The influence of distance on health facility delivery in rural Zambia

PhD thesis

Sabine Gabrysch

Maternal and newborn mortality could be reduced if all women delivered in settings where skilled attendants can provide Emergency Obstetric Care in case complications arise. Research on determinants of skilled attendance at delivery has so far focussed on household and individual factors, neglecting the influence of the health service environment, in part due to a lack of suitable data. Linking national household survey data with national health facility census data in a Geographic Information System, this study showed that lack of geographic access to quality obstetric care is a key factor explaining why most rural deliveries in Zambia still occur at home without skilled care.

Department of Epidemiology and Population Health
LONDON SCHOOL OF HYGIENE & TROPICAL MEDICINE

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Thesis handed in: 25th September 2009

Oral examination: 3rd March 2010

Degree awarded: 31st May 2010

Supervisor: Oona Campbell

Associate Supervisor: Simon Cousens

Advisory Committee: Jon Cox, Mike Kenward, James Hargreaves, Emma Slaymaker

This research degree was funded by a LSHTM GTA studentship. It received ethical approval from the LSHTM ethics committee on 03/07/2007 (application number 5172). The Demographic and Health Surveys obtain informed consent from all respondents.

Acknowledgements

I am very grateful to the Zambian Ministry of Health and Central Statistical Office for permission to use their data and to Jane Miller and Angela Spilsbury from DFID for making the contacts. Many thanks also to my colleague Barbara Carasso and the IDEU student fund for their help with the map purchase in Zambia and to MSc students Chitwambi Makungu and Simon Chisi for providing information about the Zambian health system. I also want to acknowledge LSHTM for supporting me with a Graduate Teaching Assistentship during my PhD and the Swedish Board for Study Support for the student aid received.

I very much thank my co-supervisor Simon Cousens for his help and support, as well as my advisory committee members: James Hargreaves, Emma Slaymaker, Jon Cox – for his advice on GIS issues – and Mike Kenward – for enlightening me about multilevel modelling and for making me nearly love statistics! Many thanks also to Rhian Daniel for her kind advice on issues related to missing data and to Jonathan Bartlett for helpful discussions on measurement error. And a big thank you to all staff and students of LSHTM for making the School such a warm and inspiring place!

This work would not have been possible without the guidance of my wonderful supervisor Oona Campbell who always believed in me, encouraged me, cheered me up during the harsh times of data problems, came up with countless brilliant ideas and is just a fantastic person to work with. Her enthusiasm about the topic and sheer excitement even over preliminary Stata output has again and again recharged my energies. It is amazing how she managed to teach me so many things without ever appearing to do so or saying a critical word. It has been a pleasure to be your student, Oona, thank you so much!

Furthermore, I want to thank all my friends, especially Anna Goodman and Philipp Zanger, for the many fruitful and enjoyable exchanges of ideas, for the fun times together and for their support during difficult episodes. And lastly, I am deeply thankful to my mother, father, brother and to Krishna Kunduri for their love, encouragement and invaluable support at all times.

Abstract

Skilled attendance at delivery is crucial for decreasing maternal and neonatal mortality. My literature review showed that epidemiological research on factors influencing whether women receive skilled attendance has so far been hampered by a lack of data on health service availability, and is often restricted to investigating household and individual factors. Distance to health services, however, is likely to play an important role.

The availability of geographic coordinates in both national household survey, population census and health facility census in Zambia provides the opportunity to combine user and provider information on a large scale. These datasets were linked to investigate the influence that distance has on place of delivery, while adjusting for other influential factors such as education, wealth and autonomy in a multilevel model.

Classifying Zambian health facilities according to their level of delivery care showed that 88% of facilities are not staffed or equipped to provide even Basic Emergency Obstetric Care (EmOC) and therefore cannot save a mother’s life in case of complications. Around half of the Zambian population lives further than 15km from a Basic EmOC facility; less than 10% in urban areas and over 70% in rural areas.

Using data from over 3000 rural births, I demonstrate that the odds of delivering in a facility are 4 times higher within 1km of a facility as compared to 20km, and additionally 2.5 times higher if that facility offers Comprehensive EmOC rather than substandard care. If all mothers lived within 5km of Basic EmOC, 16% of home deliveries could be avoided, a population attributable fraction of similar magnitude as for education or wealth.

Lack of geographical access to EmOC is a key factor explaining why most rural deliveries in Zambia still occur at home without skilled care; this needs to be addressed to lower maternal and neonatal mortality.

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Acronyms

ANC	Antenatal care
AMDD	Averting Maternal Death and Disability
BEmOC	Basic Emergency Obstetric Care (offering all 6 signal functions)
BEmOC-1	Basic Emergency Obstetric Care but may not offer assisted vaginal delivery
BEmOC-2	(Potential) Basic Emergency Obstetric Care but may lack up to 2 signal functions
BEmOC-4	(Potential) Basic Emergency Obstetric Care but may lack up to 4 signal functions
CBR	Crude Birth Rate
CEmOC	Comprehensive Emergency Obstetric Care (offering all 8 signal functions)
CEmOC-1	Comprehensive Emergency Obstetric Care but may not offer assisted vaginal delivery
CI	Confidence Interval
C-section	Caesarean section
DHS	Demographic and Health Survey
DMS	Degrees – Minutes – Seconds
DOB	Date of birth
EmOC	Emergency Obstetric Care
GIS	Geographic Information System
GPS	Geographic Positioning System
HFC	Health Facility Census
HIV	Human Immunodeficiency Virus
HMIS	Health Management Information System
ICC	Intra-cluster correlation
JICA	Japanese International Cooperation Agency
LRT	Likelihood Ratio Test
LSMS	Living Standards Measurement Survey
MCH	Maternal and Child Health
MDG	Millenium Development Goal
MMR	Maternal Mortality Ratio
NGO	Non-governmental organisation
OR	Odds Ratio
PAF	Population Attributable Fraction

PCA	Principal Components Analysis
SAM	Service Availability Mapping
SPA	Service Provision Assessment
TBA	Traditional Birth Attendant
UN	United Nations
UNICEF	United Nations Children's Fund
UNFPA	United Nations Population Fund
USAID	United States Agency for International Development
UTM	Universal Transverse Mercator
WHO	World Health Organization
WHR	World Health Report
24/7	24 hour services 7 days a week

CHAPTER 1

BACKGROUND

In this background chapter I first briefly introduce the motivation behind this work and describe the study's aims and objectives. I then discuss various issues relevant to my outcome variable, including how to operationalise and measure access to care, skilled attendance and Emergency Obstetric Care. Next I discuss similar conceptual and measurement issues related to my primary exposure of interest – distance to a health facility – as well as two potential confounders, ability to pay and women's autonomy. This is followed by a brief methodological excursion into analysis of clustered data. The chapter concludes with a review of the literature on determinants of skilled attendance.

1.1 Introduction

1.1.1 Maternal and newborn mortality

Every year, more than 500,000 maternal deaths occur worldwide, 4 million newborns die and another 4 million babies are stillborn [1, 2]. 99% of these deaths take place in the developing world and most could be prevented with currently available medical care [1, 3]. Furthermore, many women and newborns suffer from long-term consequences of complications.

