held constant.

Registered General Nurses' active stock is projected to increase by 27% from 59,986 in 2020 to 76,158 by 2025, with a further 18% increase to 89,903 by 2030. If the production rate continued unabated, the stock of Registered General Nurses could reach 101,585 by 2035. Besides, the baseline stock of 24,494 Community Health Nurses is projected to reach 54,108 (120.9% increase) by 2035 as were Enrolled Nurses to increase from 37,182 in 2020 to 77,816 by 2030 (109% increase) and 90,998 by 2035 or 16.9% further boost from the stock anticipated in 2030. Finally, the expected output of Laboratory Technicians showed a ramp-up in recent years whereby the baseline stock of 855 is likely to increase by three and a half folds to 3,810 by 2025 and nearly ten folds to 8,857 by 2035. Table 2 provides details of the annual projections of health professionals' supply if the current trend continued without interventions to either abate or accelerate the production.

Table 2: Projected supply of health professionals, 2020 – 2035

No.	Health Professionals	Projected Supply, 2020 - 2035															
		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
1	General Practitioner (Generalist Doctor)	6,173	6,831	7,442	8,010	8,537	9,027	9,483	9,906	10,299	10,664	11,003	11,318	11,610	11,882	12,135	12,369
2	Physician Assistant (Medical)	3,118	3,572	4,018	4,455	4,884	5,305	5,718	6,123	6,520	6,910	7,292	7,667	8,035	8,396	8,750	9,097
3	Midwife	12,786	15,589	18,171	20,549	22,739	24,756	26,613	28,324	29,900	31,351	32,688	33,919	35,053	36,097	37,058	37,944
4	Registered General Nurse	59,986	63,434	66,772	70,003	73,131	76,158	79,089	81,926	84,672	87,330	89,903	92,394	94,805	97,139	99,398	101,585
5	Enrolled Nurse	37,182	42,350	47,236	51,853	56,217	60,343	64,242	67,927	71,411	74,703	77,816	80,757	83,538	86,166	88,650	90,998
6	Community Health Nurse	24,494	27,197	29,773	32,229	34,570	36,802	38,929	40,956	42,889	44,731	46,487	48,160	49,756	51,276	52,726	54,108
7	Nutritionist and Dietician	334	735	1,127	1,511	1,886	2,254	2,615	2,967	3,312	3,650	3,981	4,305	4,622	4,933	5,237	5,534
8	Biomedical Scientist	1,355	1,696	2,029	2,356	2,677	2,991	3,299	3,600	3,896	4,186	4,470	4,748	5,021	5,288	5,550	5,806
9	Laboratory Technician	855	1,471	2,075	2,665	3,244	3,810	4,364	4,907	5,438	5,958	6,467	6,966	7,454	7,931	8,399	8,857
10	Pharmacist	1,052	1,322	1,590	1,856	2,119	2,380	2,638	2,895	3,148	3,400	3,649	3,896	4,141	4,384	4,624	4,862
11	Pharmacy Technician	1,055	1,175	1,292	1,407	1,519	1,629	1,737	1,842	1,945	2,046	2,145	2,242	2,337	2,429	2,520	2,609
	Total	148,390	165,372	181,525	196,894	211,524	225,454	238,725	251,372	263,429	274,929	285,900	296,372	306,370	315,921	325,047	333,770
	Net Annual Increase		16,982	16,153	15,369	14,629	13,931	13,271	12,647	12,057	11,499	10,971	10,472	9,999	9,551	9,126	8,724
	Annual % net increase		11.4%	9.8%	8.5%	7.4%	6.6%	5.9%	5.3%	4.8%	4.4%	4.0%	3.7%	3.4%	3.1%	2.9%	2.7%

Note: Supply values for 2020 are not projections but the baseline data

5.4.2 Projected needs-based requirements for health professionals, 2020 - 2035

The projections show that based on the population (size and demographics), disease burden, the package of health services and the professional standards for delivering those services, Ghana needed 221,593 health professionals across the 11 categories included in the analysis for primary health services. At the rate of change of 5.5% (range: 3.2% - 10.7%) per annum, the aggregate requirement is likely to reach 407,897 by 2030 (84.1% increase) and a further 21.4% increase to 495,273 by 2035.

Specifically, General Practitioners' needs-based requirement is estimated to be roughly 14,049 in 2020, which is anticipated to averagely increase at an annual rate of 5.7% (range is 2.7% to 11.2%). With this trajectory, the need for General Practitioners could increase by 89% to 26,560 by 2030 and then reach 32,199 by 2035, an additional needs-based increase of 21.2% between 2030 and 2035.

Physician Assistants' baseline requirement is estimated to be 8,590 in 2020 and expected to double to 17,633 (an increase of 105%) by 2030 and almost 21,487 by 2035, about two and half times that of the baseline requirement in 2020. Also, about 14,002 Midwives are estimated to be needed in 2020, increasing progressively at an annual average rate of 4.9% (range: 4.5% -5.5%) to 17,586 by 2025 and 28,805 by 2035 (about 106% increase between 2020 and 2035).

At an annual rate of increase averaging 5.5% (range: 3.1% - 12.5%), the need for Registered General Nurses could increase from 66,948 at baseline in 2020 to 148,983 by 2035, which represents a cumulative change of ~123% increase between 2020 and 2035. For Enrolled Nurses, the needed number in 2020 is estimated to be 45,354 and is anticipated to grow at an annual rate of 5% (range: 3.1% to 9.6%) to reach 94,381 by 2035.

Similarly, the need for Community Health Nurses is estimated to be 41,787 at baseline in 2020 and is likely to increase at an average annual rate of 5.7% (range is 3.3% to 12%) to 77,071 by 2030 and 96,233 by 2035; as the need for 5,937 Nutritionists and Dietitians is also likely to increase by 19.5% to 7,094 in 2035. The need for Biomedical scientists could also increase by 3.3 folds from 4,581 in 2020 to 14,933 by 2035, similar to Laboratory Technicians whose estimated need is 8,585 in 2020 but projected to increase dramatically to 21,663 in 2035. Finally, the need for Pharmacist is estimated to grow at an annual average of 6.6% (range is 3.4% to 12.4%) from 3,993 in 2020 to 10,340 by 2035, similar to the Pharmacy Technicians whose needs-based requirement is projected to escalate by 147% from 7,766 in 2020 to 19,154 by 2035 (an annual average growth rate of 6.3%, range: 3.1% - 11.7%). Table 3 provides the projected annual need for various health professionals.

Table 3: Projected needs-based requirements of health professionals, 2020 - 2035

No.	Health Professionals	Needs-based Requirements, 2020 - 2035															
		2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
1	General Practitioner (Generalist Doctor)	14,049	15,366	16,875	18,765	20,169	21,923	22,692	23,520	24,414	25,383	26,560	27,712	28,973	30,358	31,352	32,199
2	Physician Assistant (Medical)	8,590	9,775	10,929	12,157	13,171	14,511	15,023	15,578	16,180	16,837	17,633	18,422	19,290	20,247	20,921	21,487
3	Midwife	14,002	14,639	15,312	16,023	16,775	17,586	18,429	19,321	20,265	21,264	22,440	23,569	24,766	26,035	27,379	28,805
4	Registered General Nurse	66,948	73,001	80,527	90,625	97,194	105,290	108,627	112,155	115,892	119,861	125,129	129,711	134,615	139,879	144,507	148,983
5	Enrolled Nurse	45,354	48,317	52,048	57,064	61,078	66,649	68,746	70,950	73,271	75,718	79,246	82,048	85,021	88,180	91,252	94,381
6	Community Health Nurse	41,787	46,816	51,499	56,121	59,159	62,267	64,712	67,368	70,259	73,411	77,071	80,873	85,046	89,637	93,125	96,233
7	Nutritionist and Dietician	5,937	5,931	5,932	5,941	5,959	6,038	6,080	6,132	6,194	6,266	6,445	6,548	6,664	6,793	6,936	7,094
8	Laboratory Scientist	4,581	5,043	5,680	6,592	7,298	8,151	8,613	9,131	9,713	10,369	11,125	11,966	12,921	14,009	14,577	14,933
9	Pharmacist	3,993	4,488	5,004	5,592	6,104	6,790	7,054	7,337	7,642	7,970	8,372	8,759	9,179	9,637	10,004	10,340
10	Pharmacy Technician	7,766	8,673	9,616	10,693	11,626	12,906	13,372	13,871	14,406	14,983	15,726	16,406	17,146	17,952	18,583	19,154
11	Laboratory Technician	8,585	9,486	10,835	12,894	14,039	15,282	15,763	16,282	16,844	17,456	18,150	18,882	19,687	20,574	21,175	21,663
	Total	**221,593**	**241,534**	**264,257**	**292,467**	**312,573**	**337,392**	**349,111**	**361,645**	**375,081**	**389,518**	**407,897**	**424,898**	**443,309**	**463,300**	**479,812**	**495,273**
	Net Annual Increase		**19,942**	**22,722**	**28,210**	**20,106**	**24,819**	**11,719**	**12,534**	**13,436**	**14,437**	**18,379**	**17,001**	**18,411**	**19,992**	**16,512**	**15,461**
	Annual % net increase		**9.0%**	**9.4%**	**10.7%**	**6.9%**	**7.9%**	**3.5%**	**3.6%**	**3.7%**	**3.8%**	**4.7%**	**4.2%**	**4.3%**	**4.5%**	**3.6%**	**3.2%**

Note: 2020 values are the needs-based baseline requirements

5.4.3 Health professionals' supply versus need gap analysis, 2020 - 2035

We compared the projected supply of the health professionals with that of the projected needs, which showed that at baseline, the stock of the health professionals included in the analysis met about 67% of their aggregate needs-based requirements in 2020, leaving a gap of 33%, translating into a needs-based shortage of 73,203 health professionals across 11 cadres. Without any intervention to increase the production of these health professionals, the ratio of future supply to the need (staff availability ratio) is likely to remain fairly constant (with marginal fluctuations) until 2030, when it is likely to be roughly 70%%. However, the absolute gaps are likely to increase by 66.7% from 73,203 in 2020 to 121,997 by 2030 and then to 161,502 by 2035.

However, beneath the aggregate estimates are huge imbalances whereby there is a seemingly adequate production of Enrolled Nurses and an anticipated overproduction of Midwives. At the same time, for six out of 11 health professionals considered in this analysis (namely, General Practitioner, Laboratory Scientist, Laboratory Technician, Pharmacist, Pharmacy Technician and Physician Assistant), the projected supply will likely fail to meet even 50% of the needs-based requirement by 2035 if no corrective intervention(s) is undertaken to enhance health professions education.

At baseline in 2020, Midwives and Registered General Nurses appear to have marginal needs-based shortages of 8.7% and 10.4%, respectively. However, over 15 years, the supply of Registered General Nurses is likely to meet only 68.2% of the need if the trajectory of need and supply remains unchanged. On the other hand, the supply of Midwives is likely to exceed that of the need by 41% in 2025, 46% by 2030 and then 32% by 2035 if the levers of production (and supply) viz-a-viz the need remain constant. Additionally, the projected supply of Enrolled Nurses met about 82% of the needs-based requirement and is anticipated to incrementally improve to between 96.4% and 98.2% from 2030 to 2035 – reaching a near-equilibrium between need and supply. The needs-based shortage of Community Health Nurses is estimated to be 17,293, which represents a 41.4% needs-based shortfall in 2020 which, given a high rate of internal attrition to other professions like midwifery and general nursing, the needs-based shortage is likely to worsen to 44% by 2035; leaving a need for additional 42,125 Community Health Nurses in 2035.

Similarly, General Practitioners' baseline stock represents only 43.9% of the needs-based requirement, and the rate of supply seems to be outpaced by the rate of increasing need, leaving a needs-based shortfall increasing from 7,876 in 2020 to 19,830 by 2035. Under the current trend, the needs-based shortage of General Practitioners could worsen from 56.1% to 55.7% by 2030 and further escalate to a shortage of 61.3% of General Practitioners by 2035. Additionally, the baseline stock of Physician Assistants in 2020 covers only 36.3% of the need, with the shortage estimated to be 5,472, which is likely to increase steadily to 12,390 by 2035. During this time, the projected supply will represent only 42.3% of the needs-based requirements.

Furthermore, Nutritionists and Dieticians are projected to have the most severe shortage at baseline, which the stock meets just 5.6% of the need; leaving a needs-based shortage of 94.4%, but owing to an already started massive expansion in intake in the last few years, will likely reduce the needs-based shortage to 38.2% by 2030 and 22% by 2035. This will translate into reducing the absolute shortage of Nutritionists and Dieticians from 5,603 in 2020 to only 1,560 by 2035. Similarly, the baseline supply of Pharmacy Technicians represents only 13.6% of the needs-based requirement (which is expected to remain similar for the 15-year horizon of the projection), leaving an absolute needs-based shortage of 6,711 in 2020, which is projected to increase dramatically to 16,545 by 2035. In the same vein, the baseline stock of Laboratory Technicians is estimated to represent only 10% of the need in 2020, leaving a needs-based shortage of 7,730, which under the prevailing trends the needs-based shortage for Laboratory Technicians could reach 12,806 by 2035. However, in relative terms, the supply to need ratio is likely to improve gradually to 35.6% by 2030 and 40.9% by 2035.

Biomedical Scientists' baseline stock represents only 29.6% of the needs-based requirement at the PHC level, which is expected to improve marginally to 40.2% by 2030 and decline to 38.9% by 2035 if there are no interventions to influence the elements affecting production (and supply) and the need for Biomedical Scientists. The additional need of 3,226 Biomedical Scientists represents a 70.4% needs-based shortfall in 2020, but the absolute shortage could escalate by 106.3% to 6,655 by 2030 if corrective interventions are not taken, and this shortage could reach even 9,126 by 2035. Similarly, Pharmacists' needs-based shortage is estimated to be 2,941 at baseline in 2020, representing a 73.7% shortage of Pharmacists. Under the prevailing production and attrition rates, the absolute shortage could reach 5,478 by 2035, but relative to the needs-based requirement, it will represent a 53% shortfall in 2035. Table 4 shows the projected supply versus need gap analysis in absolute and relative terms for all the health professionals considered in the analysis.

Table 4: Supply versus needs-based gaps, 2020 - 2035

No.	Health professionals	2020				2025				2030				2035			
		Need (a)	Supply (b)	Gap (b-a)	SAR (b/a)	Need (a)	Supply (b)	Gap (b-a)	SAR (b/a)	Need (a)	Supply (b)	Gap (b-a)	SAR (b/a)	Need (a)	Supply (b)	Gap (b-a)	SAR (b/a)
1	Community Health Nurse	41,787	24,494	(17,293)	58.6%	62,267	36,802	(25,465)	59.1%	77,071	46,487	(30,585)	60.3%	96,233	54,108	(42,125)	56.2%
2	Enrolled Nurse	45,354	37,182	(8,172)	82.0%	66,649	60,343	(6,306)	90.5%	79,246	77,816	(1,430)	98.2%	94,381	90,998	(3,383)	96.4%
3	General Practitioner (Generalist Doctor)	14,049	6,173	(7,876)	43.9%	21,923	9,027	(12,895)	41.2%	26,560	11,003	(15,557)	41.4%	32,199	12,369	(19,830)	38.4%
4	Laboratory Scientist	4,581	1,355	(3,226)	29.6%	8,151	2,991	(5,160)	36.7%	11,125	4,470	(6,655)	40.2%	14,933	5,806	(9,126)	38.9%
5	Laboratory Technician	8,585	855	(7,730)	10.0%	15,282	3,810	(11,472)	24.9%	18,150	6,467	(11,683)	35.6%	21,663	8,857	(12,806)	40.9%
6	Midwife	14,002	12,786	(1,216)	91.3%	17,586	24,756	7,170	140.8%	22,440	32,688	10,248	145.7%	28,805	37,944	9,139	131.7%
7	Nutritionist and Dietician	5,937	334	(5,603)	5.6%	6,038	2,254	(3,784)	37.3%	6,445	3,981	(2,464)	61.8%	7,094	5,534	(1,560)	78.0%
8	Pharmacist	3,993	1,052	(2,941)	26.3%	6,790	2,380	(4,410)	35.0%	8,372	3,649	(4,722)	43.6%	10,340	4,862	(5,478)	47.0%
9	Pharmacy Technician	7,766	1,055	(6,711)	13.6%	12,906	1,629	(11,278)	12.6%	15,726	2,145	(13,580)	13.6%	19,154	2,609	(16,545)	13.6%
10	Physician Assistant (Medical)	8,590	3,118	(5,472)	36.3%	14,511	5,305	(9,206)	36.6%	17,633	7,292	(10,341)	41.4%	21,487	9,097	(12,390)	42.3%
11	Registered General Nurse	66,948	59,986	(6,962)	89.6%	105,290	76,158	(29,132)	72.3%	125,129	89,903	(35,227)	71.8%	148,983	101,585	(47,399)	68.2%
	Ghana	***221,593***	***148,390***	***(73,203)***	***67.0%***	***337,392***	***225,454***	***(111,938)***	***66.8%***	***407,897***	***285,900***	***(121,997)***	***70.1%***	***495,273***	***333,770***	***(161,502)***	***67.4%***

Note: Supply values for 2020 are not projections but the baseline data; 2020 values are the needs-based baseline requirements

5.4.4 Implications for planning the annual intake into health professions education institutions

Table 5 summarises the gaps and the recommended number of admissions per year for each category of health professionals to fill the projected needs-based shortages effectively. Notably, the analysis shows a need to ramp-up most health professionals' training while also maintaining or even reducing a few others, assuming the prevailing pass rates and attrition rates (as shown in Table 1) were held constant. For instance, 173 Pharmacy Technicians' annual intake per year needs to be tremendously escalated by almost seven and a half folds to about 1,475 annually. Also, the average annual intake of 4,180 for Community Health Nurses is projected to culminate in a future supply that will fail to offset the anticipated needs-based shortage of 42,125 by 2035; hence there might be the need to increase their intake by some 72% to 7,217 per year. Similarly, General Practitioners' annual enrolments need to be increased by 110% from 1,556 (inclusive of local and foreign training) to 3,285 annually.

In comparison, Biomedical Scientists and Physician Assistants may also need to be escalated by 165% and 155%, respectively. Thus, Biomedical Scientists' intake might need to increase from 396 to 1,048, and that of Physician Assistants might need to increase from 638 to 1,625 annually to address the anticipated needs-based shortage by 2035. The annual intake of Pharmacists may also have to be expanded by 126% from 343 to about 775 per annum. The annual intake of Midwives could be scaled down by 15% from 4,827 (from direct and post-basic streams) to 4,090. On the other hand, Registered General Nurses may have to be ramped up by 55% from an annual average intake of 7,353 to 11,366 to meet the needs-based shortage by 2035, which are occasioned by expanding population health needs and attrition from general nursing to specialists and other careers as well as escalating out-migration.

Table 5: Needs-based health professions training requirements

No.	Health Workforce Category	Health Professionals Needed To Train						
		Needs-based gap at baseline (2020)	Total additional Training to fill needs-based gaps by 2035	Average changes in admissions required	Current annual admissions	Needs-based optimal admissions per year	Needs-based % change from current annual admissions	Suggested decision
1	Community Health Nurse	17,293	42,125	3,033	4,184	7,217	72%	Increase
2	Enrolled Nurse	8,172	3,383	257	8,379	8,636	3%	Increase
3	General Practitioner (Generalist Doctor)	7,876	19,830	1,719	1,566	3,285	110%	Increase
4	Laboratory Scientist	3,226	9,126	652	396	1,048	165%	Increase
5	Laboratory Technician	7,730	12,806	913	682	1,595	134%	Increase
6	Midwife	1,216	(9,139)	(737)	4,827	4,090	-15%	Decrease
7	Nutritionist and Dietician	5,603	1,560	109	429	538	25%	Increase
8	Pharmacist	2,941	5,478	432	343	775	126%	Increase
9	Pharmacy Technician	6,711	16,545	1,302	173	1,475	752%	Increase
10	Physician Assistant (Medical)	5,472	12,390	987	638	1,625	155%	Increase
11	Registered General Nurse	6,962	47,399	4,013	7,353	11,366	55%	Increase
	Overall	**73,203**	**161,502**	**12,680**	**28,970**	**41,650**		

5.4.5 Cost implications for investing in health professions education

Using the average annual fee-paying rates and the estimated number of admissions required to fill the needs-based gaps by 2035 while adjusting for inflation (at a rate of 10% per annum), the cost of training to fill the aggregate gap of 170,529 health professionals across the 11 categories included in this analysis is estimated to be US$ 480.39 million. Of this amount, 28.8% (US$ 138.59 million) will be required for the training of Registered General Nurses up to 2035. Also, 15.4% (US$ 74.10 million) will be required for the training of General Practitioners. In comparison, Pharmacy Technicians who are expected to experience the most severe degree of shortage by 2035 will require US$ 15.33 million investments in their training (~3.2% of the aggregate estimated cost of training). Figure 3 shows the estimated cost of training for filling the anticipated needs-based gaps by 2035.

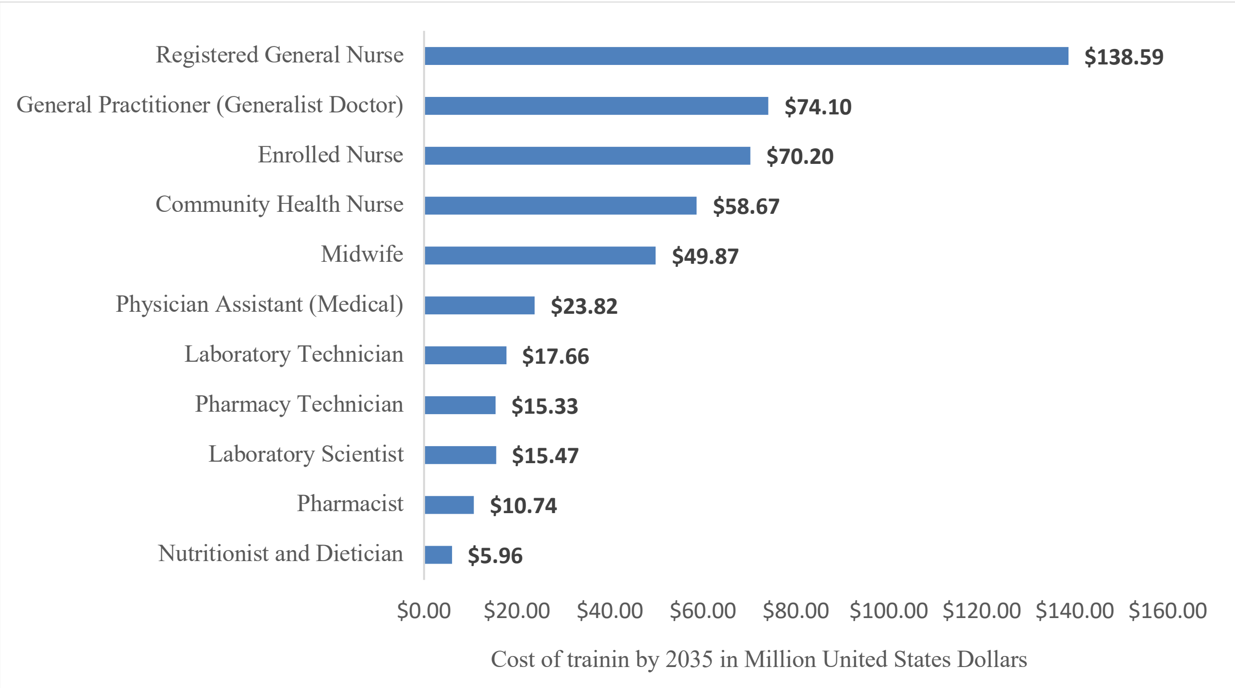

Figure 3: Estimated Cost for Training Health Professionals Needed to Fill Needs-based Shortages by 2035 (Million USD)

5.4.6 Cost implications for employment planning for health professionals

Using the average income level of health professionals in the public sector (Table 1) and the projected supply and needs (Tables 2 and 3, respectively), we conservatively estimated the annual cost of employment with 10% annual salary upward adjustments or increases in response to inflation and based on historical patterns of annual wage adjustments. It is estimated that the cost of wages for the current stock of the eleven groups of health professionals (using public sector salary levels) was about US$667.24 million in 2020 which Registered General Nurses accounted for 44% of the aggregate cost (US$295.59 million) followed by Enrolled Nurses which accounted for 18% or US$117.06 million; General Practitioners and Community Health Nurses also accounting for 11% and 12% respectively. In contrast, the cost of employment to fill all the estimated needs-based requirements in 2020 (assuming the supply was readily available to fill the need) was projected to be US$1.180 billion, of which 30% would have been for Registered General Nurses; 15% for General Practitioners; 12% for Community Health Nurses and 13% for Enrolled Nurses.

Holding all the aforesaid assumptions, by 2035, the projected cost of employment of the supply of these health professionals (i.e., sustaining the jobs of those already employed and recruitment of those being trained) would likely be around US$1.496 billion as compared to US$ 2.374 billion if the employment were to be based on need. Thus, meeting the needs-based requirements by 2035 would require an additional investment of US$ 878.37 million for employment compared with the cost of employment for the baseline supply in 2020. This implies that by 2035, US$ 2.374 billion must be planned for the employment of those that would have to be trained to fill the needs-based shortages and for sustaining the employment of those currently available.

Without supply-side corrective measures to reflect the needs-based gaps on the intake or number of admissions into health professions education institutions to correct the projected mismatches, the annual cost of inappropriate skill mix from the supply pipeline could be up to US$ 44.58 million or 7% of the baseline cost of employing the available stock. Some of the mismatches could manifest in the form of unemployment and/or employment of skills that are not needed thereby bloating the wage budget (especially in the public sector) and reducing the fiscal space for the employment of other equally essential health professionals. For instance, by 2035, the employment cost of the needs-based requirement of Enrolled Nurses would be roughly 13% of the aggregate estimate (for the occupational groups considered in this projection), which would translate into US$297.14 million. However, the current supply trend would likely yield US$ 286.49 million, which represents 19% of the aggregate estimate if no corrective measures are taken in line with the needs-based requirements. Similarly, whereas the cost of employing the needs-based requirement of midwives would be US$140.50 million (6% of the aggregate) by 2035, the cost of employment based on the prevailing trend of supply would likely be US$185.08 million or 12%

of the aggregate estimate. Thus, failing to adjust the production of Midwives in line with the needs could cost US$44.58 million by 2030. In contrast, if no corrective measures are taken in increasing intake, the employment cost of the supply of General Practitioners in 2035 would be around $145.41 million while the need require US$378.52 - which will be US$233.11 million (or 62%) short of the cost of investment necessary to cover needs-based employment of General Practitioners. Table 6 provides details of the projected cost of employment, comparing the prevailing supply trends and the needs-based requirements for eleven health professionals.

Table 6: Investments required for employment: anticipated supply versus needs-based requirement of health professionals, 2020-2035

NO.	HEALTH PROFESSIONAL	ESTIMATED EMPLOYMENT COST IN MILLION UNITED STATES DOLLARS (US$)								PROPORTIONAL SHARE (%) OF THE ESTIMATED COST			
		2020		2025		2030		2035		2020		2035	
		Needs-based	Supply-based	Needs-based	Supply-based	Needs-based	Supply-based	Needs-based	Supply-based	Needs-based	Supply-based	Needs-based	Supply-based
1	Community Health Nurse	144.72	77.12	196.04	115.86	242.65	146.36	302.97	170.35	12%	12%	13%	11%
2	Enrolled Nurse	157.07	117.06	209.83	189.98	249.49	244.99	297.14	286.49	13%	18%	12%	19%
3	General Practitioner (Generalist Doctor)	181.67	72.57	257.72	106.12	312.22	129.34	378.52	145.41	15%	11%	16%	10%
4	Laboratory Scientist	31.12	8.37	50.34	18.47	68.71	27.61	92.23	35.86	3%	1%	4%	2%
5	Laboratory Technician	65.23	4.17	105.75	18.58	125.47	31.54	149.67	43.20	6%	1%	6%	3%
6	Midwife	75.15	62.37	85.80	120.75	109.47	159.44	140.52	185.08	6%	9%	6%	12%
7	Nutritionist and Dietician	40.34	2.06	37.29	13.92	39.81	24.59	43.81	34.18	3%	0%	2%	2%
8	Pharmacist	29.02	6.95	44.86	15.72	55.31	24.11	68.31	32.12	2%	1%	3%	2%
9	Pharmacy Technician	38.30	4.73	57.87	7.30	70.51	9.62	85.89	11.70	3%	1%	4%	1%
10	Physician Assistant (Medical)	58.36	19.26	89.62	32.76	108.90	45.04	132.71	56.19	5%	3%	5%	4%
11	Registered General Nurse	359.20	292.59	513.56	371.47	610.33	438.51	726.68	495.49	30%	44%	30%	33%
Overall		**1,160.99**	**667.24**	**1,617.45**	**1,010.95**	**1,955.92**	**1,281.14**	**2,374.44**	**1,496.07**	**100%**	**100%**	**100%**	**100%**

Notes: Exchange rate used: 1 United States dollar = 5.8 Ghana Cedis; Estimates adjusted for wage increases which are usually benchmarked to the annual inflation rate, assumed to be about 10%.

5.4.7 Sensitivity Analysis: Testing the impact of the different assumptions on the projections

To examine the impact of key assumptions on the projection results, we conducted a one-way sensitivity analysis. We varied some of the assumptions one after the other, each time holding all others constant.

From our cross-sectional survey [58], the average practice variation in how much time health professionals perform the various task was ±18%. Altering all the professional standards by ±18%, the staffing requirements increased by 25% when the upper limits are assumed but reduced by 15% when the lower limits are assumed. This shows that the total variability in the staffing requirements attributed to practice variations is roughly 40%, which is substantial. It largely underscored that monitoring practice variations, especially those that could be influenced by evolving technologies, are imperative for adjusting the staffing projections and, subsequently, the policies and strategies thereof.

One main distinction between this model and others is that the present model assumes that future rate of change in disease patterns will mirror past trends, which may not necessarily be exact but somewhat overcomes a limitation where the previous models assumed that present prevalence rates would remain constant into the future. When our assumption was relaxed, health professionals' projected requirements were reduced by an average of 27%. In other words, in Ghana's context, future changes in disease patterns (if they mirror the previously observed trends) require about 27% more health workers within the next 15 years. Also, if the anticipated evolution in the disease burden was not taken into account, the health workforce requirements for the future would have been underestimated by some 27%. Figure 4 shows the trajectory of the projected aggregate needs-based requirements of eleven health professionals' categories under various alternative assumptions.

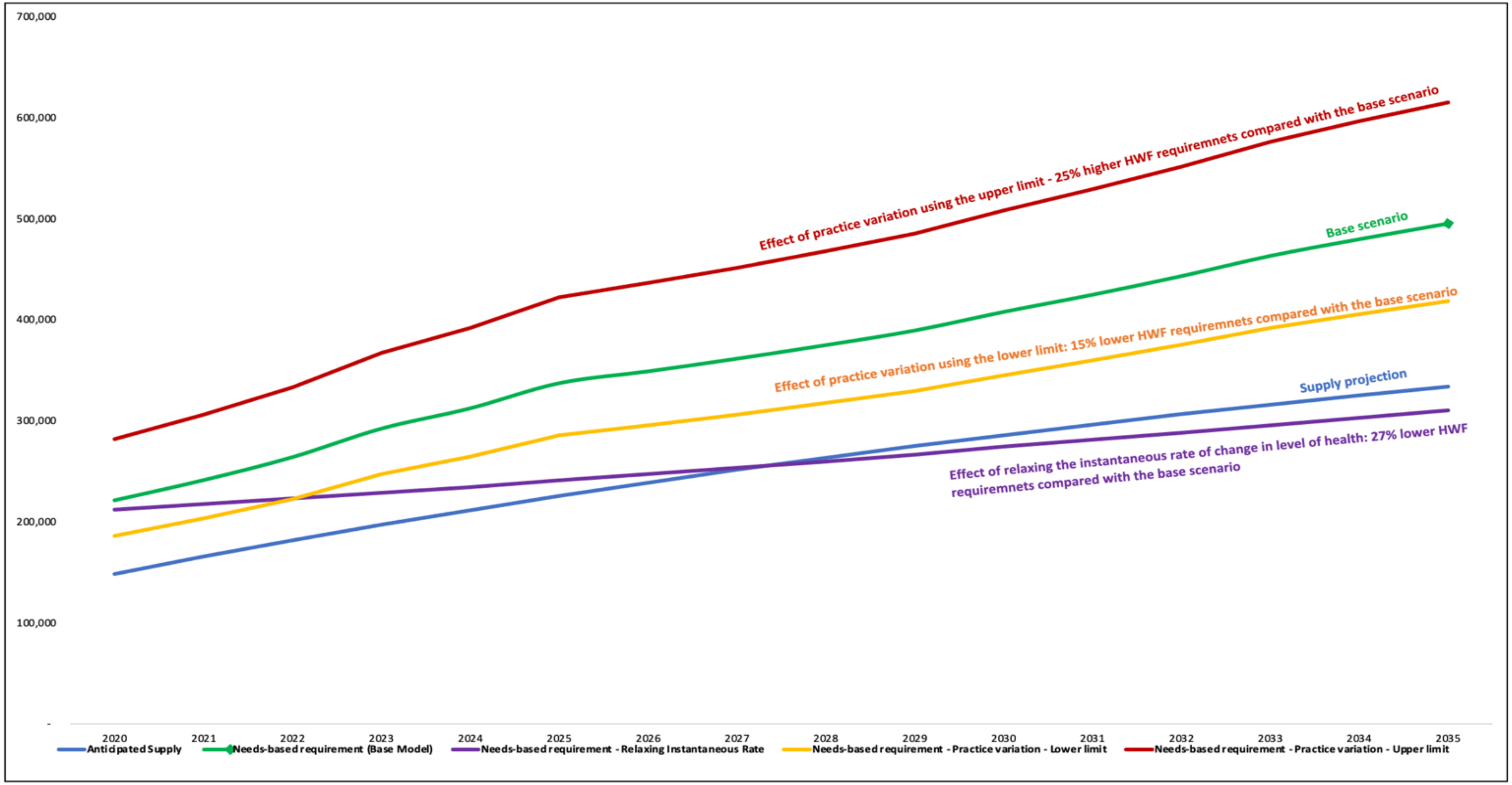

Figure 4: Sensitivity Analysis by varying need-related assumptions and variables

From the supply side, if the pass rate of the various professional licensing examinations is increased to 100%, it would improve the overall supply of the eleven health professionals by 12% by 2035, which will, in turn, improve the overall supply to need adequacy ratio from 67% to 79% by 2030. A similar result was found if the overall attrition rates were reduced by 50%. Interventions to concurrently improve the pass rate to 100% and reduce the attrition rate by up to 50% could lead to a 25% improvement in the supply of health professionals by 2035, yielding a supply versus need adequacy ratio of 96%. Figure 5 shows the trajectory of eleven categories of health professionals under various alternative assumptions.

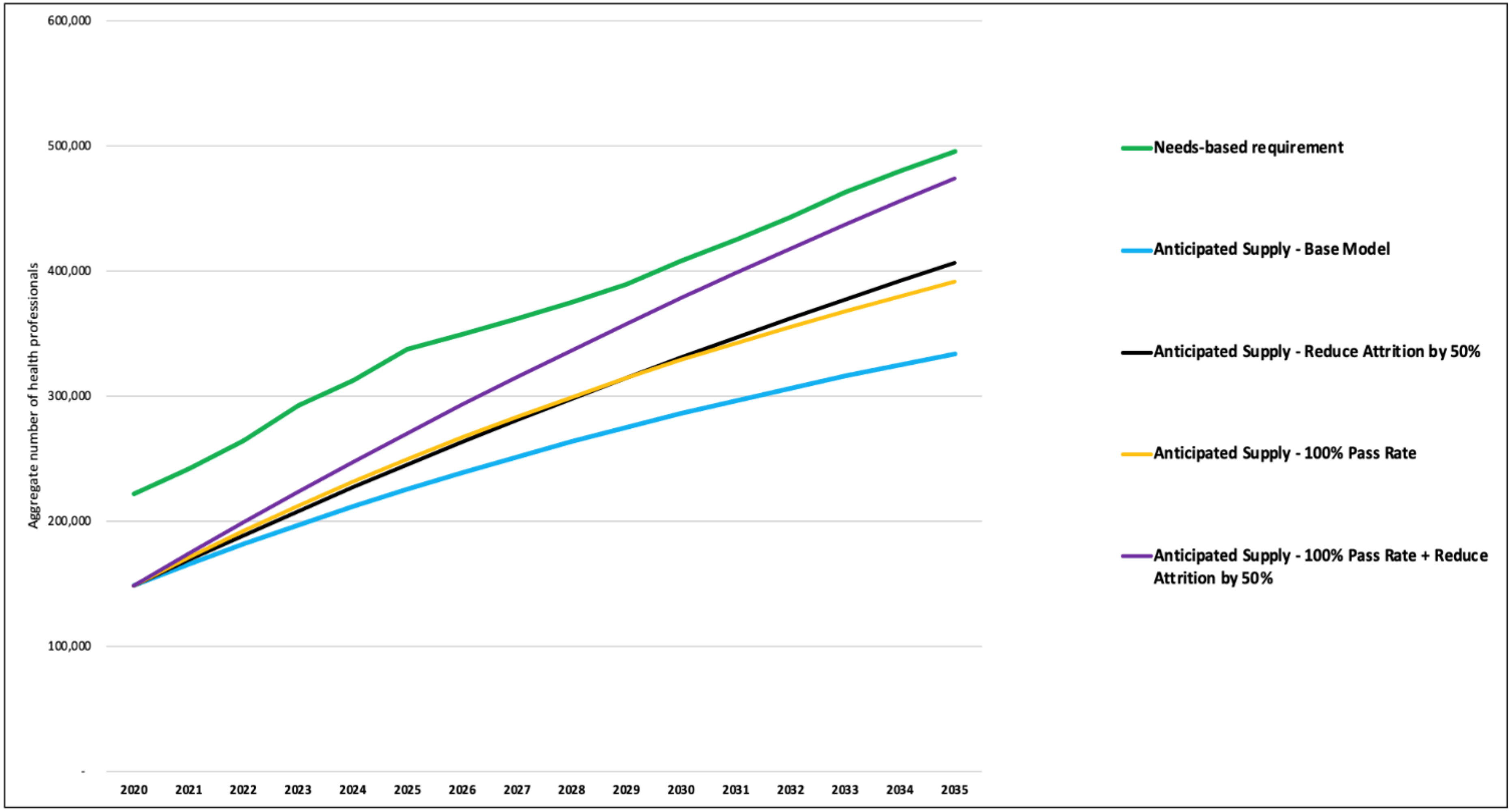

Figure 5: One-way sensitivity analysis of supply-side variable

5.5 DISCUSSION

The analysis demonstrates the feasibility and value of using the needs-based framework for health system-level planning for the health workforce, especially linking population health needs to quantifying the required intake into health professions education institutions. To the best of our knowledge, this study is the first attempt to undertake a multi-professional needs-based health workforce projection in Ghana, which accounts for diseases and risk factors that constitutes 98% of the burden of morbidity and mortalities; taking a comprehensive approach (across public and private sectors) and for the level of health care that caters for 95% of health service utilisation. Previous works have either been based on health facility staffing norms linked to current workloads [59] or normative ratios focused on only Physicians, Nurses and Midwives [13] and/or limited the scope to only the public sector.

The projection shows that the health professionals' aggregate supply could meet 67% of the needs-based requirements, which is expected to remain somewhat similar, improving to 70% by 2030 and then declining back to 67.4% by 2035. Previous estimates [59], which were based on a utilisation-oriented health facility staffing norms (health service development and analysis, HeSDA), suggested that, in aggregate, the public health sector had 68% of its requirements in 2016. A similar analysis also conducted by the Ghana Health Service (the institution mandated to provide primary and secondary health services in Ghana) in using its health facility staffing norms versus those employed by 2018 concluded that it had 68.7% of the staff required for service delivery. However, when clinical staff alone was considered, it had only 49% of its requirements, which substantially differed compared to the 67% estimated in the present study. The present study also projects anticipated oversupply of midwives by roughly 32% by 2035 if interventions are not undertaken to ensure a balance.

The supply of Enrolled Nurses and Registered General Nurses seem to be near equilibrium with the need at baseline. For Registered General Nurses a widening shortage looms quickly the further into the future the projection is extended. These should, however, be interpreted and compared with the previous works with caution as the present analysis took a comprehensive sector view, including public and private health services for PHC. In contrast, the previous works were based on only publicly funded health facilities. Also, one comparative study found that needs-based models (as in the case of the present study) tended to produce about 53.5% (44% - 57%) higher staffing requirements as compared to utilisation or demand-based models [60] because the needs-based model usually accounted for unexpressed or unmet health needs of the population which are missed out in utilisation or demand-based models. In line with this evidence, the current needs-based projection has estimated HWF requirements for 2020 that are on average 42% (range: 26% - 63%) higher than that of the previous facility-based modelling study [59].

Nonetheless, the overarching findings of the present study are largely consistent with various reports and studies. For example, the annual holistic assessment reports of the Ministry of Health have since 2014 warned of over-supply of midwives, noting "… the productivity of midwives had significantly deteriorated by 51.3% … [resulting in] in a surplus of about 2,766 midwives [representing 28.9%] during the period under review [for 2017]" [21]. Although the Midwives' productivity analysis methodology used in the holistic assessments has been debated, a separate analysis also suggested that GHS in 2018 was 13% overstaffed with midwives albeit inequitably distributed [19], which could lend further credence to the potential midwives' over-production hypothesis. Similarly, the State of the World's Nursing in 2020 report also suggested a potential overproduction of nurses (professionals and auxiliaries combined) [61] while the State of the World's Midwifery Report 2021 estimated that Ghana had between 74% and 91% of its need for midwives. Whereas the aforementioned analyses adopted different methodologies from the present study and also used global assumptions (instead of the country-specific data used in the present study), the similarities in conclusions tend to validate this study.

It is also important to note that since the present analysis took a comprehensive approach, the estimated needs and gaps comprise both public and private sectors. However, translating the needs-based requirements into actual demand or job creation to employ the health professionals, as well as adjusting the training outputs to respond to the needs, can take some time and depend on a web of multi-sectoral and multi-stakeholder actions – many of which may fall outside the remit of the health sector. From the employment perspective, there are bound to be a dynamic surplus of health professionals in which some health facilities may experience shortages and high vacancy rates for some health professionals even though they are available in the market for employment but rigidities in employment and budget allocation processes [14]. However, with the Government of Ghana's pledge to expand health infrastructure by establishing (and expanding) 111 district and regional hospitals, as well as infectious diseases and mental health hospitals, a programme that is known as 'Agenda 111' [62], the demand for health professionals, could move a bit closer to the needs-based projections herein.

Also, from the supply side, although the analysis revealed a need for significant expansion in the intake of various health professionals while scaling down others, these have significant implications on infrastructure, equipment and faculty, which may take a longer time to address. For instance, Biomedical Scientists and Pharmacists' training institutions are rapidly introducing more extended periods of training (changing from 4 to 6 years), leading to doctoral qualifications, which could exacerbate infrastructural challenges as the students would have to spend two more years in school, thereby limiting the capacity for increased admissions. These may result in rigidities in adjusting intake into health professions education which could lead to dynamic shortage where the demand (jobs) may become available, but it takes several years to produce the needed calibre of health professionals. On the other hand, a dynamic surplus could be looming where the health professionals who are not in high demand would continue to be produced by the health professions education institutions either due to time lag in adjusting production downwards in response to the decreased demand or the health professions education institutions merely focusing on the income generation side especially in the profit-driven private-sector production. These institutions' focus may be to produce health professionals' categories requiring less input cost and with rapid turnarounds, such as the training of enrolled nurses and top-up programmes. As some of these programmes have lower entry requirements, the market for health professional's education (applicants) abounds, but soon after employment, the graduates seek career advancements through top-up courses to become Midwives or Registered General Nurses [14].

The analysis shows that without corrective interventions to reflect the projected needs-based gaps on the intake (number of annual admissions) into health professions education institutions, the cost of inappropriate skill mix by 2035 could reach US$44.58 million or 7% of the cost of employing the baseline supply of the health professionals, mainly from the potential oversupply of midwives by 2035. This will likely manifest in the form of unemployment and/or employment of skills not needed, which will balloon the wage budget (especially in the public sector), reducing the fiscal space for the other equally essential health professionals with high vacancy rates. A recent analysis that supports this finding revealed that about 28% (range:16-38%) of public health sector wage was already being lost to inefficiency due to maldistribution and inappropriate skill mix, which costs the government some US$295.4 million annually [63].