Maternal mortality is the public health indicator with the widest gap between rich and poor countries. While the maternal mortality ratio (MMR) estimate in Sub-Saharan Africa is 920 maternal deaths per 100,000 live births, it is only 24 in Europe [3]. There are also enormous disparities within lower-income countries, with the poor and those living in rural areas at particular disadvantage.

Recently, attention to this problem has been growing [1, 2], but it is clear that increased efforts will be necessary to reach the 4^{th} and 5^{th} Millennium Development Goal (MDG) of reducing maternal mortality by three quarters and mortality in children under five by two thirds by 2015.

Most obstetric complications occur around the time of delivery and cannot be predicted [2]. Therefore it is important that all pregnant women have access to someone with midwifery skills, who is able to manage a normal delivery and who can recognize and manage obstetric complications, or refer in time if needed, i.e. a skilled attendant.

Skilled attendance at delivery is advocated as the “single most important factor in preventing maternal deaths” [4] and the “proportion of births attended by skilled health personnel” has been chosen as an indicator for MDG5. Access to skilled delivery care is also crucial to prevent stillbirths and to improve newborn survival, given that the majority of newborn deaths occur shortly after delivery and within the first few days of life [1]. Skilled attendants can perform deliveries either at home, in health centres or in hospitals, but it is argued that the most efficient strategy for lower-income countries is to place such skilled attendants in health centres with referral capacity [5]. In practice, skilled attendance in most countries is synonymous with facility delivery.

The factors influencing use of skilled attendance at delivery include demographic, socioeconomic and other characteristics of the mother and her family as well as aspects of service provision such as distance to the nearest health facility and quality of care. While many epidemiological studies have investigated the demographic and socioeconomic factors, few have included distance or quality of care, despite wide acknowledgement of the importance of taking service availability into account. Most studies simply lacked information about the facilities available in their area. Geographical studies of facility use, on the other hand, have often remained at the ecological level because they lacked household data in the same area.

By linking health facility census data with Demographic and Health Survey (DHS) household data using geographic coordinates, this study aims to help fill this gap and to investigate the influence of distance from delivery services on facility use for childbirth in Zambia.

1.1.2 Zambia

Like many African countries, Zambia has a high maternal mortality ratio, estimated to be 591 maternal deaths for every 100,000 live births, according to the 2007 DHS [6]. I chose Zambia as the setting for this study because it is one of the few countries with a high maternal mortality ratio (MMR) where suitable facility and household data are available for analysis.

Zambia is a large (750,000 km^2) landlocked country in Southern Africa with a population of around 11.4 million in 2005 of whom 65% live in rural areas [7]. The GDP per capita was approximately 1000 US$ in 2006, infant mortality is around 10% and life expectancy at birth is 39 years [7]. In the Human Development Index Zambia ranks 163rd out of 177 countries [8]. The total fertility rate is over 5 children per woman and the crude birth rate is around 40 births per 1000 population [7]. Half of all births occur in health facilities with a skilled attendant; over 80% of births in urban areas and about 30% in rural areas [6].

According to Countdown 2015 [9] Zambia has partially costed implementation plans for maternal, newborn and child health and midwives are partially authorised to administer a core set of life-saving interventions. The per capita total expenditure on health is 63US$, of which 32% is out-of-pocket expenditure and the density of health workers is 1 per 1000 population [10]. Official Development Assistance to maternal and neonatal health per live birth is 45US$ and the national availability of Emergency Obstetric Care Services is 41% of the recommended minimum [9]. Zambia's National Health Strategic Plan 2006-2010 highlights integrated reproductive health as a public health priority but predicts that the country is unlikely to reach its MDG5 goal of reducing MMR to below 200 deaths per 100,000 live births by 2015 [11].

1.1.3 Aims and objectives

1.1.2.1 Overall aim

The aim of this study is to investigate how distance from a skilled attendant in a functioning health facility affects women's use of health facilities for delivery, using available national data from Zambia.

1.1.2.2 Research Objectives

1. To ascertain how many of Zambia's hospitals and health centres meet the criteria established for Emergency Obstetric Care (EmOC) services,
2. To ascertain the geographical distribution of delivery services, in particular EmOC services, in relation to the population in Zambia,
3. To ascertain the effect of distance to *any* health facility offering delivery care, and of distance to a health facility offering *EmOC* on whether women in rural areas deliver in a health facility,
4. To explore whether other factors (season, transport means, wealth, education, women's autonomy and attitudes) modify the effect of distance,
5. To estimate the proportion of home deliveries that can be attributed to long distance (population attributable fraction), and compare to other important determinants of delivery service use.

1.2 Concepts and measurement

1.2.1 Access to skilled attendance

1.2.1.1 Access to health services

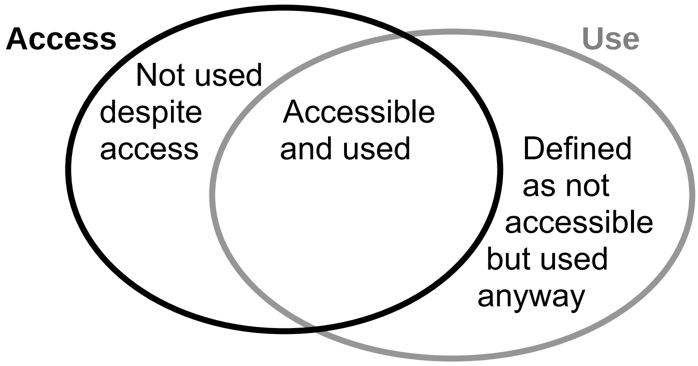
The concept of access to health services has repeatedly been criticised as ill-defined [12, 13]. A simple definition of access is the ability to use services when needed. Need is often difficult to establish in situations where a medical diagnosis is required, however, in the case of delivery care this problem is less relevant because arguably all pregnant women need skilled attendance at delivery.

Access has also been described in terms of the barriers that need to be overcome to access care, or as the degree of fit between patient needs and what the health care system offers [13]. Barriers can be classified as geographical or non-geographical, the latter comprising economic, organisational, informational, social and cultural factors. Geographical access has been operationalised in different ways, for example as presence of a health facility within 5 km distance (by the Kenyan Government) or within 1 hour travel time (by the World Bank). When knowing the size of the population in need (denominator), these criteria can be used to calculate population coverage of health services.

Finally, as discussed in an influential article by Aday and Andersen [12], access can be evaluated in terms of potential access or realised access. Investigating health care system characteristics (resources and organisation) and population characteristics (predisposing, enabling and need components) tells us about the factors influencing potential access, but some form of external validation is needed to know whether these factors actually make a difference in terms of getting care [12]. Use of health care services and consumer satisfaction can provide such validation [12].

Yet access is not the same as use, since people can be unwilling to use services despite their being accessible (although unwillingness can be hard to distinguish from services being insensitive to women's needs or culturally inappropriate) and people can use services despite their being extremely difficult to access, e.g. by walking for many hours or by borrowing money to cover high costs (Figure 1).

Figure 1: Access to and use of facilities for childbirth



The definition of what is judged “accessible” in terms of one barrier (e.g. distance) is somewhat arbitrary as its importance depends on other barriers (e.g. available transport, ability to pay). It is the interplay between health care system characteristics and user characteristics that determine access [12]. Therefore, the factors determining access and thus the measures needed to improve access necessarily differ between contexts and over time. A recent review [14] recommends taking the dynamic aspects of access into account, including feedbacks between the health care system and its users, such as learning and adaptation. This requires acknowledging the complex nature of access to health care, where decisions are usually not made by fully informed rational individuals but rather with insufficient information and embedded in a particular social context, involving trade-offs and interactions between barriers. [15]. This is particularly true for delivery care where the need is usually anticipatory / preventive and health-seeking is required quickly when labour starts or complications arise.

<u>1.2.1.2 Skilled attendance</u>

Skilled attendance has been defined as “the process by which a woman is provided with adequate care during labour, delivery, the postpartum and immediate newborn periods.” [16] This requires a skilled attendant as well as an enabling environment.

"A skilled attendant is a health professional − such as a midwife, doctor or nurse − who has been educated and trained to proficiency in the skills needed to manage normal (uncomplicated) pregnancies, childbirth and the immediate postnatal period, and in the identification, management and referral of complications in women and newborns." [1]

The enabling environment is "…a supportive health system that ensures they [the skilled attendants] have access to essential infrastructure, medicines and equipment" [17], "as well as an efficient and effective system of communication and referral/ transport" [16].

Therefore the usual survey question used to monitor the achievement of MDG5 about place of delivery and delivery attendants is "only a proxy measure of skilled attendance for several reasons" [18]: Firstly, the skills of the attendant are not measured and "it cannot be assumed that all health professionals are skilled in delivery care" [18]. Furthermore, types of attendants and their training differ between countries and the WHO definition leaves room for interpretation. It is even unclear how well women can identify the type of attendant [19]. Secondly, the questions do not measure the presence of an enabling environment. Thus giving birth in a health facility with a doctor, nurse or midwife does not necessarily imply either skill or sufficient equipment, drugs and referral possibilities.

In fact, even the definition of a hospital or health centre is often unclear and varies between countries. While deliveries in health facilities are likely to be attended by health professionals, this is not necessarily the case and women might only be attended by untrained staff such as nursing assistants or even cleaners [20, 21]. But also trained providers are not necessarily skilled. A study of provider knowledge and skills in Benin, Ecuador, Jamaica and Rwanda demonstrated widely varying and generally poor skill levels, for instance only 12% of midwives could perform bimanual uterine compression [22].

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[1] Definition endorsed by: WHO, UNFPA, World Bank, the International Confederation of Midwives (ICM) and the International Federation of Gynecology and Obstetrics (FIGO) http://www.who.int/making_pregnancy_safer/health_systems/skilled_attendants/en/index.html

The "Skilled attendance index" is an attempt to measure how skilled the "skilled attendance" really is by establishing a list of clinical procedures, interventions and components deemed necessary for safe deliveries (e.g. taking the blood pressure and writing a partograph). Researchers can then check clinical records against the index to see whether the criteria were met [18]. This assumes that what was recorded was performed and what was not recorded was not performed – which might not necessarily be the case. For example, one study in Kintampo District in Ghana [18] found that less than 20% of facility deliveries met at least 75% of the criteria. Given that in that region one third of women deliver in health facilities, this suggests that only 6% of deliveries truly qualify as skilled attendance (20% of 33% = 6%).

Operationalising skilled attendance as a binary outcome requires grouping several different categories (Figure 2). Three main groups can be identified. While one can be fairly confident in classifying traditional birth attendants (TBAs), relatives, others or no helpers in the home (green circle) as unskilled attendance and (with the above mentioned caveats) health professionals in a health facility setting (yellow circle) as skilled attendance, the third group of home deliveries by various health professionals (orange circle) is more difficult to classify, in part because of the difficulty in determining whether the home provides an adequate enabling environment.

Figure 2: Categories of place of delivery and attendant

(The number of "x"s represents the relative frequency in an arbitrary setting)

	Doctor	Midwife	Nurse	TBA	Relative/ other	Alone
Hospital	xxx	xx	x			
Health centre	xx	xxx	xxx	x	x	
Home	x	xxx	xx	xxx	xxx	xx

When using type of attendant as the criterion (red line), professional delivery at home (orange group) is classified as having skilled attendance but when using place of delivery (blue line), it is not. In order to make an informed judgement of what is most appropriate, it is important to have information on the frequency of these categories as well as on skills and enabling environment in a particular setting.

This knowledge is also essential in order to appreciate what the comparison category comprises. One study in Brazil and South Africa [23], for example, examined the influence of a woman's race on whether a "doctor [was] present at delivery". Without further knowledge about the country, it is hard to tell whether the comparison category was mainly delivery by midwife or delivery by unskilled personnel.

1.2.2 Emergency Obstetric Care

Emergency Obstetric Care (EmOC) is a subset of Essential Obstetric Care (EOC) that focuses on emergency services for obstetric complications. The broader EOC category also includes management of problem pregnancies, monitoring of normal labour, newborn special care and provision of contraceptive methods. The terms have sometimes been used interchangeably.

While there is wide agreement that availability, accessibility and functioning of emergency obstetric services is crucial for preventing women who develop obstetric complications and their babies from dying [24], there is debate whether all women should deliver in a setting that can provide EmOC. The 'skilled attendance for all' approach promotes this notion, pointing out that most complications are impossible to predict and many need quick attention, while some advocates of EmOC consider a clean setting sufficient for most births provided timely detection and referral for complications can be ensured. [25]

1.2.2.1 Signal functions

In their 1997 "Guidelines for monitoring the availability and use of obstetric services" [26] UNICEF, WHO and UNFPA suggest a list of "signal functions" to classify health facilities in terms of their emergency obstetric care services, defining two levels of care: basic and comprehensive EmOC (Box 1). The signal functions are not meant to be a comprehensive list of important obstetric functions, but rather a practical monitoring tool.

Box 1: Signal functions used to identify Basic and Comprehensive EmOC

Adapted from UN Guidelines [26]

Basic EmOC services	Comprehensive EmOC services
(1) Administer parenteral* antibiotics (2) Administer parenteral* oxytocic drugs (3) Administer parenteral* anticonvulsants for pre-eclampsia and eclampsia (4) Perform manual removal of placenta (5) Perform removal of retained products (e.g. manual vacuum aspiration) (6) Perform assisted vaginal delivery (forceps or vacuum extraction)	(1–6) All of those included in Basic EmOC (7) Perform surgery (C-section) (8) Perform blood transfusion

A Basic EmOC facility is one that performs **all** of functions 1–6.

A Comprehensive EmOC facility is one that performs **all** of functions 1–8.