Finally, as the estimates of needs-based requirements reported in this paper are aggregates, they do not guarantee geographical distributional equity but may be best suited for sector-wide policies and planning regarding targets for training and employment while other evidence-based management tools such as flexible staffing norms or WISN analysis is used to ensure equitable distribution of the health professionals produced. The disaggregation of how much of the needs-based requirements could be absorbed by the public or private sectors are not included in the analysis. This study was focused on needs and gaps for training rather than a demand-based labour market analysis which a separate study is imperative.

5.6 LIMITATIONS OF THE STUDY

The study has a number of limitations relating to the scope, data quality and methodological assumptions that should be taken into account when interpreting the findings and/or using them for decision making.

First of all, whereas the model could be applied for the entire health service need for health professionals in Ghana (from primary to tertiary and quaternary settings of health care), the present analysis focused on PHC, which is accessed by more than 95% of the population during outpatient care. The PHC level currently accounts for at least 62.5% of health workers employed in the public sector [64]. Hence, when interpreting the findings, it must be borne in mind that it may not represent the complete picture of needs-based requirements of some of the health professionals that may also be needed at the more sophisticated secondary, tertiary and quaternary levels of care (these levels combine to roughly provide advanced services for 5% of the population's health needs).

Secondly, the data used as inputs into the model were triangulated from various sources with varying quality and completeness levels. For instance, although it would have been preferable to rely solely on periodic national surveys for disease prevalence (and incidence) data, there was no STEPS survey done in Ghana to reliably obtain the prevalence of most non-communicable diseases and their risk factors. Under the circumstance, peer-reviewed papers were used in which we prioritised systematic reviews, single large-scale surveys and other well-conducted analytical pieces. Similarly, we relied on health professional regulatory bodies' registers for data on health professionals' stocks. However, due to weak regulatory enforcement, it is possible that some health professionals may not be up-to-date in renewing their practice licenses and hence may have been missed, thereby underestimating the stock of health professionals; or on the other hand, those that have migrated abroad or not practising their professions may remain in good standing with the regulatory bodies and thereby inflating the estimated stock. Also, we used data from the public sector (which employs about 80% of the health professionals) relating to average income and attrition rates, but the income and attrition in the public sector could vary from that of the private sector. Future studies to estimate and compare income and attrition rates between public and private sectors would help refine the projections.

Thirdly, methodologically, the model makes an explicit assumption that the current prevalence rates of diseases and their risk factors or even coverage rates will not remain constant throughout the horizon of the projection, but data on what to expect in the future is often not available for all diseases and risk factors. Hence, the model assumes that the future rate of change in disease (and risk factors) pattern will mirror past trends. Although this may seem a hard assumption, we believe that its benefit in the approximation outweighs the limitation where previous models assumed that present prevalence rates would remain constant into the future. Nonetheless, the absence of independent projections of the future trajectories of the prevalence of various diseases and risk factors for the country do expose the projections herein to potential deviations. However, in the sensitivity analysis, we demonstrate that relaxing the aforesaid methodological assumption (assuming the constant level of health as done in previous models) could underestimate the aggregate staffing needs by 27%. We thus, lean on the argument of leading needs-based theorists that *"problems with data are not avoided by adopting or reverting to the conceptually invalid models most commonly used by HRH planners ... [but]... the continual refinement of the application of a conceptually valid approach is superior to adopting conceptually invalid approaches based on the availability of data*" [36].

Finally, although health emergencies, such as the COVID-19 pandemic, have a significant implication on health professionals' requirements and hence should be taken into account in needs-based projections, there was limited information at the time of modelling if the COVID-19 will become endemic like other infectious diseases or will be eliminated within the very near future. Added to that, there was no population-based prevalence data in Ghana; hence, it was not feasible to include it in future projections. There are appropriate tools for estimating health workforce requirements in situations of health emergencies and disrupted health systems.

5.7 CONCLUSION

The study demonstrates the feasibility of using the needs-based framework for national-level planning. It shows potential value in linking population health needs to the required intake of students into health professions education institutions. It reveals that for the eleven categories of health professionals, Ghana's supply in 2020 satisfies about 67% of the aggregate needs-based requirements for primary healthcare, but a gap of 33% (or roughly 73,203) remains. Without any corrective intervention, the aggregate needs-based shortage in supply will likely be 161,502 by 2035, with the supply of 6 out of the 11 health professionals (~54.5%) failing to match 50% of the needs by 2035, but that of Midwives will likely be oversupplied by 32% in 2035. Priority areas for health professions education include scaling-up the production of Pharmacy Technicians by 7.5-fold; General Practitioners by 110% whilst scaling down Midwives production by 15%. About US$ 480.39 million investment is required in health professions education to fill the needs-based gaps and correct the mismatches by 2035, without which there will be a 33% shortage of essential health professionals and coupled with at least US$44.58 million losses to inappropriate skill mix by 2035. The adverse technical impact on interprofessional team compositions and, eventually, the quality of health care cannot be overemphasised.

5.8 REFERENCES

1. Kavya S, Sanjay PZ, Abhay G, Syed ZQ. Methodological issues in estimating and forecasting health manpower requirement. Journal of Public Administration and Policy Research. 2014;6: 25–33. doi:10.5897/JPAPR2011.067
2. Lopes MA, Almeida ÁS, Almada-Lobo B. Handling healthcare workforce planning with care: where do we stand? Human Resources for Health. 2015;13. doi:10.1186/s12960-015-0028-0
3. Birch S, Gibson J, McBride A, Munros T. Opportunities for, and implications of, skill mix changes in health care pathways: Pay, productivity and practice variations in a needs-based planning framework. Social Science and Medicine. 2020;250. doi:10.1016/j.socscimed.2020.112863
4. Birch S, Mason T, Sutton M, Whittaker W. Not enough doctors or not enough needs? Refocusing health workforce planning from providers and services to populations and needs. Journal of Health Services Research and Policy. 2013;18: 107–113. doi:10.1177/1355819612473592
5. Tomblin Murphy G, Kephart G, Lethbridge L, O'Brien-Pallas L, Birch S. Planning for what? Challenging the assumptions of health human resources planning. Health Policy. 2009;92: 225–233. doi:10.1016/j.healthpol.2009.04.001
6. WHO. Global strategy on human resources for health: workforce 2030. World Health Organisation. 2016. Available: https://www.who.int/hrh/resources/globstrathrh-2030/en/.
7. de Graft Aikins A, Addo J, Ofei F, Bosu WK, Agyemang C. Ghana's burden of chronic non-communicable diseases: future directions in research, practice and policy. Ghana medical journal. 2012;46: 1–3. Available: https://www.ajol.info/index.php/gmj/article/viewFile/88731/78321
8. Kushitor MK, Boatemaa S. The double burden of disease and the challenge of health access: Evidence from Access, Bottlenecks, Cost and Equity facility survey in Ghana. PLOS ONE. 2018;13: e0194677. doi:10.1371/journal.pone.0194677
9. World Health Organization. Primary health care on the road to universal health coverage: 2019 monitoring report. Geneva: WHO. 2019.
10. Asamani JA, Chebere MM, Barton PM, D'Almeida SA, Odame EA, Oppong R. Forecast of Healthcare Facilities and Health Workforce Requirements for the Public Sector in Ghana, 2016–2026. Int J Health Policy Manag. 2018;7: 1040–1052. doi:10.15171/ijhpm.2018.64

11. MOH. National Health Policy: Creating Wealth Through Health. Ministry of Health, Ghana; 2007. Available: http://www.moh-ghana.org/UploadFiles/Publications/NATIONAL%20HEALTH%20POLICY_22APR2012.pdf
12. Saleh K. The Health Sector in Ghana: A Comprehensive Assessment. World Bank Publications; 2013.
13. Scheffler RM, Mahoney CB, Fulton BD, Dal Poz MR, Preker AS. Estimates of health care professional shortages in sub-Saharan Africa by 2015. Health Affairs. 2009. doi:10.1377/hlthaff.28.5.w849
14. Asamani JA, Amertil NP, Ismaila H, Akugri FA, Nabyonga-Orem J. The imperative of evidence-based health workforce planning and implementation: lessons from nurses and midwives unemployment crisis in Ghana. Hum Resour Health. 2020;18: 16. doi:10.1186/s12960-020-0462-5
15. Campbell J, Buchan J, Cometto G, David B, Dussault G, Fogstad H, et al. Human resources for health and universal health coverage: fostering equity and effective coverage. Bulletin of the World Health Organization. 2013;91: 853–863. Available: http://www.scielosp.org/scielo.php?pid=S0042-96862013001100853&script=sci_arttext
16. MOH. Staffing Norms for the Health Sector of Ghana (Volume 1). Ministry of Health, Ghana; 2015.
17. Asamani JA, Chebere MM, Barton PM, D'Almeida SA, Odame EA, Oppong R. Forecast of Healthcare Facilities and Health Workforce Requirements for the Public Sector in Ghana, 2016–2026. International Journal of Health Policy and Management. 2018;0. Available: http://www.ijhpm.com/article_3525.html
18. Asamani JA, Amertil NP, Ismaila H, Akugri FA, Nabyonga-Orem J. The imperative of evidence-based health workforce planning and implementation: lessons from nurses and midwives unemployment crisis in Ghana. Human Resources for Health. 2020;18: 16. doi:10.1186/s12960-020-0462-5
19. GHS. Health Workforce Gaps and Cost-Benefit Analysis of Proposed Staff Redistribution in the Ghana Health Service. Accra: Ghana Health Service; 2018.
20. Appiah-Denkyira E, Herbst CH. Toward Evidence-Based Interventions for HRH. 2013. Available: http://elibrary.worldbank.org/doi/abs/10.1596/9780821396674_CH01
21. MOH. Health Sector Holistic Assessment of the Health Sector Performance - 2017. Ministry of Health, Ghana; 2018.

22. MOH. National Community-Based Health Planning and Services (CHPS) Policy: Accelerating attainment of Universal Health Coverage and bridging the access inequity gap. Ministry of Health, Ghana; 2015.
23. Asamani JA, Christmals CD, Reitsma GM. The needs-based health workforce planning method: A systematic scoping review of analytical applications. Health Policy and Planning. 2021;Inprint.
24. Ahern S, Woods N, Kalmus O, Birch S, Listl S. Needs-based planning for the oral health workforce - Development and application of a simulation model. Human Resources for Health. 2019;17. doi:10.1186/s12960-019-0394-0
25. Birch S, Gibson J, McBride A, Munros team. Opportunities for, and implications of, skill mix changes in health care pathways: Pay, productivity and practice variations in a needs-based planning framework. Social Science and Medicine. 2020;250. doi:10.1016/j.socscimed.2020.112863
26. Birch S, Kephart G, Tomblin-Murphy G, O'Brien-Pallas L, Alder R, MacKenzie A. Human resources planning and the production of health: A needs-based analytical framework. Canadian Public Policy. 2007;33: S1–S16. doi:10.3138/9R62-Q0V1-L188-1406
27. Laurence CO, Karnon J. Improving the planning of the GP workforce in Australia: a simulation model incorporating work transitions, health need and service usage. Hum Resour Health. 2016;14: 13. doi:10.1186/s12960-016-0110-2
28. MacKenzie A, Tomblin Murphy G, Audas R. A dynamic, multi-professional, needs-based simulation model to inform human resources for health planning. Human Resources for Health. 2019;17. doi:10.1186/s12960-019-0376-2
29. Segal L, Guy S, Leach M, Groves A, Turnbull C, Furber G. A needs-based workforce model to deliver tertiary-level community mental health care for distressed infants, children, and adolescents in South Australia: a mixed-methods study. The Lancet Public Health. 2018;3: e296–e303. doi:10.1016/S2468-2667(18)30075-6
30. Asamani JA, Christmals CD, Reitsma GM. Advancing the Population Needs-based Health Workforce Planning Methodology: A Simulation Model for Country Application. International Journal of Environmental Research and Public Health. 2021;Inprint.
31. Birch S, Kephart G, Murphy GT, O'Brien-Pallas L, Alder R, MacKenzie A. Health human resources planning and the production of health: development of an extended analytical framework for needs-based health human resources planning. Journal of public health

management and practice : JPHMP. 2009;15: S56-61. Available: http://files/5885/wamvalidate.html http://files/5886/wamvalidate.html
32. Grossman M. On the concept of health capital and the demand for health. Journal of Political economy. 1972;80: 223–255. Available: http://www.jstor.org/stable/1830580
33. Lopes MA, Almeida ÁS, Almada-Lobo B. Handling healthcare workforce planning with care: where do we stand? Human resources for health. 2015;13: 38. Available: http://files/3783/s12960-015-0028-0.html
34. Tomblin Murphy G, Kephart G, Lethbridge L, O'Brien-Pallas L, Birch S. Planning for what? Challenging the assumptions of health human resources planning. Health Policy. 2009;92: 225–233. doi:10.1016/j.healthpol.2009.04.001
35. Segal L, Guy S, Leach M, Groves A, Turnbull C, Furber G. A needs-based workforce model to deliver tertiary-level community mental health care for distressed infants, children, and adolescents in South Australia: a mixed-methods study. The Lancet Public Health. 2018;3: e296–e303. doi:10.1016/S2468-2667(18)30075-6
36. MacKenzie A, Tomblin Murphy G, Audas R. A dynamic, multi-professional, needs-based simulation model to inform human resources for health planning. Human Resources for Health. 2019;17. doi:10.1186/s12960-019-0376-2
37. Birch S, Gibson J, McBride A, Munros team. Opportunities for, and implications of, skill mix changes in health care pathways: Pay, productivity and practice variations in a needs-based planning framework. Social Science and Medicine. 2020;250. doi:10.1016/j.socscimed.2020.112863
38. Birch S, Kephart G, Tomblin-Murphy G, O'Brien-Pallas L, Alder R, MacKenzie A. Human resources planning and the production of health: A needs-based analytical framework. Canadian Public Policy. 2007;33: S1–S16. doi:10.3138/9R62-Q0V1-L188-1406
39. MacKenzie A, Tomblin Murphy G, Audas R. A dynamic, multi-professional, needs-based simulation model to inform human resources for health planning. Human Resources for Health. 2019;17: 42. doi:10.1186/s12960-019-0376-2
40. Roberfroid D, Leonard C, Stordeur S. Physician supply forecast: Better than peering in a crystal ball? Human Resources for Health. 2009;7: 1–13. doi:10.1186/1478-4491-7-10
41. World Health Organization. Workload indicators of staffing need - User Manual. 2010 [cited 11 Oct 2015]. Available: http://apps.who.int/iris/handle/10665/44414
42. GSS. Demography: Population Projection. In: Ghana Statistical Service [Internet]. 2020 [cited 14 Nov 2020]. Available: https://statsghana.gov.gh/gssdatadownloadspage.php

43. IHME I of HM and E. Global Burden of Disease Study. In: GHDX [Internet]. 2019 [cited 14 Feb 2021]. Available: http://ghdx.healthdata.org/gbd-2019
44. GHS. Facts and Figures. Accra: Ghana Health Service; 2017.
45. GHS. Health Sector Facts and Figures - 2017. Ghana Health Service, Policy, Planning Monitoring and Evaluation Division; 2018.
46. GSS, GHS, ICF International. Ghana Demographic and Health Survey 2008. Rockville, Maryland, USA: Ghana Statistical Service; 2009. Available: https://dhsprogram.com/publications/publication-FR307-DHS-Final-Reports.cfm
47. GSS, GHS, ICF International. Ghana Demographic and Health Survey 2014. Rockville, Maryland, USA: Ghana Statistical Service; 2015. Available: https://dhsprogram.com/publications/publication-FR307-DHS-Final-Reports.cfm
48. GSS-, GHS-, ICF. Ghana Maternal Health Survey 2007. 2008 [cited 12 Jun 2020]. Available: https://www.dhsprogram.com/publications/publication-fr340-other-final-reports.cfm
49. GSS-, GHS-, ICF. Ghana Maternal Health Survey 2017. 2018 [cited 12 Jun 2020]. Available: https://www.dhsprogram.com/publications/publication-fr340-other-final-reports.cfm
50. MOH. Holistic Assessment of the Health Sector Programme of Work 2013. Accra: Ministry of Health, Ghana; 2014. Available: http://www.moh.gov.gh/wp-content/uploads/2016/02/Holistic-Assessment-Report-June-2014140811072318.pdf
51. MOH. Holistic Assessment of the Health Sector Programme of Work 2015. Accra: Ministry of Health, Ghana; 2016. Available: www.moh.gov.gh
52. MOH. Standard Treatment Guidelines. Accra: Ghana National Drugs Programme (GNDP); 2017. Available: https://www.moh.gov.gh/manuals-guidelines/GHANA-STG-2017-1
53. GHS, MOH. National Reproductive Health Service Policy and Standards. Accra: Ghana Health Service; 2014 p. 135.
54. MOH. National Policy for the Prevention and Control of Chronic Non-Communicable Diseases in Ghana. Ministry of Health, Ghana; 2012. Available: http://www.iccp-portal.org/sites/default/files/plans/national_policy_for_the_prevention_and_control_of_chronic_non-communicable_diseases_in_ghana(1).pdf
55. Ghana AIDS Commission. Ghana National HIV and AIDS Strategic Plan , 2016 - 2020. Accra: Ghana AIDS Commission; 2016 Jul.
56. GHS. Guidelines for the Clinical Management of TB and HIV Co-infection in Ghana. Accra: Ghana Health Service; 2007. Available: https://www.moh.gov.gh/manuals-guidelines/GHS-TB-HIV-Clinical-Mgmt-Guidelines.pdf

57. Asamani JA, d'Almeida SA, Chebere M, Yeboah G, Asabir K, Kyereboah F, et al. Workload Indicators of Staffing Needs (WISN) implementation in Ghana: Technical Report of Staffing Norms for the health Sector of Ghana. Technical Reports. Accra: Ministry of Health, Ghana; 2014. doi:10.13140/2.1.3251.2806
58. Asamani JA, Christmals CD, Reitsma GM. Health service activity standards and standard workloads for primary healthcare in Ghana: A cross-sectional survey of health professionals. South Africa; 2021.
59. Asamani JA, Chebere MM, Barton PM, D'Almeida SA, Odame EA, Oppong R. Forecast of healthcare facilities and health workforce requirements for the public sector in Ghana, 2016–2026. International journal of health policy and management. 2018;7: 1040.
60. Fakhri A, Seyedin H, Daviaud E. A combined approach for estimating health staff requirements. Iranian journal of public health. 2014;43: 107. Available: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4454024/
61. WHO. State of the world's nursing 2020: investing in education, jobs and leadership. 2020.
62. NPP. Leadership of Service: Protecting Our Progress, Transforming Ghana for All - 2020 Manifesto. Accra: New Patriotic Party; 2020.
63. Asamani JA, Ismaila H, Plange A, Ekey VF, Ahmed A-M, Chebere M, et al. The cost of health workforce gaps and inequitable distribution in the Ghana Health Service: An analysis towards evidence-based health workforce planning and management. Human Resources for Health. 2020 [cited 22 Sep 2020]. doi:10.21203/rs.3.rs-21946/v3
64. GHS. Human Resources Information and Management System (HRIMS). Ghana Health Service; 2020. Available: https://www.ghsnewhrims.org/Progress.php

SUPPLEMENTARY MATERIAL

Supplementary material 1: Summary table on level of health evidence (prevalence of diseases and risk factors)

No	Disease, Risk Factor, Public Health Intervention	Type of indicator	Value (Recent Estimate)	Lower Bound	Upper Bound	Year of the recent estimate	Value (Previous estimate)	Year of the previous estimate	Reference	Web-link 1	Web-link 2
1.	Influenza and Pneumonia (general population)	Prevalence	4.0%	4.0%	4.0%	2016	4.0%	2014	(GSS et al., 2015: 113)	https://dhsprogram.com/publications/publication-FR307-DHS-Final-Reports.cfm	
2.	Coronary Heart Disease	Prevalence	17.0%	7.2%	17.0%	2017	7.2%	2005	(Appiah et al., 2017)	https://onlinelibrary.wiley.com/doi/full/10.1002/clc.22753	
3.	Stroke (50+ years)	Prevalence	4.6%	2.6%	4.6%	2016	2.6%	2007	(Sanuade et al., 2019)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6415815/	http://ugspace.ug.edu.gh/handle/123456789/22927
4.	HIV/AIDS (15- 49 years)	Prevalence	1.7%	1.7%	2.0%	2019	1.7%	2014	(Ghana AIDS Commission, 2019; GSS et al., 2015)	https://www.ghanaids.gov.gh/pages/fact-sheets-reports	
5.	Malaria (all ages)	Prevalence	36.0%	36.0%	47.0%	2014	36.0%	2011	(GSS et al., 2015)	https://dhsprogram.com/publications/publication-FR307-DHS-Final-Reports.cfm	
6.	Tuberculosis (All ages)	Prevalence	1.7%			2017	1.7%	2013	(Addo et al., 2019)	https://www.scirp.org/journal/paperinformation.aspx?paperid=93384	http://ghdx.healthdata.org/record/ghana-national-tuberculosis-prevalence-survey-2013
7.	Low Birth Weight (% of live births)	Incidence	10.0%	10.0%	29.6%	2015	10.0%	2014	(Abubakari et al., 2015; GSS et al., 2015)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4681076/	
8.	Road Traffic Accidents (% of motorists)	Incidence	4.0%			2011			(Konlan et al., 2020; Kudebong et al., 2011)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3283097/	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7285403/
9.	Birth Trauma (% of women who gave birth)	Incidence	4.4%	4.4%		2018	4.4%		(Valdes et al., 2018)	https://pubmed.ncbi.nlm.nih.gov/29742294/	
10.	Diarrhoeal diseases (general population)	Prevalence	12.0%	4.0%	12.0%	2014	4.0%	2012	(GSS et al., 2015)	https://www.researchgate.net/publication/313517537_Diarrhoea_morbidity_patterns_in_Central_Region_of_Ghana	
11.	Diabetes Mellitus	Prevalence	6.5%	6.3%	6.5%	2020	6.3%	1998	(Asamoah-Boaheng et al., 2019)	https://academic.oup.com/inthealth/article/11/2/83/5115490	https://www.sciencedirect.com/science/article/abs/pii/S0033350607002053