*Parenteral administration of drugs means by injection or intravenous infusion (‘drip’).

In order to really measure life-saving capacity, it is important to evaluate “how facilities are actually functioning, and not […] how they are supposed to function” [26]. Therefore, assessments generally inquire about whether each signal function was performed at least once during the previous 3 months, as this implies the presence of a number of essential factors such as providers competent to perform the procedures and availability of equipment and drugs. “The notion that these services are available 24 h a day, 7 days a week (24/7) is also implicit in the definition.” [27] The procedure used by the Averting Maternal Deaths and Disability Program (AMDD) during a needs assessment therefore involves checking of registers, drugs, equipment and staffing during visits to potential EmOC facilities in order to establish actual functioning [27].

In a large number of countries, assisted vaginal delivery using either forceps or vacuum extractor is no longer taught or promoted and therefore not routinely performed [28, 29]. While this is regrettable given that in particular vacuum extraction certainly is beneficial [28], it would be misleading in these settings to discount facilities as EmOC just because they lack one signal function [30]. The AMDD program therefore proposed calling such facilities “Basic EmOC minus 1” (BEmOC-1) or “Comprehensive EmOC minus 1” (CEmOC-1), specifying that the missing function is assisted vaginal delivery [30, 31]. The terms BEmOC-2 and BEmOC-4 (for facilities lacking 2 or 4 basic signal functions) have been suggested for tracking progress [31] since these facilities do provide some useful services but need upgrading to qualify for BEmOC status.

A recent overview of the availability of signal functions in 13 developing countries [32] found that while differences between countries are large, the medical functions, especially antibiotics and oxytocics, are generally more often available than the manual procedures. Assisted vaginal delivery is the least frequently available basic function. It was also found that availability of C-section and blood transfusion are not necessarily linked.

1.2.2.2 UN process indicators

The UN Guidelines [26] also contain six process indicators - known as the UN process indicators - for monitoring EmOC coverage and to some degree performance. While easier to measure than maternal mortality, these process indicators are also valuable in providing information on where the problem lies and thus which interventions are needed to improve the situation.

The six indicators include 1) the number of facilities offering basic and comprehensive EmOC functions; 2) their geographic distribution; 3) the proportion of all births occurring in EmOC facilities; 4) the percentage of women with complications treated in those facilities (met need) among women assumed to need services because of complications; 5) the C-section rate and 6) the obstetric case fatality rate.

The first two indicators deal with coverage or availability of EmOC facilities. The updated guideline from 2009 suggests that there should be at least 5 EmOC facilities per 500,000 population (or 20,000 births) of which at least one should be a comprehensive EmOC facility, both at the national level (indicator 1) and for each subnational level (indicator 2) [33].

Examining “global patterns in the availability of emergency obstetric care” [27] shows that while there are usually enough comprehensive facilities (CEmOC) per population on the national level, basic facilities (BEmOC) are consistently missing in sufficient numbers. This is because the majority of health centres providing maternity services lack some signal functions [27]. Moreover, even where there are enough CEmOC facilities on a national level, these tend to be concentrated in the largest cities and the required level is rarely met in all subnational areas [27]. The lack of BEmOC facilities becomes even more extreme at subnational level, in particular in rural areas [27].

The 1997 UN guidelines recommend monitoring the number of EmOC facilities “in areas smaller than the country as a whole – the smaller the better” as “an efficient way of checking on the distribution of E[m]OC services throughout the country” [26]. They also suggest that “it might be possible to establish a reasonable standard” such as “Basic E[m]OC available within three hours’ travel of most women and Comprehensive E[m]OC available within 12 hours” [26]. In a setting where the population walks, and assuming a swift walking speed of 5 km per hour, this means 15 km for BEmOC and 60 km for CEmOC. Assuming driving at 60 km per hour, this means 180 km for BEmOC and 720 km for CEmOC. The report laments, however, that collecting and analysing the necessary data would need too much time and resources [26].

A review of the six UN process indicators and their application showed that monitoring “the geographic distribution of EmOC facilities […] remains globally under-used” [34]. “Lacking the technology (digital maps, geographic information systems), most projects have difficulty in assessing and expressing this important indicator of equity”, the authors report [34]. This is echoed in Paxton’s reflections on a decade of experience with the process indicators, which suggest that “it would be useful in the future to create more complex maps that show facilities' EmOC status, the distance (both in travel time, roads and other measurement units) to communities in their catchment area, their location in relation to population density, and any elements that may inhibit women's access” [31].

1.2.2.3 Required staffing levels

In the “benchmarks for supply-side needs” published in the World Health Report (WHR) 2005 [35], the estimates of required staffing levels for universal delivery care assume that a midwife can easily assist 175 births per year, a figure that seems reasonable, though is not based on evidence of the ideal number of deliveries per midwife, but rather refers to the observed median of certain Sub-Saharan district hospitals associated with Medicus Mundi in situations with unclear catchment population [36]. The WHR 2005 calculates that for a district with 3600 births annually (corresponding to 120,000 population if the crude birth rate (CBR) is 30 and to 90,000 if CBR is 40), this implies that 20 midwives are needed to assist all the births. The report further suggests that half of them work at the district hospital while the others work in small teams in health centres across the district [35].

The WHR 2005 likewise estimates that around 7% of deliveries require backup care, which corresponds to 250 out of 3600 births, and that 2-3% are surgical cases (70-100 deliveries out of 3600). Furthermore, it estimates that 9-15% of newborns require backup care for complications. The recommendation is to have at least “one full-time equivalent doctor” in such a district of 3600 births around the clock. This may mean 3 doctors who work in obstetrics part of their time taking shifts. [35]

1.2.2.4 Previous EmOC studies in Zambia

In 1996, a Safe Motherhood Needs Assessment was carried out in 9 Zambian districts, covering a sample of 11 hospitals and 102 health centres in both urban and rural areas. Serious gaps were identified in the quality of maternal health care services. “This was largely due to lack of midwives at most health centres and lack of essential equipment and consumables. In addition, referral systems and linkages were found to be poor with most facilities having no communication facilities at all.” [37]

In 2001, UNICEF carried out an “Essential Obstetric Care needs assessment” in three districts in the Eastern Province of Zambia [37]. This involved the collection of basic information on all 49 health centres providing maternal care there and a detailed survey of two district hospitals and 15 health centres using questionnaires and interviews with providers, mothers and TBAs.

The results showed that only about 16% of deliveries in the area occurred in health facilities, mostly in hospitals, with some health centres having very low numbers of deliveries. The two district hospitals qualified as CEmOC and CEmOC-1, but most health centres did not qualify as BEmOC since the manual signal functions (manual removal of placenta, removal of retained products, assisted vaginal delivery) were often lacking. The BEmOC-1 classification was not used. A third of all health centres were staffed with only one clinically trained health worker and interviews revealed a severe lack of knowledge and skills in emergency obstetric care among health workers. "When asked directly, 42% felt they were not competent enough to deal with obstetric emergencies." [37] Infection prevention measures were not widespread with only 24% of health workers wearing clean gloves before an obstetric exam and only 16% washing their hands with soap before and after the exam. Newborn care was also poor, including in the hospitals, where resuscitation trolleys were lacking. In terms of equipment, basic supplies such as cord clamps were often absent. Only 28% of health centres had working communication tools and very few had ambulances. [37]

In 2005, the Central Board of Health with help of UNICEF carried out a national survey on Emergency Obstetric Care in Zambia. [21] The aim was to assess the level of basic and comprehensive EmOC in Zambia based on UN process indicators and to explore factors that contribute to non-availability. All 13 provincial and general hospitals and a sample of 42 other hospitals and 175 health centres were included in the survey, starting from a national list of potential EmOC facilities. [21]

According to the report, six out of the 55 hospitals only offered basic but not comprehensive EmOC, while another three did not even fulfill the criteria for basic EmOC. Of the surveyed 175 health centres, none fulfilled the basic EmOC criteria since one or more of the basic signal functions were missing; especially manual removal of placenta, removal of retained products and instrumental deliveries were often not provided. EmOC facilities were concentrated in the urban areas of the Copperbelt and the capital Lusaka. [21]

The survey found a severe shortage of midwives in all districts and many of those available lacked life-saving skills. In several hospitals there was only one doctor, frequently lacking EmOC skills, or no doctor was available at all. The shortage of qualified staff was most severe in rural areas, where nonmedical workers and TBAs frequently run the clinics. It was found that only half of the facilities followed the guidelines for management of the third stage of labour, that infection prevention measures were poor and that basic equipment and drugs such as cord clamps, ambu bags, oxytocin and magnesium sulfate were in short supply. Furthermore, sufficient numbers of beds and toilet facilities were often lacking. Referral was still a problem, but most facilities by 2005 had functioning radio or phone communication and there was an ambulance in each district – even if the latter may have served up to 37 health facilities in all directions. [21]

Most recently, an EmOC survey was carried out in Central Province in 2006/07 as a baseline assessment for a collaborative EmOC initiative between the Zambian Government and the Massachusetts General Hospital's Center for Global Health [38]. It visited a random sample of 29 health centres performing deliveries and found "notable gaps in medication supply and equipment" as oxytocics and magnesium sulfate were unavailable in the majority of health centres and only few facilities had vacuum extractor, forceps or aspiration syringe. While the vast majority of interviewed staff felt comfortable giving intravenous medications and manually removing a placenta, only half were confident in treating eclampsia or removing retained products and only 2 out of 35 were confident in performing assisted vaginal deliveries. The study considered a signal function present at a facility if both a confident provider and the necessary tools were available, even if the function had not been performed in the previous 3 months. None of the surveyed health centres had all 6 basic signal functions present, 7% provided 5 functions, 10% provided 4 functions and 59% provided 2 or 3 functions.

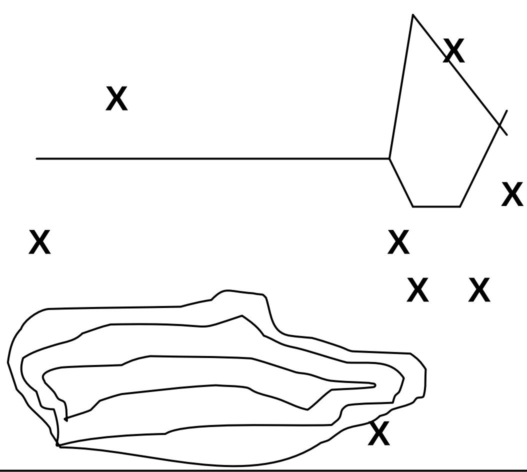
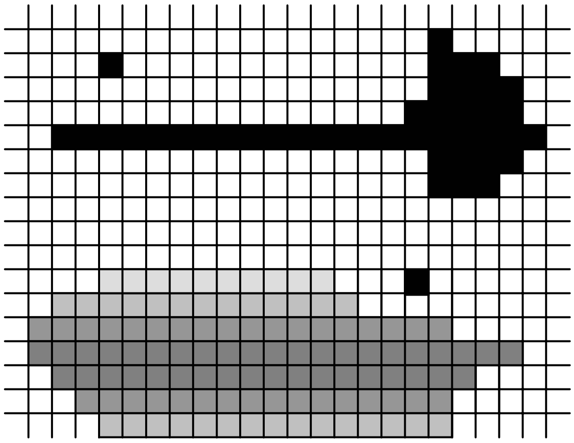
1.2.3 GIS and distance measurement

1.2.3.1 Geographic information systems

A geographic information system (GIS) is a computer system that has been set up to facilitate the analysis of spatial data. It links the geographic coordinates of an object with certain attributes. The resulting files are often referred to as shapefiles. As the surface of the Earth is curved, projections are used to 'flatten out' the areas of interest, e.g. the Universal Transverse Mercator (UTM) system.

There are two types of GIS, vector and raster. In vector GIS objects are represented by their coordinates while in raster GIS they are represented by cells in a grid. Vector GIS is the more common form, but raster GIS is needed when looking at continuous surfaces (Figure 3).

Figure 3: Vector and Raster GIS

Vector GIS	**Raster GIS**
	

1.2.3.2 Distance measures

The simplest way to measure distance is straight-line, “as the crow flies”, also called Euclidian distance. It can be a good approximation to the actual distance travelled. However, it can also be too crude, particularly where significant barriers (e.g. mountains, lakes) force people to take a longer route around.

Where data are available on the actual road (or river) network, it is possible to adjust for this problem by measuring distance along those lines from one point to another. One can also estimate travel time by assigning speeds to different pieces of road or river. Taking account of this is possible within a vector GIS.

However, in many poor countries, one cannot assume that people travel along roads. They might instead walk over the terrain and on small paths. Furthermore, altitude should be considered. Walking over a mountain is a longer distance than through a tunnel, and walking uphill or downhill might take longer or shorter than walking on a plain. Using a raster GIS, one can assign travel speeds to all passable grid cells according to their surface characteristics and steepness, and thus create a friction surface. The time cost assigned to crossing each cell then allows to calculate a “cost distance” as the minimum travel time from a starting cell to a destination cell [39].

Even though this “cost distance” or “cost-surface friction” method gives a more realistic picture of travel time in rural areas than using straight-line distance or relying on roads, it is still a crude approximation. One can only guess how easy it is to cross a certain cropland or forest or even river and it will differ by season. Also, travel speeds strongly depend on mode of transport, which differs between people and is often unknown.

1.2.3.3 Applications

The majority of research using GIS to examine health service use has been at the ecological level and located in developed countries. A common approach is to construct “catchment areas”, i.e. areas around hospitals or health centres from where people can reach those facilities within a certain time limit (e.g. 1 hour). Combined with census data and utilisation data, this allows calculating the proportion of the population underserved. It can also be used to look at associations with health outcomes.