No	Disease, Risk Factor, Public Health Intervention	Type of indicator	Value (Recent Estimate)	Lower Bound	Upper Bound	Year of the recent estimate	Value (Previous estimate)	Year of the previous estimate	Reference	Web-link 1	Web-link 2
12.	Meningitis	Incidence	0.214%	0.006%	0.214 %	2016			(Domo et al., 2017; Nuoh et al., 2016)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5292117/	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5870784/
13.	Endocrine Disorders	Prevalence	13.1%	2.2%	13.1%	2017			(Sarfo-Kantanka et al., 2017)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5343284/	
14.	Kidney Disease (% diabetics and hypertensives)	Prevalence	13.3%	13.3%	30.0%	2018	13.3%	2015	(Adjei et al., 2018; Ephraim et al., 2015)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4630826/	https://academic.oup.com/ndt/article/33/10/1812/4803283
15.	Violence	Incidence	17.0%	40.0%	33.6%	2016	40.0%	2008	(GSS et al., 2009; Owusu Adjah and Agbemafle, 2016)	https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889-016-3041-x	
16.	Alzheimers & Dementia	Prevalence	19.2%	13.4%	19.2%	2020	13.4%	2010	(Cleret de Langavant et al., 2020)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7453145/	
17.	Fall-related injuries	Incidence	2.6%			2015			(Stewart Williams et al., 2015)	https://bmcmedicine.biomedcentral.com/articles/10.1186/s12916-015-0390-8	
18.	Maternal Conditions	Prevalence	12.0%	12.0%	12.0%	2017	12.0%		(GSS et al., 2018: 117)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
19.	Hypertension	Prevalence	30.0%	19%	55%	2019			(Bosu et al., 2019; Sanuade et al., 2018)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3645150/?report=reader	https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205985
20.	Inflammatory Heart diseases	Prevalence	6.1%			2005			(Akosa and Armah, 2005)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1790827/	
21.	Cervical Cancer (15 – 49 years)	Incidence	0.0264%			2011			(MOH, 2011)		
22.	Asthma (general population)	Prevalence	2.2%			2020			(Aheto et al., 2020)	https://www.researchgate.net/publication/236688411_A_Review_of_Epidemiological_Studies_of_Asthma_in_Ghana	
23.	Breast Cancer	Prevalence	19.7%	19.7%	33.9%	2019			(Laryea et al., 2014)	https://bmccancer.biomedcentral.com/articles/10.1186/s12885-019-5480-0	https://bmccancer.biomedcentral.com/articles/10.1186/1471-2407-14-362
24.	Peptic Ulcer Disease (15+ years)	Prevalence	9.0%	9.0%	24.5%	2019			(Archampong et al., 2016, 2019)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4994551/	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6639557/

No	Disease, Risk Factor, Public Health Intervention	Type of indicator	Value (Recent Estimate)	Lower Bound	Upper Bound	Year of the recent estimate	Value (Previous estimate)	Year of the previous estimate	Reference	Web-link 1	Web-link 2
25.	Skin Disease (general population)	Prevalence	5.1%	2.3%	5.1%	2019			(Ampah et al., 2016; Kaburi et al., 2019; Rosenbaum et al., 2017)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6567626/	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4831816/
26.	Schistosomiasis (school children, 7 -18 years)	Prevalence	10.3%	7.8%	13.3%	2019			(Abaka-Yawson et al., 2019)	https://www.journalajmah.com/index.php/AJMAH/article/view/30128	
27.	Prostate Cancer	Incidence per 100,000	8.8			2013			(O'Brien et al., 2013)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4274943/	https://bmccancer.biomedcentral.com/articles/10.1186/1471-2407-14-362
28.	Hepatitis B (general population)	Prevalence	12.3%	7.2%	14.3%	2019	7.2%	2015	(Abesig et al., 2020; Ofori-Asenso and Agyeman, 2016)	https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0234348	
29.	Drug Use (Adolescents and adults)	Prevalence	5.2%	5.2%	16.2%	2014	5.2%	2012	(Doku et al., 2012; Oppong Asante et al., 2014)	https://www.afro.who.int/health-topics/substance-abuse	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4258041/
30.	Colon-Rectum Cancers (adults)	Prevalence	0.01%			2010			(Dakubo et al., 2010)	http://ugspace.ug.edu.gh/handle/123456789/3635	https://pubmed.ncbi.nlm.nih.gov/20665462/
31.	Epilepsy (general population)	Prevalence	1.00%			2015			(Ae-Ngibise et al., 2015)	https://www.afro.who.int/publications/fight-against-epilepsy-initiative-ghana	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4561141/
32.	Rheumatic Heart Disease (adults)	Prevalence	3.60%			2005			(Akosa and Armah, 2005)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1790827/	
33.	Stomach Cancer (adults)	Prevalence	5.3%					2012	(Laryea et al., 2014)	https://bmccancer.biomedcentral.com/articles/10.1186/1471-2407-14-362	
34.	Oral Cancer	Prevalence	3.5%	3.5%		2020	3.5%	2015	(Owusu-Afriyie et al., 2020)	https://bmcresnotes.biomedcentral.com/articles/10.1186/s13104-020-05233-9	
35.	Other Neoplasms	Prevalence	1.4%			2015			(Stefan, 2015)	https://academic.oup.com/tropej/article/61/3/165/1714119	
36.	Lung Cancers	Prevalence	5.3%					2012	(Laryea et al., 2014)	https://bmccancer.biomedcentral.com/articles/10.1186/1471-2407-14-362	
37.	Alcohol use (15+ years)	Prevalence	2.7%	5.3%	2.7%	2016	5.3%	2010	(World Health Organization et al., 2018)	https://www.who.int/publications/i/item/9789241565639	
38.	Ovary Cancer	Prevalence	11.3%			2012			(Laryea et al., 2014)	https://bmccancer.biomedcentral.com/articles/10.1186/1471-2407-14-362	

No	Disease, Risk Factor, Public Health Intervention	Type of indicator	Value (Recent Estimate)	Lower Bound	Upper Bound	Year of the recent estimate	Value (Previous estimate)	Year of the previous estimate	Reference	Web-link 1	Web-link 2
39.	Sickle Cell Disease	Prevalence	2.0%			2013			(Ohene-Frempong et al., 2008; Piel et al., 2013)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3282939/#:~:text=Sickle%20Cell%20Disease%20%28SCD%29%20is%20a%20significant%20public,Ghanaians%20has%20the%20hemoglobin%20S%20and%2For%20C%20gene.	
40.	Full vaccination coverage (Penta 3 as proxy)	Coverage	93.3%			2016	84.2%	2006	(GHS, 2017)		
41.	Schizophrenia (General population)	Prevalence	1%	0.96%	1%	2005	0.96%	1984	(Addo et al., 2013; Read and Doku, 2012; Saha et al., 2005)		
42.	Depression	Prevalence	11%			2010			(Anand, 2015)		
43.	Children with Stunting	Prevalence	19%	19%	28%	2014	28%	2008	(GSS et al., 2009, 2015)		
44.	Children with wasting	Prevalence	5%	5%	9%	2014	9%	2008	(GSS et al., 2009, 2015)		
45.	Children with Underweight	Prevalence	11%	11%	14%	2014	14%	2008	(GSS et al., 2009, 2015)		
46.	Children with overweight	Prevalence	3%	3%	5%	2014	5%	2008	(GSS et al., 2009, 2015)		
47.	Family planning use (% 15-49 years)	Prevalence (Coverage)	25.0%	25.0%	25.0%	2017	22.0%	2014	(GSS et al., 2008, 2015, 2018)		
48.	Abortion (all forms) - (% of all pregnancies)	Incidence	22.0%	22.0%	22.0%	2017	18.0%	2007	(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
49.	Miscarriage (% of all pregnancies)	Incidence	12.0%	12.0%	12.0%	2017	9.0%	2007	(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
50.	Induced abortion (% of all pregnancies)	Incidence	10.0%	10.0%	10.0%	2017	7.0%		(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
51.	Still births (% of all pregnancies)	Incidence	2.0%	2.0%	2.0%	2017	2.0%		(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	

No	Disease, Risk Factor, Public Health Intervention	Type of indicator	Value (Recent Estimate)	Lower Bound	Upper Bound	Year of the recent estimate	Value (Previous estimate)	Year of the previous estimate	Reference	Web-link 1	Web-link 2
52.	Antenatal care (at least 4 visits)	Coverage	89.0%	89.0%	89.0%	2017	77.0%	2007	(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
53.	Skilled Birth Attendance (% of all pregnancies)	Coverage	79.0%	79.0%	79.0%	2017	55.0%	2007	(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
54.	Spontaneous vaginal delivery (% of all pregnancies)	Incidence	80.0%	80.0%	80.0%	2017	85.0%	2007	(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
55.	Assisted deliveries (instrumental) (% of all pregnancies)	Incidence	4.0%	4.0%	4.0%	2017	3.0%	2007	(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
56.	Indications for caesarean section (% of all deliveries)	Incidence	16.0%	16.0%	16.0%	2017	12.0%	2007	(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
57.	Complications of pregnancy (% of all pregnancies)	Prevalence	19.0%	19.0%	19.0%	2017	17.0%	2007	(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
58.	Haemorrhage (mostly bleeding after childbirth) - (% of all pregnancies)	Incidence	5.7%	5.7%	5.7%	2017	5.0%	2007	(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
59.	Puerperal sepsis (infections usually after childbirth) - (% of all pregnancies)	Prevalence	3.2%	2.0%	5.0%	2015	5.0%	2007	(GSS et al., 2008, 2015, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
60.	Oedema and high blood pressure during pregnancy (pre-eclampsia) - (% of all pregnancies)	Prevalence	2.5%	2.5%	2.5%	2017	2.0%	2007	(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
61.	Eclampsia during delivery (% of all deliveries)	Prevalence	1.9%	1.9%	1.9%	2017	1.0%	2007	(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	

No	Disease, Risk Factor, Public Health Intervention	Type of indicator	Value (Recent Estimate)	Lower Bound	Upper Bound	Year of the recent estimate	Value (Previous estimate)	Year of the previous estimate	Reference	Web-link 1	Web-link 2
62.	Other complications of pregnancy and delivery (% of all deliveries)	Prevalence	4.2%	4.2%	4.2%	2017	9.0%	2007	(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
63.	Postnatal care of the Newborn (% of all live births)	Coverage	84.0%	84.0%	84.0%	2017	60.0%	2007	(GSS et al., 2008, 2018)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
64.	Ectopic pregnancies (% of all pregnancies)	Prevalence	4.0%			2015			(GSS et al., 2015)	https://dhsprogram.com/publications/publication-fr340-other-final-reports.cfm	
65.	Acute Ear Infection	Prevalence	0.88%							https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-020-4950-y	
66.	Acute Urinary Tract Infection	Prevalence	15.9%			2015			(Donkor et al., 2019)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6628945/	
67.	Anaemia in pregnancy	Prevalence	33.0%			2019				https://pubmed.ncbi.nlm.nih.gov/32153953/	
68.	Intestinal Worms	Prevalence	14.3%			2020			(Abaka-Yawson et al., 2020)	https://www.hindawi.com/journals/jeph/2020/9315025/	
69.	Malaria in Pregnancy	Prevalence	2.0%			2019				https://pubmed.ncbi.nlm.nih.gov/32153953/	
70.	Pneumonia	Prevalence	18.4%			2018			(Osei et al., 2018)	https://myjournal.afrijcmr.org/index.php/ajcmr/article/view/28	
71.	Rheumatic and Joint Diseases (50 years +)	Prevalence	16.56%			2007			(Brennan-Olsen et al., 2017)	https://bmcmusculoskeletdisord.biomedcentral.com/articles/10.1186/s12891-017-1624-z	
72.	Septicaemia	Prevalence	18.4%	10.5%	35.2%	2016			(Lester et al., 2020)	https://academic.oup.com/jac/article/75/3/492/5632029	
73.	Typhoid Fever	Prevalence	2.1%	0.1%	2.1%	2016	0.1%	2012	(Fusheini and Gyawu, 2020)	https://www.annalsofglobalhealth.org/articles/10.5334/aogh.2833/	
74.	Upper respiratory tract infection	Prevalence	22%	16.2%	47.3%	2014	12.3%	1993	(Seidu et al., 2019)	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6558297/	

No	Disease, Risk Factor, Public Health Intervention	Type of indicator	Value (Recent Estimate)	Lower Bound	Upper Bound	Year of the recent estimate	Value (Previous estimate)	Year of the previous estimate	Reference	Web-link 1	Web-link 2
75.	Vaginal Discharge	Prevalence	56.4%	56.4%	66%	2019			(Aubyn and Tagoe, 2013; Konadu et al., 2019)	https://bmcpregnancychildbirth.biomedcentral.com/articles/10.1186/s12884-019-2488-z	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4027303/
76.	General Anaemia	Prevalence	42.4%	41.2%	43.9%	2014	58.7%	2008	GSS et al., 2009, 2015)		
77.	Overweight and obesity	Prevalence	30%	19%	55%	2016			(Ofori-Asenso et al., 2016)		
78.	Hernia	Prevalence	10.8%	8%	13.6%	2016			(Ohene-Yeboah et al., 2016)	https://pubmed.ncbi.nlm.nih.gov/26578320/	

5.9 REFERENCES FOR SUPPLEMENTARY MATERIAL

Abaka-Yawson A, Hotorvi C, Oduro EA, et al. (2019) Prevalence and Associated Factors of Urinary Schistosomiasis among Basic School Children in the Akyemansa District, Ghana. *Asian Journal of Medicine and Health*: 1–10. DOI: 10.9734/ajmah/2019/v15i430128.

Abaka-Yawson A, Sosu SQ, Kwadzokpui PK, et al. (2020) Prevalence and Determinants of Intestinal Parasitic Infections among Pregnant Women Receiving Antenatal Care in Kasoa Polyclinic, Ghana. Hindawi. DOI: https://doi.org/10.1155/2020/9315025.

Abesig J, Chen Y, Wang H, et al. (2020) Prevalence of viral hepatitis B in Ghana between 2015 and 2019: A systematic review and meta-analysis. *PLOS ONE* 15(6). Public Library of Science: e0234348. DOI: 10.1371/journal.pone.0234348.

Abubakari A, Kynast-Wolf G and Jahn A (2015) Prevalence of abnormal birth weight and related factors in Northern region, Ghana. *BMC Pregnancy and Childbirth* 15. DOI: 10.1186/s12884-015-0790-y.

Addo KK, Addo SO, Bonsu C, et al. (2019) Population-Based Tuberculosis Disease Prevalence Survey in Ghana: The Role and Lessons Learnt from the Laboratory. *Journal of Tuberculosis Research* 7(2). 2. Scientific Research Publishing: 95–108. DOI: 10.4236/jtr.2019.72009.

Addo R, Nonvignon J and Aikins M (2013) Household costs of mental health care in Ghana. *J Ment Health Policy Econ* 16(4): 151–9.

Adjei DN, Stronks K, Adu D, et al. (2018) Chronic kidney disease burden among African migrants in three European countries and in urban and rural Ghana: the RODAM cross-sectional study. *Nephrology Dialysis Transplantation* 33(10): 1812–1822. DOI: 10.1093/ndt/gfx347.

Ae-Ngibise KA, Akpalu B, Ngugi A, et al. (2015) Prevalence and risk factors for Active Convulsive Epilepsy in Kintampo, Ghana. *The Pan African Medical Journal* 21. DOI: 10.11604/pamj.2015.21.29.6084.

Aheto JMK, Udofia EA, Kallson E, et al. (2020) Prevalence, socio-demographic and environmental determinants of asthma in 4621 Ghanaian adults: Evidence from Wave 2 of the World Health Organization's study on global AGEing and adult health. *PLOS ONE* 15(12). Public Library of Science: e0243642. DOI: 10.1371/journal.pone.0243642.

Akosa A and Armah H (2005) Cardiomegaly in Ghana: An Autopsy Study. *Ghana Medical Journal* 39(4): 122–127. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1790827/ (accessed 3 January 2021).

Ampah KA, Asare P, Binnah DD-G, et al. (2016) Burden and Historical Trend of Buruli Ulcer Prevalence in Selected Communities along the Offin River of Ghana. *PLoS Neglected Tropical Diseases* 10(4). DOI: 10.1371/journal.pntd.0004603.

Anand A (2015) Understanding Depression among Older Adults in Six Low-Middle Income Countries using WHO-SAGE Survey. *Behavioral Health* 1.

Appiah LT, Sarfo FS, Agyemang C, et al. (2017) Current trends in admissions and outcomes of cardiac diseases in Ghana. *Clinical Cardiology* 40(10): 783–788. DOI: https://doi.org/10.1002/clc.22753.

Archampong TN, Asmah RH, Richards CJ, et al. (2019) Gastro-duodenal disease in Africa: Literature review and clinical data from Accra, Ghana. *World Journal of Gastroenterology* 25(26): 3344–3358. DOI: 10.3748/wjg.v25.i26.3344.

Archampong TNA, Asmah RH, Wiredu EK, et al. (2016) Factors associated with gastro-duodenal disease in patients undergoing upper GI endoscopy at the Korle-Bu Teaching Hospital, Accra, Ghana. *African Health Sciences* 16(2): 611–619. DOI: 10.4314/ahs.v16i2.32.

Asamoah-Boaheng M, Sarfo-Kantanka O, Tuffour AB, et al. (2019) Prevalence and risk factors for diabetes mellitus among adults in Ghana: a systematic review and meta-analysis. *International Health* 11(2): 83–92. DOI: 10.1093/inthealth/ihy067.

Aubyn GB and Tagoe DNA (2013) Prevalence of vaginal infections and associated lifestyles of students in the university of Cape Coast, Ghana. *Asian Pacific Journal of Tropical Disease* 3(4): 267–270. DOI: 10.1016/S2222-1808(13)60068-7.

Bosu WK, Reilly ST, Aheto JMK, et al. (2019) Hypertension in older adults in Africa: A systematic review and meta-analysis. *PloS one* 14(4). Public Library of Science.

Brennan-Olsen SL, Cook S, Leech MT, et al. (2017) Prevalence of arthritis according to age, sex and socioeconomic status in six low and middle income countries: analysis of data from the

World Health Organization study on global AGEing and adult health (SAGE) Wave 1. *BMC Musculoskeletal Disorders* 18(1): 271. DOI: 10.1186/s12891-017-1624-z.

Cleret de Langavant L, Bayen E, Bachoud-Lévi A, et al. (2020) Approximating dementia prevalence in population-based surveys of aging worldwide: An unsupervised machine learning approach. *Alzheimer's & Dementia : Translational Research & Clinical Interventions* 6(1). DOI: 10.1002/trc2.12074.

Dakubo JC, Naaeder SB, Tettey Y, et al. (2010) Colorectal carcinoma: an update of current trends in Accra. *West African Journal of Medicine* 29(3): 178–183. DOI: 10.4314/wajm.v29i3.68218.

Doku D, Koivusilta L and Rimpelä A (2012) Socioeconomic differences in alcohol and drug use among Ghanaian adolescents. *Addictive Behaviors* 37(3): 357–360. DOI: 10.1016/j.addbeh.2011.11.020.

Domo NR, Nuolabong C, Nyarko KM, et al. (2017) Uncommon mixed outbreak of pneumococcal and meningococcal meningitis in Jirapa District, Upper West Region, Ghana, 2016. *Ghana Medical Journal* 51(4): 149–155. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5870784/ (accessed 3 January 2021).

Donkor ES, Horlortu PZ, Dayie NT, et al. (2019) Community acquired urinary tract infections among adults in Accra, Ghana. *Infection and Drug Resistance* 12: 2059–2067. DOI: 10.2147/IDR.S204880.

Ephraim RK, Biekpe S, Sakyi SA, et al. (2015) Prevalence of chronic kidney disease among the high risk population in South-Western Ghana; a cross sectional study. *Canadian Journal of Kidney Health and Disease* 2. DOI: 10.1186/s40697-015-0076-3.

Fusheini A and Gyawu SK (2020) Prevalence of Typhoid and Paratyphoid Fever in the Hohoe Municipality of the Volta Region, Ghana: A Five-Year Retrospective Trend Analysis. *Annals of Global Health* 86(1). 1. Ubiquity Press: 111. DOI: 10.5334/aogh.2833.

Ghana AIDS Commission (2019) 2019 National HIV Estimates and Projection. Accra. Available at: https://www.ghanaids.gov.gh/pages/fact-sheets-reports (accessed 3 January 2021).

GHS (2017) *Facts and Figures*. Accra: Ghana Health Service.

GSS, GHS, and ICF International (2009) *Ghana Demographic and Health Survey 2008.* Survey. Rockville, Maryland, USA: Ghana Statistical Service. Available at: https://dhsprogram.com/publications/publication-FR307-DHS-Final-Reports.cfm.

GSS, GHS, and ICF International (2015) *Ghana Demographic and Health Survey 2014.* Survey. Rockville, Maryland, USA: Ghana Statistical Service. Available at: https://dhsprogram.com/publications/publication-FR307-DHS-Final-Reports.cfm.

GSS GSS-, GHS GHS- and ICF (2008) Ghana Maternal Health Survey 2007. Available at: https://www.dhsprogram.com/publications/publication-fr340-other-final-reports.cfm (accessed 12 June 2020).

GSS GSS-, GHS GHS- and ICF (2018) Ghana Maternal Health Survey 2017. Available at: https://www.dhsprogram.com/publications/publication-fr340-other-final-reports.cfm (accessed 12 June 2020).

Kaburi BB, Ameme DK, Adu-Asumah G, et al. (2019) Outbreak of scabies among preschool children, Accra, Ghana, 2017. *BMC Public Health* 19. DOI: 10.1186/s12889-019-7085-6.

Konadu DG, Owusu-Ofori A, Yidana Z, et al. (2019) Prevalence of vulvovaginal candidiasis, bacterial vaginosis and trichomoniasis in pregnant women attending antenatal clinic in the middle belt of Ghana. *BMC Pregnancy and Childbirth* 19(1): 341. DOI: 10.1186/s12884-019-2488-z.

Konlan Kennedy Diema, Doat AR, Mohammed I, et al. (2020) Prevalence and Pattern of Road Traffic Accidents among Commercial Motorcyclists in the Central Tongu District, Ghana. *The Scientific World Journal* 2020. DOI: 10.1155/2020/9493718.

Kudebong M, Wurapa F, Nonvignon J, et al. (2011) Economic Burden of Motorcycle Accidents in Northern Ghana. *Ghana Medical Journal* 45(4): 135–142. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3283097/ (accessed 3 January 2021).

Laryea DO, Awuah B, Amoako YA, et al. (2014) Cancer incidence in Ghana, 2012: evidence from a population-based cancer registry. *BMC Cancer* 14(1): 362. DOI: 10.1186/1471-2407-14-362.

Lester R, Musicha P, van Ginneken N, et al. (2020) Prevalence and outcome of bloodstream infections due to third-generation cephalosporin-resistant Enterobacteriaceae in sub-Saharan Africa: a systematic review. *Journal of Antimicrobial Chemotherapy* 75(3): 492–507. DOI: 10.1093/jac/dkz464.