Sophisticated approaches allow for different speeds along a road network (as has been done in Canada and New Zealand for example [40, 41]) and even public transport timetables (e.g. in Cornwall, UK [42]). Several studies in rural areas of developing countries have used versions of the cost-surface friction method (e.g. [43, 44]). A recent analysis in South Africa developed a hybrid walking and public transport model using this method, calibrated with observed clinic use [45].

Ecological level analyses have their limitations, however. Rushton’s recent review on “Public Health, GIS and Spatial analytic tools” [46] notes that despite an “increased use of point data rather than areal data in public health applications of GIS, the use of explanatory variables at the individual level… has not yet proceeded far”. He continues: “The familiarity of ecological modeling approaches appears to be responsible for the very slow adoption of what surely should be regarded as a most promising approach.”

Similarly, the review article “GIS and health care” by McLafferty [47] on the use of GIS in analysing health care need, access and utilization also observed that most research so far used area-based measures and she calls for “innovative methods”:

> *“An exciting new approach involves the use of individual-level data and multilevel modelling to understand variations in health care utilization. With multilevel modelling, one can estimate the effects of individual characteristics, as well as GIS-based measures of local health care supply and access.”*

She reports that researchers are increasingly starting to use these methods including some who are using them to investigate the determinants of health care use [47].

A recent example is a study in Malawi linking DHS and Health Facility Census data to look at the effect of distance to reproductive health services and a number of individual and household level variables on contraceptive use [48]. Similarly, a study in Kenya used GIS to examine mosquito net use by children in relation to distance to a market, household wealth, education of the mother and other household and individual factors [49].

McLafferty’s review concludes that “research areas that can benefit from GIS, such as research on geographic variations in health care utilization, have not made full use of GIS capabilities” which is “partly a result of structural barriers”: “Data are often unavailable” and “privacy and confidentiality restrictions limit access to data” [47]. My own experience certainly confirms the latter point (see e.g. 2.4.1).

1.2.4 Ability to pay

1.2.4.1 Measures of economic status

Socioeconomic status or position is a multidimensional construct [50, 51] describing both social and economic circumstances of living. Various indicators (e.g. education, occupation, place of residence, income) describe different but related aspects [52, 53]. If one believes that these aspects can have separate effects on the outcome, it makes sense in explanatory studies not to combine them but rather try and disentangle their effects by making their proposed specific causal mechanisms explicit [54]. In this section, I examine the economic aspects that influence ability to pay. There is no consensus in the literature about the exact meaning of the various terms. I will use economic status and living standard interchangeably here.

In their attempts to measure standard of living, economists usually employ income or consumption expenditure. While income can vary substantially over time, consumption is thought to be more stable and to reflect "permanent income" [55], since saving and borrowing even out fluctuations. Consumption is widely regarded as the best measure of living standard in developing countries, where self-employment is common and fluctuations in income can be extreme. However, it has also been argued that wealth, the sum of all financial and physical assets, is a better measure because – like income – it reflects the opportunity to consume rather than actual consumption. Furthermore, since wealth represents the long-term accumulation of assets, it can have advantages when trying to measure past economic circumstances.

It is very difficult and extremely cumbersome to measure consumption, in particular in developing countries where non-monetary transactions and home production are common. While it would also be difficult to measure all physical and net monetary assets a person owns, it is easy to observe certain indicator variables that are associated with a person's (or household's) wealth. Several variables collected by the Demographic and Health Survey (DHS) have been used for this purpose [56]. The variables are combined into an asset index that is thought to measure relative wealth, usually in quintiles.

This asset-based approach has become very popular, especially since the World Bank has created and published wealth indices for many DHS countries. The component variables include valuable household goods like radio, television, bike or car, building materials of the dwelling, land ownership, presence of a domestic servant, fuel type, water source, toilet type and availability of electricity.

There are, however, some potential problems with this approach. Many of the indicator variables can have a direct effect on certain health outcomes (e.g. sanitation→ diarrhoea→ child mortality) that would then be hard to separate from their indirect effect through economic status. Secondly, some of the indicator variables are services that are usually publicly provided such as electricity and piped water. It might therefore not be justified to use them as indicators of *household* economic status. However, living in areas where those services are available is probably more expensive and therefore does tell something about a household's economic status, at least in urban areas.

While living standard can be conceptualised at the community, household or individual level, most commonly, data are collected at household level. There is agreement that income or expenditure data need to be adjusted for household size and composition to accurately reflect economic status, although there is debate on how exactly this should be done. It is less obvious that an asset-based wealth index needs such adjustment and it has been argued that this is not necessary and might even lead to distortions [56, 57].

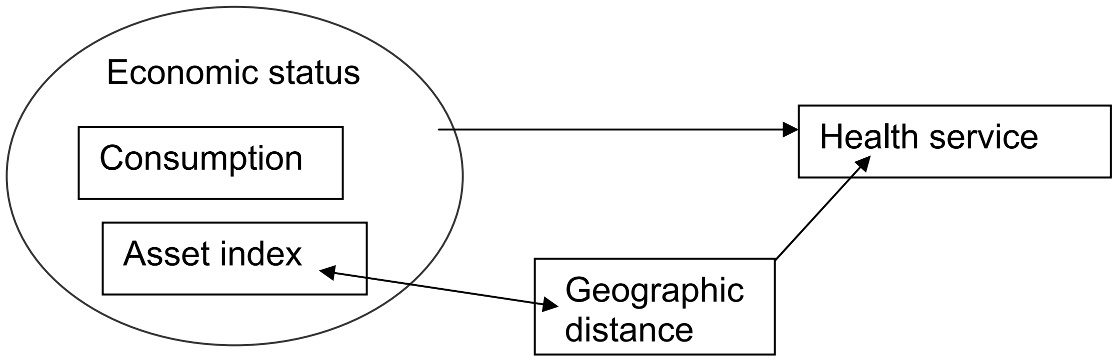
1.2.4.2 Comparison of different measures of economic status

A recent systematic review of articles comparing agreement between asset-based wealth indices and consumption expenditure found that agreement was generally weak, especially in low-income settings and when a limited number of assets was used [58].

Where rank differences between the measures are correlated with the outcome of interest, the choice of measure will influence the magnitude of associations found, e.g. when estimating health inequalities by economic status. The influence on results may be substantial or negligible and is hard to predict [57-59]. Some researchers demonstrated a better model fit to the data and more plausible results when using a simple asset index as compared to using expenditure data or monetary value-based asset indices [56, 60].

Several studies found that inequalities in health service use outcomes (including delivery care) were larger when using asset indices as compared to consumption data [56, 61]. When analysing why this was the case, Lindelow [61] realized that the probability of owning certain assets was associated with physical access to health services while consumption was not to the same degree. Availability of running water, electricity, housing materials and consumer goods is closely linked to availability of decent roads and health services. This can be regarded as confounding of economic status by remoteness or geographical distance to services (Fig. 4).

Figure 4: Confounding of the relationship between economic status and health service use by geographic distance when using an asset index.



Lindelow acknowledges that “the bivariate perspective is […] quite restrictive. It confounds the impact of many different determinants of health and health service outcomes” [61]. Even when controlling for urban/rural residence and region of residence, there was still an association of economic ranking with remoteness “as measured by distance to a health center” [61]. He concluded that “physical access to health services is a key factor” in explaining the underuse of health services and that “most likely other factors are also at play, including at individual, household and community level”. Since the observed economic inequality gradient depends on the correlation of economic status with those other factors, we should also explore “inequalities along other dimensions than socioeconomic status” [61].

This demonstrates that care must be taken when using an asset index (in particular one including infrastructure assets) to disentangle the effects of financial and geographical factors on health service use.

1.2.4.3 Application issues of asset indices

Although some researchers have used other weighting systems to combine assets into a wealth index (e.g. reciprocal weights [62]), and simple sums seemed to perform quite well in Bollen's comparison [60], principal component analyses (PCA) has been most popular in recent years [63] and was also used by the World Bank to create a wealth index from DHS data. This statistical technique extracts several uncorrelated components from a set of correlated variables. The components are linear weighted combinations of the original variables. The first component is chosen to explain a maximum amount of the variation observed in the data and is usually assumed to represent the concept of interest (here wealth). It can be used as a continuous variable or categorized (often into wealth quintiles).

In order for PCA to work well, the assets included need to be correlated with each other (and measure a common concept) and they should exhibit some variation over households. If there is little variation in asset possession, most households will get similar scores, a phenomenon referred to as clumping or heaping [63]. The longer the list of assets, the better PCA can differentiate between households [60]. While Filmer found his results to be robust to which assets were included [57], Houweling's analysis from 10 countries [54] concluded that results were mostly sensitive to excluding certain variables from the index (variables thought to have a direct effect and infrastructure variables). Moreover, the direction of change in the inequality was not always as theoretically predicted [54].

The large differences in assets owned between urban and rural areas have motivated some researchers to create separate indices for urban and rural areas and perform separate analyses. This may allow a better differentiation between rural households, which otherwise would be mostly lumped into the lower categories of a combined urban-rural asset index.

It should be considered that PCA was originally developed for the multivariate normal distribution and therefore works best on variables that are continuous and approximately normal [64]. As Kolenikov and Angeles point out further [64], results might be biased and inconsistent when using PCA on discrete data. They show this is even worse if categorical variables are binarised into dummy variables as has been suggested by Filmer and Pritchett [57]. A better performance in a simulation study could be achieved when using a large number of indicator variables with many categories, having equal distances (Likert scale) between ordinal categories (e.g. 1,2,3,…), avoiding heavily tailed distributions, and standardising variables [64].

1.2.5 Women's autonomy

Women's autonomy has been defined as the ability to make decisions and act upon them, while women's status is rather about social position and respect and does not necessarily include the ability to execute one's own preferences [65]. Women's empowerment refers to a gain in influence [65] but is also used in a similar sense as autonomy, as the power to control one's own destiny even when one's interests are opposed to those of others [66].

In the context of skilled delivery care, women's autonomy could be an important determinant if women want to use the service but others oppose. This is not necessarily the case. For example, for fertility, the importance of female autonomy has been questioned, given that husband and wife often agree on the desired number of children [67]. However, this could also be due to women not daring to disagree and adjusting their preferences to their husband's.

Furthermore, female autonomy can only exert a positive influence where choices exist. A study in India [68] found that more autonomous women are more likely to use health facilities for delivery, and that this was only the case for urban, but not for rural women. Where access to maternal health care is extremely limited, even autonomous women cannot obtain care.

In terms of measurement of female autonomy, surveys have started to ask direct autonomy questions in recent years. The DHS for example now inquires who has the final say on various decisions such as household purchases, health care and visits to relatives, as well as about attitudes towards wife beating and women's right to refuse sex. Previously, research relied on proxies such as woman's age, employment, difference in age and education compared to the husband, or age at marriage. The reasoning was that these factors are linked to autonomy via experience and self-confidence, a closer relationship to the husband, proven reproductive success, and independence through own earnings among others. [69].

While proxies have been shown to be reasonably related to the more direct measures of autonomy when comparing between countries, this seems to be less the case within countries, where inter-individual differences tend to be smaller [69]. Furthermore, it has never been very clear which of the many aspects of autonomy any of the proxies are measuring [69] and how to disentangle their autonomy implication from their other effects. The new direct DHS questions on some aspects of autonomy were meant to capture the concept in a better way, but they also have problems.

The first issue to consider is that the various dimensions of autonomy are not necessarily correlated and that the pattern of correlation depends on the context [69]. Women can for example have a lot of say in financial decisions but their movement outside the house may be restricted or they may be able to decide on daily food and purchases but not on health care and family planning. Even when restricting our interest to health care decisions, women's decision-making power may depend on the particular problem and circumstances. For example, in the Middle East, women decide on their own health care themselves, but infant care is a domain of the mother-in-law. This makes it difficult to generalise from the few questions asked in multipurpose surveys such as the DHS.

Moreover, different communities, men and women, or different individuals might interpret autonomy questions in different ways, as suggested by the substantial disagreement found in studies comparing couples' responses [65, 70]. While latent constructs can deal with random measurement error, the fundamental question whether the "survey items are [really] capturing an underlying level of autonomy, or something else" [65] remains. And if we cannot trust the validity of our questions, then any observed association between women's autonomy and health outcomes is hard to interpret [65].

It has been suggested that one should separate instrumental decisions such as cooking the family's food or taking a sick child to hospital from "selfish" decisions that only benefit the woman, such as her own health care or leisure activities like visiting friends or watching television, since true empowerment is only represented by the latter [71]. Skilled attendance at delivery benefits both mother and child, so this separation seems less important here.

Mason and Smith [69] pointed out that instead of staying at the individual level, it might make more sense to conceptualise autonomy at the social-system level and to use aggregate measures. Their analysis of data from five Asian countries showed that gender systems with their social norms explain most of the variation in women's empowerment across communities while individual factors explain only little [69]. A potential explanation is that "even highly empowered women, when living in a society where women have little say, may find their power diminished" and that "a community that views women as capable of making independent decisions might positively influence a woman who has little power in her day-to-day life" [72]. A study on the influence of female empowerment on several health outcomes in 12 countries found that the effect of average community decision-making power was much larger than the effect of individual decision-making power [72]. This is in line with Mason's conclusion that empowerment is more a social than an individual trait [69].

1.2.6 Clustered data

After having described various conceptual and measurement issues of outcome, exposure and two potential confounders above, I will now briefly touch on some important issues related to the analysis method.

When cluster sampling has been employed, as in the DHS, observations are not independent, i.e. births from the same cluster are more similar to each other in terms of delivery circumstances than to those from other clusters. Ignoring this dependency in the model will give wrong standard errors. This is often dealt with by using a so-called sandwich estimator for the error, yielding robust standard errors [73].