MOH (2011) *National Strategy for Cancer Control in Ghana, 2012 - 2016*. Accra: Ministry of Health, Ghana.

Nuoh RD, Nyarko KM, Nortey P, et al. (2016) Review of meningitis surveillance data, upper West Region, Ghana 2009-2013. *The Pan African Medical Journal* 25(Suppl 1). DOI: 10.11604/pamj.supp.2016.25.1.6180.

O'Brien KS, Soliman AS, Awuah B, et al. (2013) Establishing Effective Registration Systems in Resource-Limited Settings: Cancer Registration in Kumasi, Ghana. *Journal of registry management* 40(2): 70–77. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4274943/ (accessed 3 January 2021).

Ofori-Asenso R and Agyeman AA (2016) Hepatitis B in Ghana: a systematic review & meta-analysis of prevalence studies (1995-2015). *BMC Infectious Diseases* 16(1): 130. DOI: 10.1186/s12879-016-1467-5.

Ofori-Asenso R, Agyeman AA, Laar A, et al. (2016) Overweight and obesity epidemic in Ghana—a systematic review and meta-analysis. *BMC Public Health* 16(1): 1239. DOI: 10.1186/s12889-016-3901-4.

Ohene-Frempong K, Oduro J, Tetteh H, et al. (2008) SCREENING NEWBORNS FOR SICKLE CELL DISEASE IN GHANA. *Pediatrics* 121(Supplement 2). Am Acad Pediatrics: S120–S121.

Ohene-Yeboah M, Beard JH, Frimpong-Twumasi B, et al. (2016) Prevalence of Inguinal Hernia in Adult Men in the Ashanti Region of Ghana. *World Journal of Surgery* 40(4): 806–812. DOI: 10.1007/s00268-015-3335-7.

Oppong Asante K, Meyer-Weitz A and Petersen I (2014) Substance use and risky sexual behaviours among street connected children and youth in Accra, Ghana. *Substance Abuse Treatment, Prevention, and Policy* 9. DOI: 10.1186/1747-597X-9-45.

Osei FA, Mensah KA, Ansong D, et al. (2018) Prevalence of pneumonia and risk factors of pneumonia mortality among children under five years. *African Journal of Current Medical Research* 2(2). 2. DOI: 10.31191/afrijcmr.v2i2.28.

Owusu Adjah ES and Agbemafle I (2016) Determinants of domestic violence against women in Ghana. *BMC Public Health* 16(1): 368. DOI: 10.1186/s12889-016-3041-x.

Owusu-Afriyie O, Owiredu WKBA, Oti AA, et al. (2020) Survival rates of head and neck cancers in Ghana: a retrospective study at the Komfo Anokye Teaching Hospital. *BMC Research Notes* 13(1): 392. DOI: 10.1186/s13104-020-05233-9.

Piel FB, Patil AP, Howes RE, et al. (2013) Global epidemiology of sickle haemoglobin in neonates: a contemporary geostatistical model-based map and population estimates. *The Lancet* 381(9861): 142–151. DOI: 10.1016/S0140-6736(12)61229-X.

Read UM and Doku VCK (2012) Mental health research in Ghana: A literature review. *Ghana Medical Journal* 46(2). 2: 29–38. DOI: 10.4314/gmj.v46i2.

Rosenbaum BE, Klein R, Hagan PG, et al. (2017) Dermatology in Ghana: a retrospective review of skin disease at the Korle Bu Teaching Hospital Dermatology Clinic. *The Pan African Medical Journal* 26. DOI: 10.11604/pamj.2017.26.125.10954.

Saha S, Chant D, Welham J, et al. (2005) A Systematic Review of the Prevalence of Schizophrenia. *PLOS Medicine* 2(5). Public Library of Science: e141. DOI: 10.1371/journal.pmed.0020141.

Sanuade OA, Boatemaa S and Kushitor MK (2018) Hypertension prevalence, awareness, treatment and control in Ghanaian population: Evidence from the Ghana demographic and health survey. *PLOS ONE* 13(11). Public Library of Science: e0205985. DOI: 10.1371/journal.pone.0205985.

Sanuade OA, Dodoo FN-A, Koram K, et al. (2019) Prevalence and correlates of stroke among older adults in Ghana: Evidence from the Study on Global AGEing and adult health (SAGE). *PLoS ONE* 14(3). DOI: 10.1371/journal.pone.0212623.

Sarfo-Kantanka O, Sarfo FS, Ansah EO, et al. (2017) Spectrum of Endocrine Disorders in Central Ghana. *International Journal of Endocrinology* 2017. DOI: 10.1155/2017/5470731.

Seidu A-A, Ameyaw EK, Ahinkorah BO, et al. (2019) Ecological zone and symptoms of acute respiratory infection among children under five in Ghana: 1993–2014. *SSM - Population Health* 8. DOI: 10.1016/j.ssmph.2019.100414.

Stefan DC (2015) Patterns of Distribution of Childhood Cancer in Africa. *Journal of Tropical Pediatrics* 61(3): 165–173. DOI: 10.1093/tropej/fmv005.

Stewart Williams J, Kowal P, Hestekin H, et al. (2015) Prevalence, risk factors and disability associated with fall-related injury in older adults in low- and middle-incomecountries: results from the WHO Study on global AGEing and adult health (SAGE). *BMC Medicine* 13(1): 147. DOI: 10.1186/s12916-015-0390-8.

Valdes V, Adongo PB, Nwameme AU, et al. (2018) Risk factors for self-reported postpartum hemorrhage in Ga East, Ghana. *International Journal of Gynaecology and Obstetrics: The Official Organ of the International Federation of Gynaecology and Obstetrics* 142(2): 201–206. DOI: 10.1002/ijgo.12523.

World Health Organization, Management of Substance Abuse Team, and World Health Organization (2018) *Global Status Report on Alcohol and Health 2018.* Available at: http://www.who.int/substance_abuse/publications/global_alcohol_report/en/ (accessed 3 January 2021).

CHAPTER 6:
SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

6.1 INTRODUCTION

Globally, health policy objectives have shifted towards ensuring universal coverage of essential health services to populations based on their health needs – and eliminating non-need barriers to accessing health care. Attaining this aspiration is intricately linked with having an adequate number of health professionals who are competent and well-skilled to respond to the health needs of the population. Thus, any population's health needs should be the basis for how many, how, and what the health professionals should be educated on, not the other way around (WHO, 2013). However, weak and asynchronous health workforce planning has resulted in insufficient, erratic, and sometimes misaligned investments in the production, employment, and retention of health professionals (Araujo et al., 2016; Pozo-Martin et al., 2017).

The purpose of this study was divided into three parts to contribute to addressing the abovementioned challenges from theoretical, methodological, and planning perspectives. The first was to synthesise the typology, methodological steps, and gaps of the need-based health workforce planning approach from published analytical applications. In the second instance, the study sought to build on the evidence derived from the synthesis to develop a need-based health professions planning model that links planning the number of health professionals to train in a country to the population health needs of the country. Thirdly, the model was applied in Ghana's PHC context to inform the planning of health professions education and employment investments.

Based on the abovementioned research purpose, the specific objectives of the study were as follows:

1. To explore the extent to which need-based models have been used in health workforce planning in countries and synthesise the methodological considerations for need-based health workforce modelling through a systematic scoping review.

2. To develop a need-based health workforce planning model, based on the scoping review, that incorporates the population's level of health (disease burden), demographics, service package, and the standard time it takes health professionals to deliver the services.

3. To establish a standard time that health professionals spend in their main service delivery activities in PHC settings in Ghana.

4. To apply the need-based planning model to forecast the need and supply of health professionals to establish current and future gaps for PHC in Ghana.

5. To estimate the health professions education investment required to fill the need-based gaps for PHC in Ghana.

6. To estimate the employment investment required to absorb the health professionals needed to be trained for PHC in Ghana.

This last chapter presents a summary and conclusions of the chapters, followed by the theoretical and methodological contributions this study has made to the need-based approach to planning health professions educations and employment. Additionally, the main limitations and recommendations arising from the study are presented from research, policy and planning perspectives.

6.2 SUMMARY

This section summarises the different chapters of the thesis, focusing on the main elements and/or findings in the chapters as evidence of reaching the research objectives stated above.

Chapter 1 of the thesis highlighted the global health policy context and the role of the health workforce. The chapter underscored the weaknesses in health workforce planning across countries that have culminated in substantial misalignment between the number and mix of health professionals trained from the health professions education institutions on the one hand and the population's health and health system needs on the other hand (see Chapter 1, section 1.1, paragraphs 3 and 4). Additionally, the chapter also highlighted the overall approach to planning for health professionals by providing a synopsis of available literature on the various approaches for determining the needs and supply of health professions, including their main assumptions, merits, and demerits (see Chapter 1, section 1.2.2 and Table 1). The literature gaps identified laid the study's motivation to develop health workforce planning tools and approaches that directly align production from health professions education institutions and investment for their employment with population health needs. The particular case of health workforce mismatches in Ghana was outlined to motivate the empirical application of the need-based planning model developed in Ghana's context (see Chapter 1, section 1.3, paragraphs 1-6). Chapter 1 also contained the specific research aim and objectives with subsequent research questions (section 1.5). The research paradigm and methodology were explained (sections 1.6 and 1.7) to clarify the philosophical rationale, interest and process of the research in addition to the information provided in the articles.

Chapters 2 to 5 addressed the study's specific objectives through research articles published in peer-reviewed scientific journals.

Chapter 2 contains the first article, titled, The needs-based health workforce planning method: a systematic scoping review of analytical applications (Asamani et al., 2021a), published in the *Health Policy and Planning*. The article examined the extent to which need-based models have been empirically applied in health workforce planning, characterised the typology of such analytical applications, identified inherent methodological gaps in the existing models, and synthesised the key methodological considerations for advancing the need-based health workforce modelling to be responsive to real-life planning in countries. In the systematic scoping review, 25 peer-reviewed papers out of a possible 719 retrieved from the systematic search met the predefined and stringent inclusion criteria and were thus included in the synthesis (see Chapter 2, section 2.3.1 and 2.3.5, Figure 1 and Table 1).

The analysis showed an increased uptake of the needs-based health workforce modelling in the literature (as 84% of the studies were published between 2010 and 2020), but mostly from high-income countries – mainly Canada, Australia, England, and the United States of America (USA). Only 16% (n = 4) of the published empirical applications of need-based models focused on low- and middle-income countries, three of which were conducted in sub-Saharan Africa. Most of the need-based analyses (36%) focused on specific disease areas or programmes and sub-national levels (20%). Only a small proportion (8%) of the empirical need-based applications focused on the national health system across several disease areas or programmes.

The article (presented in Chapter 2) highlighted three main weaknesses or methodological gaps in the existing need-based models (Chapter 2, section 2.4.3.3). First, 52% of the published empirical applications were static models, as they were unable to make future projections about the health workforce requirements due to constraints in predicting epidemiological trends over time. All 48% of the studies that made future projections implicitly assumed that the current levels of population health (or disease burden/epidemiology) will remain constant over time – an assumption that is counterintuitive with known epidemiological evolution and trends in most countries.

Secondly, it was also identified that whilst most need-based models took into account the productivity of health professionals, there was no uniform approach to doing so, resulting in a wide diversity in how productivity measures were incorporated into need-based health workforce models (Chapter 2, section 2.4.4.3.2).

Finally, the existing models did not consider catalytic or support activities performed by health professionals that may not be direct patient care interventions but are very necessary for facilitating the direct patient care interventions. This must be considered a limitation as it is known that most health professionals spend a significant proportion of their working time on support or catalytic activities (Namaganda et al., 2015). To advance the need-based approach to planning for health professionals, the first article synthesised six critical methodological considerations which are summarised in Chapter 2, section 2.4.4.

Research question 1: To what extent have need-based models been used in health workforce planning in countries and what are the main methodological considerations? was fully answered in article 1.

The findings in this article laid the foundation of evidence upon which a comprehensive need-based health workforce planning model was developed (in the second article presented in Chapter 3).

The second article (contained in Chapter 3), which is titled, Advancing the population needs-based health workforce planning methodology: a simulation tool for country application (Asamani et al., 2021b), was published in the Global Health section of the *International Journal of Environmental Research and Public Health*. Building on the previous works with the view of addressing the identified methodological gaps and increasing the ease of policy-oriented applications of the need-based approach, the second article presents a comprehensive conceptual model of need-based health workforce planning and a step-by-step analytical framework to operationalise the conceptual model (Chapter 3, section 3.3). It addresses the main limitations identified in the previous models and implements the methodological considerations synthesised in the first article (Chapter 2). The conceptual model and the accompanying analytical framework (or the set of computational formulae) were built into an open-access simulation tool in Microsoft® Excel with the view of facilitating real-life health workforce analysis and planning in countries.

Two fundamental sets of mathematical sub-models underpin the tool. The first sub-model is made up of a chain of equations that quantifies the supply of health professionals. It took into account the existing stock, anticipated inflows from training institutions and immigration on the one hand, and on the other hand, attrition or exits from the stock of health professionals through retirements, deaths, career change, and emigration (Chapter 3, section 3.4.1.1, equation 1). The second sub-model also has a series of equations that estimates the need-based requirements for health professionals, taking into account (a) population size and demographics, (b) level of health or disease burden (epidemiology), (c) health service package/interventions that have been planned or are otherwise necessary to address the disease burden, and (d) the standard workload for health professionals for the different types of interventions (professional standards of productivity) (Chapter 3, section 3.4.1.2). The model then integrates the supply-side and need-side analyses by comparing them to establish the gaps in absolute and relative terms and the cost implications for health workforce policy and strategy. In illustrating how the tool works, the article contains an applied example using secondary data on maternal and new-born care in Ghana (Chapter 3, section 3.4.3). Version 1.2 of the tool, which was published alongside the peer-reviewed article as supplementary material, is downloadable from: https://www.mdpi.com/1660-4601/18/4/2113/s1.

Research question 2: Can a workforce planning model be developed to incorporate the population's level of health (disease burden), demographics, service package and the standard time it takes health professionals to deliver the services? was fully answered in article 2.

Chapter 4 presents the third article, Health service activity standards and standard workloads for primary healthcare in Ghana: a cross-sectional survey of health professionals (Asamani et al., 2021c). The article was published in the health policy section of *Healthcare*. The objective was to elicit the professional standard time that health professionals use to deliver various health service interventions and to calculate the corresponding standard workloads within each health service intervention that one professional can perform in a given year (professional standards of productivity). This empirical evidence was required to enable the application of the model developed in article 2 (Chapter 3) in Ghana's context. Amongst a nationally representative sample of 503 health professionals across eight broad health professions, the standard time and workloads were estimated for various health interventions performed by the health professionals within the PHC settings in Ghana. For example, it was estimated that general practitioners spend 16 minutes per outpatient consultation, which worked out to an annual standard workload of 6,030 outpatient consultations per year if a general practitioner dedicates all their 96,480 minutes of available working time per year to outpatient consultations (Chapter 4, section 4.4.2.1). The article also identified statistically significant variations in the professional practices between primary hospitals and health centres/polyclinics (Chapter 4, section 4.4.4). In about 19% (12 out of 67) of health service activities performed across the eight health professional groups, there was a statistically significant difference in the time spent by the health professionals between health centres/polyclinics and district/primary hospital settings. The differences were associated with having higher workload levels without commensurate staffing and the availability of equipment. In particular, the activity standards of physician assistants (medical) and that of conducting deliveries by midwives had the biggest difference between health centres/polyclinics and district/primary hospitals settings.

Comparing the professional standards (activity standards) derived from the study with that of the results of the workload indicators of staffing need (WISN) assessment conducted in Ghana in 2014 revealed vast similarities in the standard time for several of the interventions across the occupational groups (Chapter 4, section 4.5, paragraphs 4-6). The article concluded that using cross-sectional surveys to establish professional standards was not substantially different from the consensus-based professional standards advocated for in the WISN methodology, and could be suitable as a benchmark for health professionals' productivity for need-based health workforce planning. These professional standards, which were used as a proxy for productivity, were used as inputs alongside data on the other parameters of the need-based model, which were triangulated from various sources to empirically apply the model developed in this study (model presented in Chapter 3) for Ghana's PHC context.

Research question 3: How much time does it take health professionals to undertake their main service delivery tasks in PHC settings in Ghana? was, therefore, answered in article 3.

Chapter 5 presents the fourth and final article, titled, Modelling the supply and need for health professionals for primary health care in Ghana: implications for health professions education and employment planning, submitted to *PLOS ONE*. In this article, the need-based requirements viz-a-viz the supply of 11 health professionals were estimated, and the gaps determined towards planning the intake into health professions education institutions (Chapter 5, section 5.4.3, Table 4 and section 5.4.4, Table 5). The article further presents the cost implications and the required investments over 15 years to address the gaps identified. To estimate the population need for health professionals in Ghana, the following data on the following parameters were systematically triangulated and inputted into the need-based model developed in article two (see Chapter 3): (a) population size and demographics, which was obtained from the Ghana Statistical Service (GSS); (b) disease burden (prevalence rates of diseases and risk factors), obtained through a desk review of national surveys, reports, administrative or routine health service data, published studies, and unpublished research documents; (c) health service interventions (planned or otherwise needed) that address the identified disease burden were extracted from existing national policies, strategies, and standard treatment guidelines; and (d) the standard workload that health professionals can undertake per year for each of the health service interventions was empirically derived through a cross-sectional study described in article three (details in Chapter 4).

On the supply side, the data was triangulated from the following sources: (a) the existing stock and capacity of the educational institutions for the health professionals was taken from the respective professional regulatory councils, (b) income and attrition data was collected from the Ghana Health Service and Ministry of Health, and (c) the annual cost of training was taken from public and private universities.

The article presents detailed findings on the number of health professionals needed in Ghana's PHC, the anticipated supply of those health professionals, the gaps that must be filled through training from health professions education institutions, and the investments required in health professions education and employment (Chapter 5, sections 5.4.3, 5.4.4, 5.4.5, Tables 4-6 and Figure 3). The article demonstrated that at baseline (in 2020), Ghana needed an aggregate of 221,593 health professionals across 11 categories, which were likely to increase by 84% within ten years to about 407,897 in 2030 and further increase by 21.4% to 495,273 by 2035. Thus, the need for health professionals was projected to grow at an annual rate of 5.5% (range: 3.2-10.7%). On the supply side, it was estimated that in 2020, Ghana's stock of the 11 categories of health professionals included in the study was 148,390, with an estimated net growth rate of 5.6% (range: 2.7 - 11.4%). Holding the factors of health workforce attrition/outflows and inflows constant, the aggregate stock of the health professionals was estimated to increase by 92.7% to 285,900 in 2030, and a further 16.7% increase to about 333,770 in 2035 (see Chapter 5, sections 5.4.1- 5.4.3, Tables 2-4).

The gap analysis revealed that Ghana's aggregate supply of health professionals was roughly 67% of the requirements based on the population’s health needs. Addressing the need-based shortage required scaling up the production of the 11 categories of health professionals by 161,502 by 2035. There were, however, nuances and peculiarities across the various categories of health professionals. For example, whilst the evidence showed a compelling need to increase the production of pharmacy technicians by 7.5-folds, general practitioners by 110%, and general nurses by 55%, that of midwives pointed to a need to scale down production by 15%. This component of article 4 answered research question 4: How many PHC professionals need to be trained in Ghana to optimally meet the population's health needs over the next 15 years?

The article demonstrated that the overall investment required in training to fill the identified need-based gaps was estimated to be almost US$480.39 million within 15 years from both the public and private sectors (see Chapter 5, section 5.4.5, Figure 3). This component of article 4 answered research question 5: How much investment will be required in health professions education to meet the future need for PHC professionals in Ghana?

The additional investment required for employing and sustaining the jobs of those to be trained as well as maintaining the existing health professionals was estimated to be almost US$ 2.374 billion in 2035. However, without these investments from both public and private sectors, there will be a 33% shortage of essential health professionals coupled with at least US$44.58 million losses to the inappropriate skills mix by 2035 (see Chapter 5, section 5.4.6, Table 6). This component of article 4 also answered research question 6: What employment-related investments will be required to absorb the health professionals needed to be trained for primary health care?

Therefore, research questions 4, 5 and 6 were all answered in article 4 (Chapter 5).

6.3 OVERALL CONCLUSION

The four related papers presented in the thesis (in Chapters 2-5) sought to synthesise available evidence on the extent of use and methodological considerations in need-based health workforce planning. The evidence synthesised was used to develop a need-based health professions planning model that links the number of health professionals to train with the population health needs of a country and that can forecast the need, supply, number needed to train, and the associated investments required for health professionals in Ghana's PHC system. The study had six specific objectives (as outlined above). This section draws the study's main conclusions, linking how each of the study objectives was achieved.

6.3.1 Research objective 1:

The first research objective sought to conduct a scoping review to explore the extent to which need-based models have been used in health workforce planning in countries and synthesise the methodological considerations for advancing the need-based health workforce modelling. This objective was fully accomplished in article 1 (Chapter 2), in which a systematic scoping review demonstrated that despite the growing popularity of the need-based approach as a conceptually valid planning approach for health professionals in the context of UHC aspirations, its use in actual policy and planning was limited partly due to a lack of open-access tools, methodological gaps, and diversity in analytical approaches. The typology of empirical applications of the need-based approach was characterised as macrosimulation versus microsimulation, within which analysts used either current demand to weight the population health needs (also termed 'needs-informed demand analysis') or the full population health needs (termed 'complete need-based analysis') to determine the health workforce requirements. The article identified the main limitations or weaknesses in the existing need-based models and outlined the key methodological considerations and steps for systematically developing a fit-for-purpose need-based model in planning for health professionals.

6.3.2 Research objective 2:

The study's second objective was to develop a need-based health workforce planning model that incorporates the population's level of health (or disease burden), demographics, health service interventions (or package of health services), and the professional standards or standard time it takes health professionals to deliver the services. The second article (presented in Chapter 3) built on the previous article, using the methodological steps identified through the systematic scoping review to develop a comprehensive need-based model with an accompanying end-user tool in Microsoft® excel. The model, which addresses the main limitations in existing models and allows for complete need-based macrosimulation within national, sub-national, or programmatic contexts, was published alongside the methodology paper as an open-access tool to enhance its broader uptake in the scientific and policy communities. To demonstrate the methodological value, data requirements, and policy relevance of the model, an applied example was included in the methodology paper for midwives, obstetricians and gynaecologists in the context of maternal and new-born care in Ghana. Thus, objective two was addressed comprehensively in the second article and fully achieved.