While this approach corrects the standard errors, its exposure effect estimates remain the same as they still rely on the assumption that the cluster-level effect is not different from the individual-level effect (the latter usually being the effect of interest). If this assumption does not hold and the exposure-outcome relationship is indeed different on the two levels, the (individual) effect estimate from a model ignoring the clustered data structure will be biased towards the cluster level effect. [74]

This is related to the well-known concept of the ecological fallacy, where conclusions drawn from cluster-level relationships are falsely applied to individual-level relationships. However, even if individual-level data are used to estimate individual-level effects, ignoring the underlying clustered structure of the data can lead to serious bias.

An artificial example (taken from Diex-Roux's "A glossary for multilevel analysis" [75]) is shown in Figure 5. The outcome is pedestrian deaths by car accident and the exposure is poverty. Individuals (circles) are clustered inside regions (colours). Regional averages are depicted by squares (Fig. 5a). The poorer regions have less car accident deaths due to their lower car density, so the relationship on the cluster-level is negative. Inside each region, however, poor people are more likely to be killed by a car than rich people, because the poor are more likely to walk, so the individual-level relationship is positive.

Analysing these data by putting a regression line through all the points and just correcting the standard error of the slope for false precision due to cluster sampling will give a very biased estimate for the individual relationship (Fig. 5b).

Figure 5a: Example of different between- and within-cluster relations

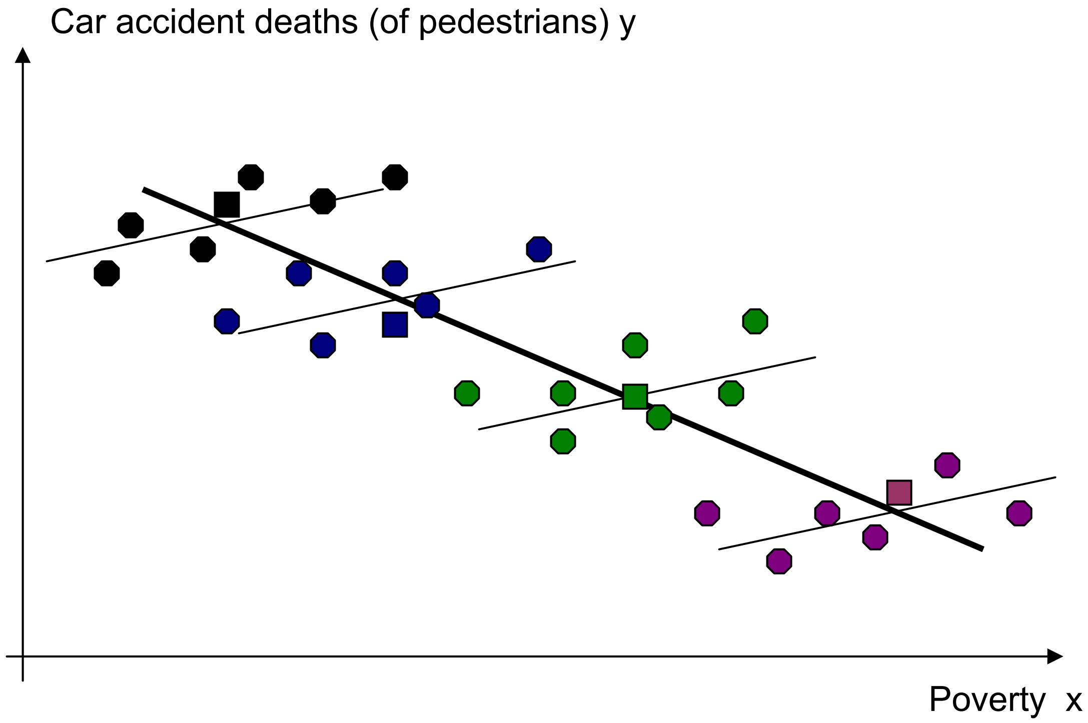
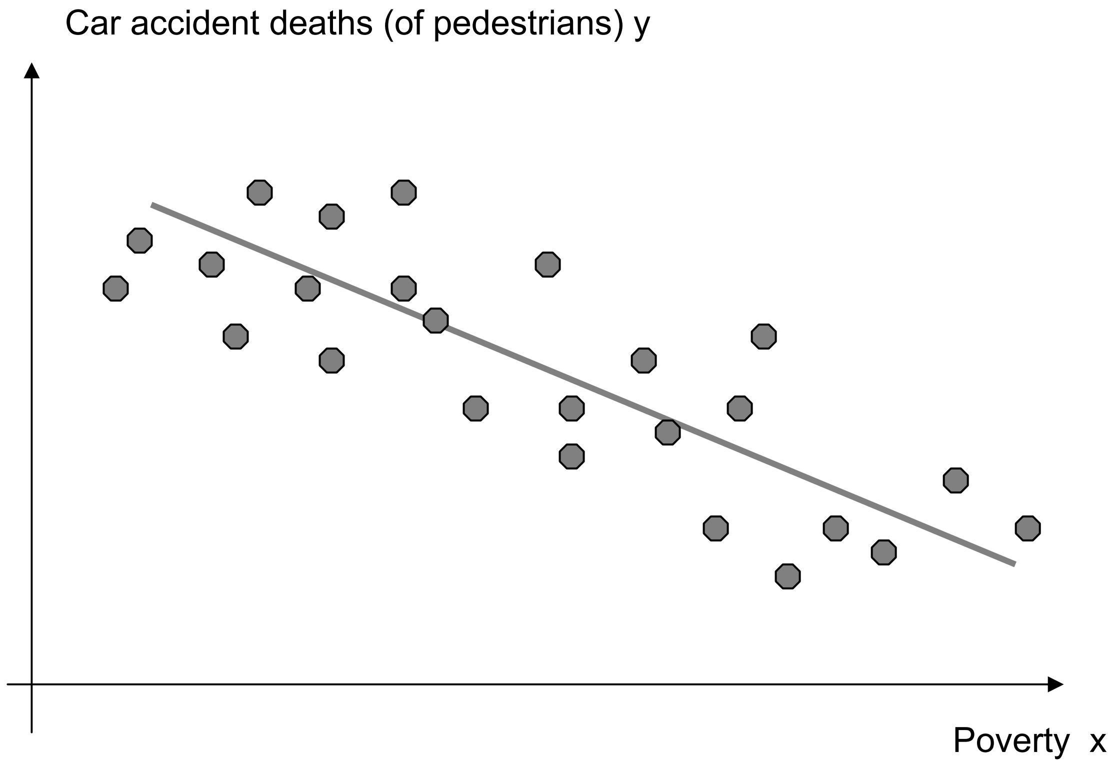


Figure 5b: Example of different between- and within-cluster relations



Instead, it is necessary to model the clustered structure explicitly. The simplest way to do this is to add an indicator variable to the model for each cluster (fixed effects model). In the example, this would estimate the level of pedestrian mortality by car accidents in each region relative to a baseline region (fixed intercepts) and the slope estimate would be the average slope *within* regions, i.e. the individual effect. However, this approach does not allow to estimate the effect of exposures on the cluster level, e.g. in this example cluster-level poverty, as all cluster-level information is absorbed into the cluster intercept.

If some exposures of interest are on the cluster level, one can use random effects models. As in fixed effects models, each