6.3.3 Research objective 3:

The third objective sought to establish a standard time that health professionals spend in their main service delivery activities in PHC settings in Ghana. In the third article (Chapter four), this objective was fully achieved through a nationally representative cross-sectional survey of 503 health professionals across eight health professions. The article estimated the standard time health professionals spent in performing different health service interventions and statistically compared any differences in the standard time between hospitals and health centres/polyclinics within the PHC setting in Ghana. Based on the estimated standard time, the standard workloads (the amount of work that one health professional can perform with a given health service intervention in a year) were determined for all the health professionals under study.

6.3.4 Research objective 4:

The fourth article addressed objectives 4-6 of the study. Objective 4 sought to forecast the need and supply of health professionals to establish current and future gaps for PHC in Ghana. In addressing this objective, the study (in article 4) projected the need, supply, and gaps that must be filled through scaling up health professions education for all 11 categories of health professionals included in the study. In summary, the article demonstrates that the need for health professionals in Ghana's PHC was 221,593 in 2020, which could increase at a rate of between 3.3% and 10.7% (average of 5.5%) per annum to reach an aggregate need for 495,273 health professionals by 2035. On the supply side, the existing stock was estimated to be 148,390 in 2020, which was anticipated to grow at a net rate of 2.7-11.4% per annum (taking into account attrition and inflows) and could reach an aggregate supply of 333,770 by 2035. Comparing the need and supply revealed an aggregate need-based shortage of 73,203 (or a 33% aggregate need-based shortage) in 2020 which may increase to 161,502 by 2035, requiring a scaling up in health professions education to fill the need-based gap. Details of the need, supply, and gaps (number needed to train) for each of the 11 categories of health professionals are provided in the fourth article in Chapter 5.

6.3.5 Research objective 5:

Research objective 5 sought to estimate the amount of investment required in health professions education to fill the need-based gaps for PHC in Ghana, which was fully achieved in the fourth article. In aggregate terms, the article demonstrated that by 2035, the cost of training to fill the aggregate need-based shortage of 161,502 health professionals across the 11 categories of health professionals by 2035 is estimated to be US$480.39 million, of which 28.8% (US$ 138.59 million) is required for the training of registered general nurses; 15.4% (US$74.10 million) for the training of general practitioners, and US$ 15.33 million (3.2%) for pharmacy technicians among others.

6.3.6 Research objective 6:

Finally, research objective 6 sought to estimate the investment cost for employment necessary to absorb the health professionals in the education pipeline and for filling the need-based shortage identified (those needed to be trained) for PHC in Ghana. In addressing this research objective, the study (in article 4) estimated the investment required to fill the need-based requirements for each of the 11 health professionals and the cost of employing the anticipated supply. In summary, it was estimated in the article that an average of US$1.762 billion per annum (and up to US$2.374 billion in 2035) must be planned for employing and sustaining the jobs of the existing health professionals as well as for the additional health professionals to be trained to fill the need-based shortages or gaps. Without making the needed investments and adjustments in the training intake for the health professional in line with the needs would result in a 33% shortage of essential health professionals coupled with at least US$44.58 million in losses per annum to the inappropriate skill mix. The adverse technical impact on interprofessional team compositions and, eventually, the quality of health care has not been evaluated in this study but could be dire.

From the above, it is evident that all the research objectives in their entirety were adequately achieved through the series of the four publications in which a pragmatic, sequential, multi-method approach was employed.

6.4 CONTRIBUTIONS OF THE STUDY

Based on the main conclusions drawn from the study, this section highlights the contributions of the study in advancing the theory and methodology of need-based health workforce planning and how it could shape policy discourse in Ghana and elsewhere.

6.4.1 Contribution to theory

In advancing the theory of need-based health workforce planning, this study is the first to clearly define and characterise the typology of need-based health workforce models. Macrosimulation and microsimulation were two types of empirical approaches identified in the application of need-based modelling (reported in the first published article, which is presented in Chapter 2). The need-based macrosimulation models use population-level parameters and data sources, and the scope of analysis usually takes a health system perspective at the national or subnational level. In contrast, the study identified that need-based microsimulation models focus on modelling the nuances of individual patient characteristics receiving specific treatment or care and translating it into health workforce requirements. Hence, these models use patient-level data, and their scope of analysis tends to take a programmatic perspective of planning (rather than health system level).

Another fundamental theoretical distinction between need-based models was 'needs-informed demand models' versus 'complete need-based models'. In the 'needs-informed demand analysis', also known as 'demand-weighted' needs-based analysis, the population need for health services is analysed and the results are weighted by currently observed levels of utilisation; the 'weighted or adjusted need' is then translated into health workforce requirements using an agreed measure of the productivity of health professionals. By contrast, in 'complete need-based models', the population's need for health services is analysed and, without adjustment for observed levels of service utilisation, is translated into health workforce requirements using an agreed measure of the productivity of health professionals. While these concepts have been mentioned only loosely in previous literature, they have been systematically characterised and presented in this study for the first time.

Although different need-based theorists agree on the core concepts, the operationalisation of the approach in real-life applications has been riddled with less standardisation, divergence, and a lack of checklists for examining rigour. In consolidating various propositions in the literature, the study also proposed a 'good practice' checklist for assessing the rigour and appropriateness of need-based health workforce analysis (or modelling). Details of the checklist and its application to assess empirical studies in this thesis are shown in Chapter 2.

The study provided the first synthesis from peer-reviewed empirical studies – six main steps in need-based modelling for health professionals. These are (1) defining the scope; (2) analysing the population health service needs; (3) translating the evidence-based service requirements into health workforce requirement; (4) exploring resource implications that stem from a gap analysis; (5) conducting sensitivity analyses including scenarios; and (6) conducting model validation statistically and through stakeholder feedback. The constituent sub-steps are described in detail in Chapter 2 (article one).

6.4.2 Contribution to the need-based methodology for health workforce planning

The study advanced the need-based modelling methodology in several ways. First, even though it is well acknowledged in the need-based modelling literature that populations' levels of health or disease burden change over time and the expected future changes in need should be reflected in the health workforce requirements (Birch et al., 2020; Murphy, 2001; O'Brien-Pallas et al., 2001; Tomblin Murphy et al., 2009), a previous study among high-income countries found ". . . *no health workforce plans that modelled the impacts of changes in population needs on HRH [Human Resources for Health] requirements*" (Murphy et al., 2016a, p. 6). Similarly, this study demonstrated (in Chapter 2) that 48% of the empirical applications reviewed could not make projections into the future and that those that made long-range projections made implicitly assumed that the baseline levels of health (health status or disease burden) of the population would remain constant throughout the horizon of the analysis (Asamani et al., 2021b). In effect, the future need for health professionals in those models only changed monotonously in line with changing population size characteristics and inadvertently ignoring evolution in the disease burden or level of health. To address this important methodological limitation, in this study an instantaneous rate of change in the disease burden or level of health was incorporated into the analytical model and in the accompanying planning tool (Asamani et al., 2021a). In this novelty, the prevalence or incidence rates of disease or risk factors affecting the given population are taken from comparable sources for two or more different time points, and the instantaneous rate of change is estimated using standard statistical formulae (Briggs et al., 2006). The future disease burden or level of health of the population is then assumed to evolve along with the estimated instantaneous rate of change. With this, the population's need for health services, which informs the need for health professionals, can be dynamically modelled to account for the changing population characteristics and evolving level of health or disease burden. This contribution to the need-based modelling methodology is described in detail, including the statistical formulae in article 2 (Chapter 3 of the thesis).

Furthermore, although all need-based health workforce theorists agree on the importance of incorporating some proxy measure of the productivity of health professionals in quantifying the needed health professionals from the population's need for health services, there has not been consensus on what proxy measure of productivity is intuitively relevant, is easy to measure, and how to measure it. This has resulted in significant divergence in the methods used to incorporate productivity into need-based health workforce analysis and planning. In addressing this methodological lacuna, this study (in articles 2 and 3) proposed the adoption of the concept of 'standard workload' as a proxy measure of health professionals' productivity. Standard workload – which is defined as the amount of work in one health service intervention that a health professional can perform in one year if they are dedicated to performing only that intervention (WHO, 2016, 2010) – is a widely known concept used in WISN analysis and one of the utilisation-based health workforce planning tools (Ravhengani & Mtshali, 2017; WHO, 2016, 2010). To calculate the standard workload, two important parameters are important: (a) the available working time of health professionals, which is the amount of time (in minutes or hours) that a health professional has to do their work in one year, taking into account all non-working time in the year (such as leave, public holidays, weekends, etc.); (b) professional standards (also termed as 'activity standards' or 'service standards') for delivering each health service intervention, defined as the time it would take reasonably well-trained health professional to accomplish a service intervention or task in the circumstances of the given country. The standard workload for any health service intervention is calculated by dividing the available working time of the concerned health professional by the activity standards.

Finally, previous need-based models largely did not consider the catalytic or support activities that are undertaken by health workers, which may not be direct patient care interventions but are critical in ensuring the smooth delivery of direct patient care interventions. Some studies have shown that these indirect, catalytic, or support activities could, in some cases, consume up to 50% or more of a health professional's working time (Namaganda et al., 2015) and must be accounted for in estimating the need. Some previous health workforce models conceptualised it as a supply-side issue and adjusted the workforce stock by calculating available clinical focus time for health professionals (MacKenzie et al., 2019). This study, however, demonstrates that it is more a need-side issue; hence, explicitly incorporating the number of health professionals required to cover support or catalytic functions in the need for health professionals is imperative. Thus, the study contributed to addressing the conceptual and methodological issue by demonstrating (in article 2) how to appropriately account for catalytic or support activities of health professionals in the need-side of health workforce planning.

6.4.3 Contribution to the practice of health professionals, policy and planning

Despite the instinctive appeal of the need-based approach and its apparent alignment with the global aspiration for UHC (Segal et al., 2018), its uptake in real-life policy and planning processes within countries has been shown to be limited (Murphy et al., 2016b; Safarishahrbijari, 2018). This study found that the limited policy-oriented application of the need-based approach in health workforce planning was, primarily, due to a lack of ready-for-use open-access tools coupled with the relatively high burden of data requirements. To address the policy uptake challenge related to the lack of open-access tools, this study contributed by translating the conceptual and empirical model into an easy-to-use open-access planning and simulation tool, of which version 1.2 was published alongside the methodology paper, and is freely downloadable from: https://www.mdpi.com/1660-4601/18/4/2113/s1. An updated version, 1.3 (with improvements in user experience but no material difference in the methods), was submitted alongside the fourth article for publication. The tool was purposefully built in Microsoft® Excel as opposed to other specialised software or platforms to increase its potential for use even in resource-limiting settings where access to specialised software may be constrained. Following the self-explanatory step-by-step instructions in the tool, end-users require only beginner to intermediate knowledge of Excel spreadsheets to use it successfully once the fundamental principles of need-based health workforce planning are understood and data is available.

The professional standards for health service interventions, together with the established standard workloads for the various health professionals, could also contribute as benchmarks for upholding professional standards and quality of care in the context of Ghana. Finally, the estimates of the need and supply of health professionals, the gaps to be filled through training, and the required investments therefore have profound implications for health workforce policy and planning in Ghana to address the mismatches (see recommendations).

6.5 LIMITATIONS OF THE STUDY

Each of the published articles had a section discussing its specific limitations in terms of methodology, scope, and findings. However, a few limitations are still worth noting in the thesis as a whole.

First, the systematic scoping review and evidence synthesis component of the thesis (article 1) did not include grey literature such as government planning documents and unpublished research, as it focused on only filtered evidence published in peer-reviewed scientific journals. Hence, some nuances of the political and policy processes in countries during planning using the need-based approach could have been missed in the study. Thus, the study provides the requisite technical processes of sound and fit-for-purpose need-based analysis, which can be contextualised within a given country's political and policy processes.

Also, the model connects population disease burden (or level of health) and demographics to the health system plans in terms of the health service package (interventions necessary to address the disease burden) as well as the standard workload (or a measure of productivity) of the health professionals appropriately skilled to deliver the service interventions that directly address the population's health needs. Inherently, health workers whose functions are also essential but supportive in nature because they do not address specific population health needs (or health problems), such as accountants, administrators, biostatisticians, etc., cannot be directly analysed using the model.

Furthermore, while there are over a hundred cadres of health professionals in the health sector of Ghana, this study focused on just 11 professional groups across eight broad professions in the PHC setting to demonstrate the methodological value and policy relevance of the need-based approach to the health workforce planning. Thus, the analysis may not provide a comprehensive picture of the supply and need of all health professionals in Ghana and hence should be deemed as the tip of the iceberg of the potential health workforce gaps and mismatches in Ghana. However, it is the first of its kind in demonstrating how a need-based approach could be used to link health workforce planning to health professions education capacity planning across health professions, especially in Ghana's context.

Additionally, the estimated cost of training was conducted using only tuition fees, hence excluding the cost of additional infrastructure, training aids, and equipment such as computers, mannequins etc. that may be needed, as the assessment of the requirements for these educational infrastructure and equipment were outside the scope of the study.

Finally, the general planning process is complex and requires a multi-sectoral and multi-stakeholder approach for consensus-building and resource allocation decisions. However, these policy dialogue processes, which are resource-intensive, were beyond the scope of the study.

6.6 RECOMMENDATIONS

6.6.1 Further research

Although this study provides a wealth of theoretical, methodological, and practical insights and a novel advancement of the need-based approach for planning and training the optimal quantity of health professionals in a manner that directly responds to the population's health needs, some grey areas remain and are worthy of further research:

(a) There is the need to consolidate evidence to quantify potential fiscal and financial space for investing in health professions education and employment. This is important in order to incorporate financial space and economic feasibility analyses into the need-based model for testing the affordability of the need-based estimates, as issues relating to implicitly ignoring the ability to afford to remain the main sources of criticisms against need-based planning for health professionals.

(b) Further research on how population health needs can be more directly accounted for in competency-based curricula of health professions education institutions is not only imperative but urgent. If the need for health professionals and training these are planned in alignment with that of the population health needs, it is also important that the training curricula be related directly to the nuances of population health need (disease burden, risk factors and demographics trends) in the country. The WHO's guidance on transforming and scaling up health professionals' education and training buttresses this call (WHO, 2013).

6.6.2 Planning health professions education and employment in Ghana

Over the last two decades, Ghana invested heavily in health workforce production and employment, which is widely acknowledged. However, this study identified significant mismatches between the need for health professionals and the available supply (now and in the future). Some of the policy and strategic actions to address the identified gaps may lie outside the remit of the Ministry of Health alone and requires a concerted multi-stakeholder effort that includes the Ministry of Health, Ministry of Education, Health Professions Education Institutions, Ministry of Finance, Ministry of Labour, National Development Planning Commission, Professional Regulatory Bodies, private health partners, development partners, and labour unions. Effectively engaging these multi-sectoral policy actors will require further contextualisation of the evidence to take all shades of perspectives into account. To achieve this, the following may be worth considering:

(a) Conduct a comprehensive health labour market analysis that takes into account the multi-sectoral policy actors' perspectives to understand the size and levers of demand for health professionals viz-a-viz the estimated need in Ghana's health system and the knock-on effect of the demand for health professions education.

(b) Examine the available and potential fiscal and financial space for health workforce investment viz-a-viz the estimated need-based investments required in training and employment based on needs.

(c) Triangulate the available evidence and use it to develop a multi-sectoral long-term health workforce investment plan that addresses need-based health professions education, employment, retention, and regulation. Doing so will strengthen the annual Human Resources for Health forum as a stock-taking and accountability platform for planning the annual intake into health professions education institutions in line with the need-based analysis, which would be imperative.

6.6.3 Ministries of Health in other countries and International Health Institutions

The need-based approach to health service planning, especially health workforce planning, has been regarded as the most conceptually valid and consistent approach for addressing equity concerns towards the aspiration for UHC.

(a) Ministries of Health should build capacity for and adopt the need-based approach as their national planning framework or tool.

(b) International health institutions should invest in advancing need-based health workforce planning tools and guidelines and support countries to build capacity to use them in their planning processes.

(c) Countries should use the need-based approach to link the planning for health professions' education capacity with the country's population health needs.

6.7 REFERENCES

Araujo, E. C., Evans, T. G., & Maeda, A. (2016). Using economic analysis in health workforce policy-making. *Oxford Review of Economic Policy*, *32*(1), 41–63. https://doi.org/10.1093/oxrep/grw001

Asamani, J. A., Christmals, C. D., & Reitsma, G. M. (2021a). Advancing the Population Needs-Based Health Workforce Planning Methodology: A Simulation Tool for Country Application. *International Journal of Environmental Research and Public Health*, *18*(4), 2113. https://doi.org/10.3390/ijerph18042113

Asamani, J. A., Christmals, C. D., & Reitsma, G. M. (2021b). The needs-based health workforce planning method: A systematic scoping review of analytical applications. *Health Policy and Planning*, *czab022*. https://doi.org/10.1093/heapol/czab022

Asamani, J. A., Christmals, C. D., & Reitsma, G. M. (2021c). Health Service Activity Standards and Standard Workloads for Primary Healthcare in Ghana: A Cross-Sectional Survey of Health Professionals. *Healthcare*, *9*(3), 332. https://doi.org/10.3390/healthcare9030332

Birch, S., Gibson, J., McBride, A., & Munros, T. (2020). Opportunities for, and implications of, skill mix changes in health care pathways: Pay, productivity and practice variations in a needs-based planning framework. *Social Science and Medicine*, *250*. https://doi.org/10.1016/j.socscimed.2020.112863

Briggs, A., Sculpher, M., & Claxton, K. (2006). *Decision modelling for health economic evaluation*. OUP Oxford. https://books.google.co.uk/books?hl=en&lr=&id=NuYRBAAAQBAJ&oi=fnd&pg=PP1&dq=modelling+in+economic+evvaluation&ots=JJQb__Qzmh&sig=sJ-50UQZ5k-xedFyGeQHmWXJatQ

MacKenzie, A., Tomblin Murphy, G., & Audas, R. (2019). A dynamic, multi-professional, needs-based simulation model to inform human resources for health planning. *Human Resources for Health*, *17*(1), 1–13. https://doi.org/10.1186/s12960-019-0376-2

Murphy, G. T. (2001). Methodological issues in health human resource planning: Cataloguing assumptions and controlling for variables in needs-based modelling. *The Canadian Journal of*

Nursing Research = Revue Canadienne de Recherche En Sciences Infirmières, *33*(4), 51–70. http://files/5535/wamvalidate.html

Murphy, G. T., Birch, S., MacKenzie, A., Bradish, S., & Rose, A. E. (2016a). A synthesis of recent analyses of human resources for health requirements and labour market dynamics in high-income OECD countries. *Human Resources for Health*, *14*(1), 59. http://files/3788/s12960-016-0155-2.html

Murphy, G. T., Birch, S., MacKenzie, A., Bradish, S., & Rose, A. E. (2016b). A synthesis of recent analyses of human resources for health requirements and labour market dynamics in high-income OECD countries. *Human Resources for Health*, *14*(1), 59. http://files/3788/s12960-016-0155-2.html

Namaganda, G., Oketcho, V., Maniple, E., & Viadro, C. (2015). Making the transition to workload-based staffing: Using the Workload Indicators of Staffing Need method in Uganda. *Human Resources for Health*, *13*(1), 1–11.

O'Brien-Pallas, L., Baumann, A., Donner, G., Murphy, G. T., Lochhaas-Gerlach, J., & Luba, M. (2001). Forecasting models for human resources in health care. *Journal of Advanced Nursing*, *33*(1), 120–129. https://doi.org/10.1046/j.1365-2648.2001.01645.x

Pozo-Martin, F., Nove, A., Lopes, S. C., Campbell, J., Buchan, J., Dussault, G., Kunjumen, T., Cometto, G., & Siyam, A. (2017). Health workforce metrics pre- and post-2015: A stimulus to public policy and planning. *Human Resources for Health*, *15*(1). Scopus. https://doi.org/10.1186/s12960-017-0190-7

Ravhengani, N. M., & Mtshali, N. G. (2017). The Views of Health Workforce Managers on the Implementation of Workload Indicators of Staffing Need (WISN) Method in Primary Healthcare Settings in South Africa. *International Journal of Studies in Nursing*, *3*(1), 132. https://doi.org/10.20849/ijsn.v3i1.354

Safarishahrbijari, A. (2018). Workforce forecasting models: A systematic review. *Journal of Forecasting*, *37*(7), 739–753. https://doi.org/10.1002/for.2541

Segal, L., Guy, S., Leach, M., Groves, A., Turnbull, C., & Furber, G. (2018). A needs-based workforce model to deliver tertiary-level community mental health care for distressed infants, children, and adolescents in South Australia: A mixed-methods study. *The Lancet Public Health*, *3*(6), e296–e303. https://doi.org/10.1016/S2468-2667(18)30075-6

Tomblin Murphy, G., Kephart, G., Lethbridge, L., O'Brien-Pallas, L., & Birch, S. (2009). Planning for what? Challenging the assumptions of health human resources planning. *Health Policy*, *92*(2–3), 225–233. https://doi.org/10.1016/j.healthpol.2009.04.001

WHO. (2016). Workload Indicators of Staffing Need (WISN): Selected Country Implementation Experiences. *Human Resources for Health Observer Series*, *15*. http://apps.who.int/iris/bitstream/10665/205943/1/9789241510059_eng.pdf

World Health Organization. (2010). *Workload indicators of staffing need—User Manual*. http://apps.who.int/iris/handle/10665/44414

World Health Organization. (2013). *Transforming and scaling up health professionals' education and training: World Health Organization guidelines 2013.* World Health Organization, Geneva, Switzerland. http://www.ncbi.nlm.nih.gov/books/NBK298953/

ANNEXURES

ANNEXURE A: SCIENTIFIC COMMITTEE APPROVAL

NWU® | HPEd Scientific committee

Recommendation of the HPEd Scientific Committee to the NWU-HREC

Scientific Committee	**Name**	Health Professions Education Scientific Committee	**Discipline**	Health Professions Education (PhD research)
	Research Entity	CHPE	**Contact Person**	Prof Gerda Reitsma
	Faculty	Health Sciences	**E-mail**	Gerda.reitsma@nwu.ac.za
Title of the study:	Modelling Primary Health Care workforce needs for health professions education and employment investment planning in Ghana			
Researchers involved in the study:	Asamani, J.A			
Executive summary of the research:	The policy objective of most countries is to ensure universal health coverage of essential health services for people of all ages. The attainment of these goals is intricately linked to having a responsive primary health care (PHC) system underpinned by an adequate number of multidisciplinary health professionals with appropriate skill mix who are well-trained, motivated, committed, and supported to perform. However, many countries are facing a significant shortage of health professionals amidst the inequitable distribution of the existing ones. This has been partly traced to weak planning that has led to sub-optimal production from health professions education institutions and inadequate investments in employment and retention. In particular, the empirical literature shows significant gaps in linking the number of health professionals needed to be trained to the population's health needs. This gap has also resulted in a weak investment case for health professions education and employment, hence attracting less than optimum investments which in turn exacerbate existing health workforce shortages. This doctoral study will develop and apply a predictive model to estimate the health professionals needed to address the population's health needs at the PHC level in Ghana, and also address the investment needed in health professions education and employment to optimally address the current and future gaps. Leaning on pragmatism, a mixed model design will be adopted for the proposed study to allow for the use of different complementary sub-designs to address the research objectives. The study will consist of four (4) phases. The first phase will be a scoping review of applied health workforce planning models in low- and middle-income countries to provide methodological insights for the modelling. The second phase will be a cross-sectional study of PHC professionals to ascertain the time it takes them to perform their main health service delivery tasks at the PHC level. The result of these two phases will be used in the third phase to develop and apply a predictive model to estimate the health professionals needed for PHC in Ghana and the associated investment required in health professions education and employment to fill future gaps. The fourth and final phase will consist of statistical validation of the model. The study will provide an improved approach to health workforce planning and facilitate investment case analysis in health professions education and employment. Four publications may be produced from the study. A thesis will be submitted to the Faculty of Health Sciences of the North-West University, Potchefstroom in fulfilment of the requirements for the degree Doctor of Philosophy in Health Professions Education.			
Potential risk level for human participants:	No risk	☐	Motivate: This research includes the observation of participants	
	Minimal risk	☐		
	Medium risk	☒		
	High risk	☐		

Potential risk level for children and incapacitated adults:	No risk	☐	Motivate: n/a
	No more than minimal risk of harm	☐	
	Greater than minimal risk with the prospect of direct benefit	☐	
	Greater than minimal risk with no direct benefit	☐	
Recommendation for the ethics committee	Expedited review	☐	Motivate: Full review due to the observation of participants as sample.
	Full review	☒	
	Exempted from review	☐	
Any additional comments	Motivate: Click here to enter text.		
Committee members present during the review	**Members joining the online meeting:**		
	Dr Alwiena Blighaut (Reviewer)		
	Prof Lanthé Kruger (Reviewer)		
	Prof Siedine Coetzee (Reviewer)		
	Me Paula Jardim (HPEd Scientific Committee secretary)		
	Dr Yolande Heymans (Acting Chair)		
Date of review	2020/05/08		

Heymans

Signature of Acting Chairperson

Date: 2020/06/09

ANNEXURE B: ETHICS APPROVAL – GHS ETHICS REVIEW COMMITTEE

GHANA HEALTH SERVICE ETHICS REVIEW COMMITTEE

In case of reply the number and date of this Letter should be quoted.

MyRef. GHS/RDD/ERC/Admin/App /20/332
Your Ref. No.

Research & Development Division
Ghana Health Service
P. O. Box MB 190
Accra.
Digital Address: GA-050-3303
Tel: +233-0302-960628
Fax + 233-0302-685424
Mob + 233-050-3539896
Email: ethics.research@ghsmail.org
24th August, 2020

James Avoka Asamani
World Health Organisation, Regional Office for Africa
Harare, Zimbabwe

The Ghana Health Service Ethics Review Committee has reviewed and given approval for the implementation of your Study Protocol.

GHS-ERC Number	**GHS-ERC017/07/20**
Study Title	Modelling Primary Health Care Workforce Needs towards Health Professions Education and Employment Investment Planning in Ghana
Approval Date	24th August, 2020
Expiry Date	23rd August, 2021
GHS-ERC Decision	**Approved**

This approval requires the following from the Principal Investigator

- Submission of yearly progress report of the study to the Ethics Review Committee (ERC)
- Renewal of ethical approval if the study lasts for more than 12 months,
- Reporting of all serious adverse events related to this study to the ERC within three days verbally and seven days in writing.
- Submission of a final report **after completion** of the study
- Informing ERC if study cannot be implemented or is discontinued and reasons why
- Informing the ERC and your sponsor (where applicable) before any publication of the research findings.

You are kindly advised to adhere to the national guidelines or protocols on the prevention of COVID -19

Please note that any modification of the study without ERC approval of the amendment is invalid.

The ERC may observe or cause to be observed procedures and records of the study during and after implementation.

Kindly quote the protocol identification number in all future correspondence in relation to this approved protocol

SIGNED...... ....
Professor Moses Aikins
(GHS-ERC Vice Chairperson)

Cc: The Director, Research & Development Division, Ghana Health Service, Accra

ANNEXURE C: PERMISSION TO COMMENCE STUDY FROM GHANA HEALTH SERVICE

In case of reply the number
and the date of this
letter should be quoted

My Ref. No. GHS/DGS/G.2

Your Ref. :

OUR CORE VALUES

- Professionalism
- Discipline
- Team Work
- Integrity
- Innovation and Excellence
- People-Centred Service

Your Health - Our Concern

GHANA HEALTH SERVICE
PRIVATE MAIL BAG
MINISTRIES
ACCRA

GPS ADDRESS: GA-143-4609

Tel. 0302-662014
FAX: 0302-670329
E-mail: dg@ghsmail.org

1st September, 2020

JAMES AVOKA ASAMANI
WORLD HEALTH ORGANISATION
HARARE, ZIMBABWE

Dear Mr Asamani,

PERMISSION TO CONDUCT A DOCTORAL RESEARCH

Study title: modelling primary health care workforce needs towards health professions education and employment investment planning in Ghana

Ethics approval number: GHS-ERC017/07/20

Your application dated 1st September 2020 requesting for permission to conduct the above-mentioned doctoral study refers.

I have the pleasure to inform you that permission has been granted to commence your study in line with the approved protocol and conditions set out in the ethics approval letter by the Ghana Health Service Ethics Review Committee (GHSERC) dated 24th August 2020.

You are kindly reminded to share the final report of the study with the Ghana Health Service upon completion of the study.

Sincerely,

DR PATRICK KUMA ABOAGYE
DIRECTOR-GENERAL

CC:
Director, Health Research Division, GHS
Director, Human Resources Division, GHS
Director, Centre for Health Professions Education, NWU

ANNEXURE D: INTRODUCTORY LETTER FROM GHANA HEALTH SERVICE

In case of reply the number
and the date of this
letter should be quoted

My Ref. No. GHS/DGS/G.2

Your Ref. :

OUR CORE VALUES

- Professionalism
- Discipline
- Team Work
- Integrity
- Innovation and Excellence
- People-Centred Service

GHANA HEALTH SERVICE
PRIVATE MAIL BAG
MINISTRIES
ACCRA

GPS ADDRESS: GA-143-4609

Tel. 0302-662014
FAX: 0302-670329
E-mail: dg@ghsmail.org

1st September, 2020

As Per Distribution

Dear Sir/Madam,

INTRODUCTORY LETTER

Study title: modelling primary health care workforce needs towards health professions education and employment investment planning in Ghana

Ethics approval number: GHS-ERC017/07/20

This serves to introduce to you; Mr James Avoka Asamani, who has been granted ethics approval by the Ghana Health Service Ethics Review Committee (ethics number GHS-ERC017/07/20) to conduct doctoral research on the above-mentioned topic. As part of the study, he has been granted permission to survey health professionals working with Ghana Health Service at the Primary Healthcare level to estimate the average time they spend in delivering various service delivery tasks. This is intended to be used in the development of a needs-based planning model for determining the optimal health professionals needed to be trained and employed.

It will be appreciated if you could accord him and his research assistants the necessary courtesies and support in the conduct of this study which the findings may be used as part of the evidence for policies and strategies towards our push for universal health coverage.

Thank you.

DR PATRICK KUMA ABOAGYE
DIRECTOR-GENERAL

DISTRIBUTION:

- The Regional Director of Health Services, BER/GAR/UER
- Heads of sampled health facilities

CC:
The Directors, HRD/RDD
Director, Centre for Health Professions Education, NWU

ANNEXURE E: ETHICS APPROVAL – NWU- HREC

NWU®
NORTH-WEST UNIVERSITY
NOORDWES-UNIVERSITEIT
YUNIBESITI YA BOKONE-BOPHIRIMA

Private Bag X1290, Potchefstroom
South Africa 2520

Tel: 086 016 9698
Web: http://www.nwu.ac.za/

North-West University Health Research Ethics Committee (NWU-HREC)

Tel: 018 299-1206
Email: Ethics-HRECApply@nwu.ac.za (for human studies)

18 October 2020

ETHICS APPROVAL LETTER OF STUDY

Based on approval by the North-West University Health Research Ethics Committee (NWU-HREC) on 18/10/2020, the NWU-HREC hereby approves your study as indicated below. This implies that the NWU-HREC grants its permission that, provided the general and specific conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: Modelling primary health care workforce needs towards health professions education and employment investment planning in Ghana
Principal Investigator/Study Supervisor/Researcher: Dr C Christmals
Student: JA Asamani - 37205722

Ethics number:

N	W	U	-	0	0	4	1	6	-	2	0	-	A	1
Institution				Study Number						Year			Status	

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Application Type: Single study
Commencement date: 18/10/2020
Expiry date: 31/10/2021

Risk: **Minimal**

Approval of the study is provided for a year, after which continuation of the study is dependent on receipt and review of an annual monitoring report and the concomitant issuing of a letter of continuation. A monitoring report is due at the end of October annually until completion.

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, the following general terms and conditions will apply:

- *The principal investigator/study supervisor/researcher must report in the prescribed format to the NWU-HREC:*
  - *annually on the monitoring of the study, whereby a letter of continuation will be provided annually, and upon completion of the study; and*
  - *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.*
- *The approval applies strictly to the proposal as stipulated in the application form. Should any amendments to the proposal be deemed necessary during the course of the study, the principal investigator/study supervisor/researcher must apply for approval of these amendments at the NWU-HREC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*
- *Annually a number of studies may be randomly selected for active monitoring.*
- *The date of approval indicates the first date that the study may be started.*
- *In the interest of ethical responsibility, the NWU-HREC reserves the right to:*
  - *request access to any information or data at any time during the course or after completion of the study;*

- *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process;*
- *withdraw or postpone approval if:*
  - *any unethical principles or practices of the study are revealed or suspected;*
  - *it becomes apparent that any relevant information was withheld from the NWU-HREC or that information has been false or misrepresented;*
  - *submission of the annual monitoring report, the required amendments, or reporting of adverse events or incidents was not done in a timely manner and accurately; and/or*
  - *new institutional rules, national legislation or international conventions deem it necessary.*
- *NWU-HREC can be contacted for further information via Ethics-HRECApply@nwu.ac.za or 018 299 1206*

Special conditions of the research approval due to the COVID-19 pandemic:

Please note: Due to the nature of the study i.e. (face-to-face data collection, via survey, of health care professionals in primary health clinics in Ghana), this study will be able to proceed during the current alert level, following receipt of the approval letter. No additional COVID-19 restrictions have been placed on the study other than that indicated by the researcher, except that the researcher must ensure that before proceeding with the study that all research team members have reviewed the North-West University COVID-19 Occupational Health and Safety Standard Operating Procedure.

Special in process conditions of the research for approval (if applicable):

a. Please provide the NWU-HREC with copies of the goodwill permission letters from the Regional Directors of Health Services of the three regions to be included in the study.
b. Please provide the NWU-HREC with copies of the goodwill permission letters from the primary health clinics to be included in the study, granting access to the facilities.

As the study progresses the aforementioned conditions should be submitted to Ethics-HRECProcess@nwu.ac.za with a cover letter with a specific subject title indicating "Outstanding documents for approval: NWU-XXXXX-XX-XX." The letter should include the title of the approved study, the names of the researchers involved, that the documents are being submitted as part of the conditions of the approval set by the NWU-HREC, the nature of the document i.e. which condition is being fulfilled and any further explanation to clarify the submission.

The *e-mail*, to which you attach the documents that you send, should have a *specific subject line* indicating the nature of the submission e.g. "Outstanding documents for approval: NWU-XXXXX-XX-XX". The e-mail should indicate the nature of the document being sent. This submission will be handled via the expedited process.

The NWU-HREC would like to remain at your service and wishes you well with your study. Please do not hesitate to contact the NWU-HREC for any further enquiries or requests for assistance.

Yours sincerely,

Digitally signed by Prof Petra Bester
Date: 2020.10.19 11:33:31 +02'00'

Chairperson NWU-HREC

Current details:(23239522) G:\My Drive\9. Research and Postgraduate Education\9.1.5.4 Templates\9.1.5.4.2_NWU-HREC_EAL.docm
20 August 2019
File Reference: 9.1.5.4.2

ANNEXURE F: INFORMED CONSENT FORM

Private Bag X1290, Potchefstroom
South Africa 2520
Tel: +2718 299-1111/2222
Fax: +2718 299-4910
Web: http://www.nwu.ac.za

NWU-HREC Approval Date: 2020.10.18 18:21:56 +02'00'

HREC Stamp

INFORMED CONSENT DOCUMENTATION FOR HEALTH PROFESSIONALS WORKING IN PRIMARY HEALTHCARE SETTINGS TO COMPLETE A QUESTIONNAIRE

TITLE OF THE RESEARCH STUDY: Modelling primary health care workforce needs towards health professions education and employment investment planning in Ghana

ETHICS REFERENCE NUMBERS: NWU-00416-20-A1

PRINCIPAL INVESTIGATOR: JAMES AVOKA ASAMANI

POST GRADUATE STUDENT: 37205722

ADDRESS: WORLD HEALTH ORGANISATION, HARARE, ZIMBABWE

CONTACT NUMBER:+263772216883/+233209409458

You are being invited to take part in a **research study** that forms part of Doctoral study. Please take some time to read the information presented here, which will explain the details of this study. Please ask the researcher or person explaining the research to you any questions about any part of this study that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research is about and how you might be involved. Also, your participation is **entirely voluntary** and you are free to say no to participate. If you say no, this will not affect you negatively in any way whatsoever. You are also free to withdraw from the study at any point, even if you do agree to take part now.

This study has been approved by the **Health Research Ethics Committee of the Faculty of Health Sciences of the North-West University (NWU-00416-20-A1)** and will be conducted according to the ethical guidelines and principles applicable to this study. It might be necessary for the research ethics committee members or other relevant people to inspect the research records.

What is this research study all about?

- *We plan to estimate the amount of time health professionals like you usually spend in delivering services to each client. This is intended to be used to make estimations about the optimal number of health professionals needed to be trained as well as the investments needed to fill any gaps.*

- *This study will be conducted in Greater Accra, Bono East and Upper East Regions of Ghana and will be done by experienced health researchers trained in health professions education and planning; with extensive experience in collecting and analysing health workforce data. A total of 591 health professionals will be included in this study.*

Why have you been invited to participate?

- *You have been invited to be part of this research because you are a fulltime employee of the Ghana Health Service working in a primary health care setting, and have been doing so for more than one (1) year.*
- *You will unfortunately not be able to take part in this research you are on internship, national service or on relieving duties assignment. Also, if are performing managerial or other duties different from their core professional training for more than half of your daily time, you will not be able to participate in this study.*

What will be expected of you?

- *If you agree to participate, you will be expected to fill a one-time electronic questionnaire which contains questions about your background such as age, sex, rank and qualification(s) as well as professional information. The questionnaire also contains activities typically performed by members of your profession in which you will be expected objectively indicate the amount of time it averagely takes you to complete the listed activities. Completing the questionnaire may take you 20 to 25 minutes. Your responses to the questionnaire will be collected electronically but if you do not have enough time now you can answer it at your earliest convenience.*
- *You reserve the sole right to withdraw from the study or withhold your consent at any point in time and I assure you that your exercise of this right has no punitive consequence whatsoever.*

Will you gain anything from taking part in this research?

- *There will be no direct gains for you in the study.*
- *The indirect gains of the study are that, the findings may be used for improved health workforce planning leading to better staffing in the future which could result in lower workload levels and reduced burnouts for members of your profession.*

Are there risks involved in you taking part in this research and what will be done to prevent them?

- *There are no anticipated risk of physical harm associated with this study. The questionnaire requires a recall of the average time you usually spend on each patient for the services you deliver. If you experience significant discomfort with this, you may terminate your participation and/or be offered free psychological support and counselling.*

How will we protect your confidentiality and who will see your findings?

- *Anonymity of your responses will be protected by ensuring that your consent form (which is paper based) will not be in any way linked to your responses on the questionnaire which will be electronically collected. Your privacy will be respected by allowing you to complete the electronic questionnaire by yourself. Your results will be aggregated with others and without personal identifying information. The data will be kept confidential by protecting the electronic dataset with a password and processing it in line with the data protection law. Your consent form will be kept securely in a locked cabinet which will be securely disposed after 5 years in line with the data protection law of Ghana. Only the researchers and his supervisors will be able to look at your findings.*

What will happen with the findings or samples?

- *The findings of this study will only be used for this study and any publication(s) arising from it will be reported in aggregate or summary statistics and not individual responses.*

How will you know about the results of this research?

- We will give you the results of this research when the study is completed through email.
- You will be informed of any new relevant findings by email.

Will you be paid to take part in this study and are there any costs for you?

This study is self-funded by the researcher. No external funding is received for this study.
You will not be paid to take part in the study except GH¢5 (R 16) worth of airtime to enable you complete the questionnaire because you will need 20 - 25 minutes internet connection for your participation. You had no travel expenses for the purpose of your participation so you do not need to be refunded for traveling. There will thus be no costs involved for you, if you do take part in this study except your time which will be approximately 20 to 25 minutes.

Is there anything else that you should know or do?

- You can contact ***James Avoka Asamani*** using **+233 209409458** (email: jamesavoka@gmail.com) if you have any further questions or have any problems.
- You can also contact the Health Research Ethics Committee via Mrs Carolien van Zyl at 018 299 1206 or carolien.vanzyl@nwu.ac.za if you have any concerns that were not answered about the research or if you have complaints about the research.
- You will receive a copy of this information and consent form for your own purposes.

Declaration by participant

By signing below, I …………………………………..…………. agree to take part in the research study titled: **Modelling primary health care workforce needs towards health professions education and employment investment planning in Ghana**.

I declare that:

- I have read this information/it was explained to me by a trusted person in a language with which I am fluent and comfortable.
- The research was clearly explained to me.
- I have had a chance to ask questions to both the person getting the consent from me, as well as the researcher and all my questions have been answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to take part.
- I may choose to leave the study at any time and will not be handled in a negative way if I do so.
- I may be asked to leave the study before it has finished, if the researcher feels it is in the best interest, or if I do not follow the study plan, as agreed to.

Signed at (*place*) ....…........……………….. on (*date*) …………....……….. 20....

....

Signature of participant **Signature of witness**

Declaration by person obtaining consent

I *(name)* ……………………………………………..……… declare that:

- I clearly and in detail explained the information in this document to

  ……………………………………………………..
- I did/did not use an interpreter.
- I encouraged him/her to ask questions and took adequate time to answer them.

- I am satisfied that he/she adequately understands all aspects of the research, as discussed above
- I gave him/her time to discuss it with others if he/she wished to do so.

Signed at (*place*) ....…......…………….. on (*date*) …………..……….. 20....

....
Signature of person obtaining consent

Declaration by researcher

I *(name)* ……………………………………………..……… declare that:

- I explained the information in this document to ………………………………..
- I did/did not use an interpreter
- I encouraged him/her to ask questions and took adequate time to answer them

  or I was available should he/she want to ask any further questions.
- The informed consent was obtained by an independent person.
- I am satisfied that he/she adequately understands all aspects of the research, as described above.
- I am satisfied that he/she had time to discuss it with others if he/she wished to do so.

Signed at (*place*) ....…......…………….. on (*date*) …………..……….. 20....

....
Signature of researcher

ANNEXURE G: SURVEY PARTICIPANT'S INFORMATION SHEET

PARTICIPANTS INFORMATION SHEET

Title of Study: Modelling primary health care workforce needs towards health professions education and employment investment planning in Ghana

Introduction: My name is Mr James Avoka Asamani, a staff of the World Health Organisation (WHO) working as Technical Advisor on Health Workforce Health Systems for countries in Eastern and Southern Africa. I am pursuing a PhD in Health Sciences (with Health Professions Education) at the Centre for Health Professions Education, Faculty of Health Sciences at the North-West University in South Africa. As part of the study, I am conducting a research to modelling the primary health care workforce needs towards health professions education and employment investment planning in Ghana.

Invitation to participate in the research: You are hereby kindly invited to take part in a research study that forms part of Doctoral study. Please take some time to read the information presented here, which will explain the details of the study and how you might be involved as well as your right to voluntary participation, freedom of withdrawal of consent and measure being taken to ensure confidentiality of the information will provide if you consent to participate in the study.

Background of research: Ghana is making investments in health workers to facilitate the access to needed health services for all persons living in Ghana. However, it is not clear for health workers, policymakers and training institutions how many how many health workers are optimally required to fulfil the health needs of the population. In this study I plan to estimate the amount of time health professionals like you usually spend in delivering services to each client. This is intended to be used to develop a need-based mathematical model to make estimations about the optimal number of health professionals needed to be trained as well as the investments that should be made to fill any gaps.

Nature of research: The study is seeking your views and objective estimate of the amount of time health professionals like you usually spend in undertaking some health services delivery tasks. There will be no right or wrong answer. You will be given a questionnaire to complete. The participants will include health professionals who work at primary health care levels (general practitioners, nurses, midwives, pharmacist/pharmacy technicians, laboratory scientist/technicians, nutritionists/dieticians and physician assistants – medical) with at least one-year experience at their current health facilities within Greater Accra, Bono East and Upper East regions in Ghana

1

Why and how have you been invited to participate?

- You have been invited to be part of this research because you are a fulltime employee of the Ghana Health Service working in a primary health care setting (district hospital, polyclinic, health centre or CHPS), and have been doing so for more than one (1) year.
- You will unfortunately not be able to take part in this research if you are on internship, national service or on relieving duty assignment from another health facility. Also, if are performing managerial or other duties different from their core professional training for more than half of your daily time, you will not be able to participate in this study.
- Following a random selection of your health facility, you were conveniently selected once you met the criteria to participate in the study.

Participants involvement:

- **Duration /what is involved:** If you agree to participate, you will be expected to fill a one-time electronic questionnaire which contains questions about your background such as age, sex, rank and qualification(s) as well as professional information. The questionnaire also contains activities typically performed by members of your profession in which you will be expected objectively indicate the amount of time it averagely takes you to complete the listed activities. Completing the questionnaire may take you 20 to 25 minutes. Your responses to the questionnaire will be collected electronically but if you do not have enough time now you can answer it at your earliest convenience.

- **Potential Risks:** There are no anticipated risk of physical, emotional, social or psychological harm associated with this study. The questionnaire requires a recall or estimate of the average time you usually spend on each patient for the services you deliver. There will be no penalty or adverse consequence if you do not wish to participate in the study or if you participate but decide not to answer a specific question.

- **Benefits:** There will be no direct gains for you in the study. The indirect gains of the study are that, the findings may be used for improved health workforce planning leading to better staffing in the future which could result in lower workload levels and reduced burnouts for members of your profession.
- **Costs:** This study is self-funded by the researcher. No external funding is received for this study. You will not be paid to take part in the study except GH¢5 (R 16) worth of airtime to enable you complete the questionnaire because you will need 20 - 25 minutes internet connection for your participation. The questionnaire will be brought to you at your workplace so you will not incur travel expenses for the purpose of your participation. There will thus be no costs involved for you, if you do take part in this study except your time which will be approximately 25 minutes.
- **Compensation:** You will not be given any money for answering the questionnaire.
- **Confidentiality:** Anonymity of your responses will be protected by ensuring that your consent form will not be in any way linked to your responses on the questionnaire which will be electronically collected. Your privacy will be respected by allowing you to complete the electronic questionnaire by yourself. Your results will be aggregated with

This is to Certify that this Study's Inform Consent Form Has Been Approved by GHS –ERC for the Period 24.08.2020 to 23.08.2021
Sign.......... Date 01.09.2020
Name. Nana Abena Apatu
GHC-ERC Administrator

ANNEXURE H: SURVEY QUESTIONNAIRE

ACTIVITY STANDARDS QUESTIONNAIRE FOR HEALTH PROFESSIONALS

Dear Esteemed Colleague,

My name is James Avoka Asamani, a doctoral candidate of the North-West University (NWU) in South Africa. With the approval of NWU and Ghana Health Service (GHS), I'm carrying out research to understand ***the standard time it takes health professionals to deliver primary health care services in Ghana***. The study is purely for academic purposes and your responses shall be kept in strict confidence and will not be disclosed to anyone. The result of this study will be used to design a health workforce planning tool to support evidence-informed policies and strategies which could improve staffing situation in the future. You reserve the sole right to withdraw from the study at any time which will have no adverse consequence on your part. However, your participation in this study will be very valuable and appreciated.

If you are happy to participate, ensure you have signed a consent form take some time off your busy schedule to fill out this questionnaire honestly. Thank you.

PART 1: BACKGROUND INFORMATION

SECTION A: INFORMATION ABOUT HEALTH FACILITY

1. **Region: Which region is your health facility located?**
   [ ] Greater Accra [ ] Bono East [ ] Upper East

2. **Type of health facility.**
   [ ] Primary/District Hospital [ ] Health Centre/Polyclinic [ ] CHPS

3. **How would you describe the location of your health facility?**
   [ ] Urban [ ] Semi-urban [ ] Rural

4. On a scale of 0 to 5 (*where 0 is lightest workload and 5 is the heaviest workload possible in any health facility you know),* how would you rate the level of workload in this health facility? Please, circle only one choice.
   [1 2 3 4 5]

5. On a scale of 0 to 5 *(where 0 is no workload and 5 is the greatest workload possible in any Unit in this facility),* how would you rate the level of workload in your unit? Please, circle only one choice.
   [1 2 3 4 5]

6. On a scale of 0 to 5 *(where 0 is a situation all the tools/equipment are not available, and 5 is a situation that all tools/equipment are available), kindly rate the extent to which* your

facility has the tools/equipment that are necessary for your work (by circling only one choice).

[1 2 3 4 5]

SECTION B - DEMOGRAPHIC CHARACTERISTICS OF THE HEALTH PROFESSIONAL

(Please indicate by writing or ticking (√) what applies to you)

1. What is your age?: ……………… years

2. **Gender:** Male [ ] Female [ ] Other [ ]

3. How many years have you been working in your profession? ………………….

4. How long (in years) have you been working in this health facility? …………….

5. What is your highest qualification in the profession? [Please, tick only ONE]:

Certificate [ ]
Diploma [ ]
Post-Basic (Advanced) Diploma [ ]
First Degree [ ]
Masters/post-graduate specialisation [ ]
Others (please, specify) ………………………………………………………

6. For the following statements, kindly indicate by ticking (√) in the appropriate box, the extent to which you agree or disagree with each statement.

STATEMENT		RESPONSE				
		Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**	**Neutral**
	I do not feel competent enough in some of the tasks I perform					
	My colleagues take longer time than me to perform the same task that I would usually finish in a shorter time					
	I require additional training to be able to perform my duties effectively.					
	Compared with my colleagues I usually spend more time with patients when providing them services.					

7. **Which category of health professional are you?**

General Practitioner (Generalist Doctor) [ ] … *After this section go to part 2*
Physician Assistant [ ] … *After this section go to part 3*
Midwife [ ] ... *After this section go to part 4*
Clinical Nurse (General Nurse/Enrolled Nurse) [ ] ... *After this section go to part 5*
Preventive Nurse (Community Health Nurse) [ ] ... *After this section go to part 6*
Nutritionist/ Dietician [ ] ... *After this section go to part 7*
Laboratory Scientist/Technician [ ] ... *After this section go to part 8*
Pharmacist/Pharmacy Technician [ ] ... *After this section go to part 9*

PART 2: GENERAL PRACTITIONER (GENERALIST DOCTOR)

	Main Health Service Delivery Task	Do you perform this activity in this facility? (Yes or No)	If yes, *how much time in minutes* do you averagely spend to perform this task?
1.0	**Health Service Activities**		
1.1	Assessment, diagnosis and treatment of new out-patient case	Yes [ ] No [ ]	*.... minutes per patient*
1.2	Review of a follow-up out-patient case (old cases)	Yes [ ] No [ ]	*.... minutes per patient*
1.3	Review of inpatient per patient day (daily ward rounds)	Yes [ ] No [ ]	*.... minutes per patient per day*
1.4	Referral of a patient	Yes [ ] No [ ]	*.... minutes per patient*
1.5	Minor surgical procedures (e.g., suturing lacerations, incision and drainage)	Yes [ ] No [ ]	*.... minutes per patient*
1.6	Major surgical procedures	Yes [ ] No [ ]	*.... minutes per patient*
1.7	Patient education and counselling	Yes [ ] No [ ]	*.... minutes per patient*
1.8	Interventions for minor (simple) medical emergencies	Yes [ ] No [ ]	*.... minutes per patient*
1.9	Interventions for moderate-to-severe medical emergencies	Yes [ ] No [ ]	*.... minutes per patient*
1.10	Interventions for critically ill medical emergencies	Yes [ ] No [ ]	*.... minutes per patient*
1.11			
1.12			
2.0	**Support Activities**		
2.1	Clinical meetings	Yes [ ] No [ ]	*.... hours per week*
2.2			
2.3			
2.4			
3.0	**Additional Activities**		
3.1	Supervision of staff and students		*... staff for ... hours per day*
3.2			
3.3			

If you have comment(s) on your workload and the average time given for the activities, please, provide:
………
……

PART 3: PHYSICIAN ASSISTANT

	Main Health Service Delivery Task	Do you perform this activity in this facility? (Yes or No)	If yes, *how much time in minutes* do you averagely spend to perform this task?
1.0	**Health Service Activities**		
1.1	Assessment, diagnosis and treatment of new out-patient case	Yes [ ] No [ ]	*.... minutes per patient*
1.2	Review of a follow-up out-patient case	Yes [ ] No [ ]	*.... minutes per patient*
1.3	Referral of a patient	Yes [ ] No [ ]	*.... minutes per patient*
1.4	Minor surgical procedures	Yes [ ] No [ ]	*.... minutes per patient*
1.5	Patient education and counselling	Yes [ ] No [ ]	*.... minutes per patient*
1.6	Interventions for medical emergencies	Yes [ ] No [ ]	*.... minutes per patient*
1.7	Interventions for minor (simple) medical emergencies	Yes [ ] No [ ]	*.... minutes per patient*
1.8	Interventions for moderate-to-severe medical emergencies	Yes [ ] No [ ]	*.... minutes per patient*
1.9	Interventions for critically ill medical emergencies	Yes [ ] No [ ]	*.... minutes per patient*
1.10			
1.11			
2.0	**Support Activities**		
2.1	Clinical meetings	Yes [ ] No [ ]	*.... hours per week*
2.2			
2.3			
2.4			
3.0	**Additional Activities**		
3.1	Supervision of staff and students		*... staff for ... hours per day*
3.2			
3.3			

If you have comment(s) on your workload and the average time given for the activities, please, provide:
……
………

PART 4: MIDWIFE

	Main Health Service Delivery Task	**Do you perform this activity in this facility? (Yes or No)**	**If yes, *how much time in minutes* do you averagely spend to perform this task?**
1.0	Health Service Activities		
1.1	Antenatal Care Consultation	Yes [ ] No [ ]	*.... minutes per patient*
1.2	Post Natal Care Consultation	Yes [ ] No [ ]	*.... minutes per patient*
1.3	Family Planning Service (non-invasive procedure)	Yes [ ] No [ ]	*.... minutes per patient*
1.4	Family Planning invasive procedure	Yes [ ] No [ ]	*.... minutes per patient*
1.5	Prevention of Mother-To-Child Transmission of HIV during ANC	Yes [ ] No [ ]	*.... minutes per patient*
1.6	Vaginal delivery	Yes [ ] No [ ]	*.... minutes per patient*
1.7	Inpatient care per patient day (routine care for mother)	Yes [ ] No [ ]	*.... minutes per patient per day*
1.8	Inpatient care per patient day (routine care for new-born)	Yes [ ] No [ ]	*.... minutes per patient per day*
1.9	Admission processes per patient	Yes [ ] No [ ]	*.... minutes per patient*
1.10	Discharge processes per patient	Yes [ ] No [ ]	*.... minutes per patient*
1.11	Preparation for caesarean section	Yes [ ] No [ ]	*.... minutes per patient*
1.12	Patient education and counselling	Yes [ ] No [ ]	*.... minutes per patient*
1.13	Community outreach	Yes [ ] No [ ]	*.... minutes per patient*
1.14	Management of complications of pregnancy	Yes [ ] No [ ]	*.... minutes per patient per day*
1.15			
1.16			
2.0	**Support Activities**		
2.1	Daily report writing	Yes [ ] No [ ]	*.... hours per day*
2.2	Monthly reports	Yes [ ] No [ ]	*.... hours per day*
2.3	Taking-over and handing-over	Yes [ ] No [ ]	*.... hours per day*
2.4	Clinical meetings	Yes [ ] No [ ]	*.... hours per week*
2.5			
3.0	**Additional Activities**		
3.1	Supervision of staff and students		*... staff for ... hours per day*
3.2			
3.3			

If you have comment(s) on your workload and the average time given for the activities, please, provide:
……
………

PART 5: CLINICAL NURSE (GENERAL NURSE/ENROLLED NURSE)

	Main Health Service Delivery Task	**Do you perform this activity in this facility? (Yes or No)**	**If yes, *how much time in minutes* do you averagely spend to perform this task?**
1.0	**Health Service Activities**		
1.1	Out-patient care (triaging, vital signs and history taking)	Yes [ ] No [ ]	*.... minutes per patient*
1.2	Out-patient consultation (at health centres and CHPS)	Yes [ ] No [ ]	*.... minutes per patient*
1.3	Admission processes per patient (at hospitals)	Yes [ ] No [ ]	*.... minutes per patient*
1.4	Discharge processes per patient (at hospitals)	Yes [ ] No [ ]	*.... minutes per patient*
1.5	Pre-Operative preparation of patients (at hospitals)	Yes [ ] No [ ]	*.... minutes per patient*
1.6	Post-operative management which is different from routine care (at hospitals)	Yes [ ] No [ ]	*.... minutes per patient per day*
1.7	Inpatient care per patient day (routine care) for low dependent/mild cases	Yes [ ] No [ ]	*.... minutes per patient per day*
1.8	Inpatient care per patient day (routine care) for moderately dependent/severe cases (at hospitals)	Yes [ ] No [ ]	*.... minutes per patient per day*
1.9	Inpatient care per patient day (routine care) for highly dependent/critical cases (at hospitals)	Yes [ ] No [ ]	*.... minutes per patient per day*
1.10	Discharge patient education and counselling	Yes [ ] No [ ]	*.... minutes per patient*
1.11	Minor surgical procedures (suturing lacerations, incision and drainage, would dressings)	Yes [ ] No [ ]	*.... minutes per patient*
1.12			
1.13			
1.14			
2.0	**Support Activities**		
2.1	Daily report writing	Yes [ ] No [ ]	*.... hours per day*
2.2	Monthly reports	Yes [ ] No [ ]	*.... hours per day*
2.3	Student supervision and teaching	Yes [ ] No [ ]	*.... hours per day*
2.4	Taking-over and handing-over	Yes [ ] No [ ]	*.... hours per day*
2.5	Cleaning and disinfection	Yes [ ] No [ ]	*.... hours per day*
2.6	Community outreach services	Yes [ ] No [ ]	*.... hours per week*
2.7			
2.8			
3.0	**Additional Activities**		
3.1	Supervision of staff		*... staff for ... hours per day*
3.2			
3.3			

If you have comment(s) on your workload and the average time given for the activities, please, provide:
……
………

PART 6: PREVENTIVE NURSE (COMMUNITY HEALTH NURSE)

	Main Health Service Delivery Task	Do you perform this activity in this facility? (Yes or No)	If yes, *how much time in minutes* do you averagely spend to perform this task?
1.0	**Health Service Activities**		
1.1	Family planning	Yes [ ] No [ ]	*.... minutes per patient*
1.2	Out-patient consultation to manage minor ailments (at CHPS)	Yes [ ] No [ ]	*.... minutes per patient*
1.3	Referral of patients	Yes [ ] No [ ]	*.... minutes per patient*
1.4	Discharge patient education and counselling	Yes [ ] No [ ]	*.... minutes per patient*
1.5	Home visiting (per each home visit)	Yes [ ] No [ ]	*.... minutes per patient*
1.6	School health (for each pupil)	Yes [ ] No [ ]	*.... minutes per patient*
1.7	Immunisation (per child immunised)	Yes [ ] No [ ]	*.... minutes per patient*
1.8	Growth monitoring	Yes [ ] No [ ]	*.... minutes per patient*
1.9			
1.10			
1.11			
2.0	**Support Activities**		
2.2	Monthly reports	Yes [ ] No [ ]	*.... hours per day*
2.3	Cold chain management	Yes [ ] No [ ]	*.... hours per day*
2.5	Cleaning and disinfection	Yes [ ] No [ ]	*.... hours per day*
2.6	Community outreach services	Yes [ ] No [ ]	*.... hours per week*
2.7			
2.8			
3.0	**Additional Activities**		
3.1	Supervision of staff		*... staff for ... hours per day*
3.2			
3.3			

If you have comment(s) on your workload and the average time given for the activities, please, provide:
……
………
************************PART 7: NUTRITIONIST AND DIETICIAN**

	Main Health Service Delivery Task	Do you perform this activity in this facility? (Yes or No)	If yes, *how much time in minutes* do you averagely spend to perform this task?
1.0	**Health Service Activities**		
1.1	Nutritional Status Assessment	Yes [ ] No [ ]	*.... minutes per patient*
1.2	Patient education and counselling	Yes [ ] No [ ]	*.... minutes per patient*
1.3	Diet planning for patients	Yes [ ] No [ ]	*.... minutes per patient*
1.4	Follow-ups/home visits	Yes [ ] No [ ]	*.... minutes per patient*
1.5			
1.6			
1.7			
1.8			
2.0	**Support Activities**		
2.1	Report writing	Yes [ ] No [ ]	*.... hours per day*
2.2	Cleaning and disinfection	Yes [ ] No [ ]	*.... hours per day*
2.3	Community outreach services	Yes [ ] No [ ]	*.... hours per day*
2.4	Clinical meetings	Yes [ ] No [ ]	*.... hours per week*
2.5			
2.6			
3.0	**Additional Activities**		

3.1	Supervision of staff and students		*... staff for ... hours per day*
3.2			
3.3			

If you have comment(s) on your workload and the average time given for the activities, please, provide:
……
……

PART 8: LABORATORY SCIENTIST AND TECHNICIAN

	Main Health Service Delivery Task	Do you perform this activity in this facility? (Yes or No)	If yes, *how much time in minutes* do you averagely spend to perform this task?
1.0	**Health Service Activities**		
1.1	Sample taking and processing	Yes [ ] No [ ]	*.... minutes per sample*
1.2	Full Blood count (using automated machine)	Yes [ ] No [ ]	*.... minutes per sample*
1.3	Malaria test (rapid diagnostic test)	Yes [ ] No [ ]	*.... minutes per sample*
1.4	Malaria test (microscopy)	Yes [ ] No [ ]	*.... minutes per sample*
1.5	Urine routine examination	Yes [ ] No [ ]	*.... minutes per sample*
1.6	Stool Urine routine examination	Yes [ ] No [ ]	*.... minutes per sample*
1.7	Blood sugar test	Yes [ ] No [ ]	*.... minutes per sample*
1.8	Blood donor bleeding	Yes [ ] No [ ]	*.... minutes per patient*
1.9	Preparing blood for Transfusion	Yes [ ] No [ ]	*.... minutes per patient*
1.10			
1.11			
1.12			
2.0	**Support Activities**		
2.1	Report writing	Yes [ ] No [ ]	*.... hours per day*
2.2	Cleaning and disinfection	Yes [ ] No [ ]	*.... hours per day*
2.3	Blood donation campaigns/outreach services	Yes [ ] No [ ]	*.... hours per day*
2.4	Clinical meetings	Yes [ ] No [ ]	*.... hours per week*
2.5			
2.6			
3.0	**Additional Activities**		
3.1	Supervision of staff and students		*... staff for ... hours per day*
3.2			
3.3			

If you have comment(s) on your workload and the average time given for the activities, please, provide:
……
………

PART 9: PHARMACIST/PHARMACY TECHNICIAN

	Main Health Service Delivery Task	Do you perform this activity in this facility? (Yes or No)	If yes, *how much time in minutes* do you averagely spend to perform this task?
1.0	**Health Service Activities**		
1.1	Prescription auditing and dispensing for out-patient cases	Yes [ ] No [ ]	*.... minutes per patient*
1.2	Prescription auditing and dispensing for in-patient cases Inpatient	Yes [ ] No [ ]	*.... minutes per patient*
1.3	Prescription refilling for chronic conditions	Yes [ ] No [ ]	*.... minutes per patient*
1.4	Pharmaceutical interventions to correct prescription errors	Yes [ ] No [ ]	*.... minutes per patient*
1.5	Patient adherence counselling and education	Yes [ ] No [ ]	*.... minutes per patient*
1.6			
1.7			
1.8			
2.0	**Support Activities**		
2.1	Report writing	Yes [ ] No [ ]	*.... hours per day*
2.2	Reconstitution of powdered preparations	Yes [ ] No [ ]	*.... hours per week*
2.3	Community outreach services	Yes [ ] No [ ]	*.... hours per day*
2.4	Clinical meetings	Yes [ ] No [ ]	*.... hours per week*
2.5			
2.6			
3.0	**Additional Activities**		
3.1	Management of stocks		*... staff for ... hours per day*
3.2	Procurement activities		*... staff for ... hours per day*
3.3	Quality Assurance (QA), Drug and Therapeutic Committee (DTC) activities		*... staff for ... hours per day*
3.4			
3.5			

If you have comment(s) on your workload and the average time given for the activities, please, provide:
………
……

ANNEXURE I: EVIDENCE OF ARTICLE 4 UNDER PEER-REVIEW

PLOS ONE 06/07/2021, 10:14 PM

Reassignment of your PLOS ONE manuscript - [EMID:b3de71a18cac538e]

to: "Christmal Dela Christmals" <christmal.christmals@nwu.ac.za>

PONE-D-21-05604
Modelling the supply and need for health professionals for primary health care in Ghana: Implications for health professions education and employment planning
Dr Christmal Dela Christmals
PLOS ONE

Dear Dr Christmals,

Thank you for submitting your manuscript PONE-D-21-05604 to PLOS ONE. We would like to take this opportunity to give you an update on the status of your submission.

Unfortunately, the Academic Editor originally assigned to handle your submission is now unavailable. To expedite the review process, we are searching for a new editor to handle your manuscript. We sincerely apologize for this delay, but please know that we are doing all that we can to move your paper forward. We will be in contact as soon as a new Academic Editor is secured.

Thank you for your patience and understanding. If we can answer any of your questions or concerns in the meantime, please do not hesitate to get in touch.

Best wishes,

Editor Assignment Team
PLOS ONE
plosone@plos.org

In compliance with data protection regulations, you may request that we remove your personal registration details at any time. (Use the following URL: https://www.editorialmanager.com/pone/login.asp?a=r). Please contact the publication office if you have any questions.

ANNEXURE J: LANGUAGE EDITING CERTIFICATE

Language Editor's Declaration

LANGUAGE MATTERS

- Language Matters Pty Ltd
- info@languagematters.co.za
- 082 920 2991
- www.languagematters.co.za

Language editing – Translation – Transcription – Simultaneous interpreting

info@languagematters.co.za
156 O R Tambo Street
Miederpark
Potchefstroom
2531

To whom it may concern,

This document certifies that the manuscript(s)/title listed below has been edited, within reasonable, ethical and professional limits, for syntax, grammar, spelling, punctuation and specific stylistic requirements of the English language by one or more qualified language practitioner(s) at Language Matters. The editor's revisions and comments serve as recommendations; the overall quality of the final manuscript's contents remains the responsibility of the client/author. The language editor does not accept responsibility for any changes made to the manuscript after the issuing of this declaration.

Manuscript title:	Modelling primary health care workforce needs towards health professions education and employment investment planning in Ghana – Preliminary matter, Chapter 1, and Chapter 6
Author(s):	JA Asamani
Date Issued:	14 July 2021
Issued by:	BGS Language Matters and Media Services

ANNEXURE K: PLAGIARISM CHECK – SUMMARY OF TURNITIN REPORT

37205722:2_Turnitin_Checking_Final_Thesis_JA_Asamani_6_J...

ORIGINALITY REPORT

11%	5%	10%	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES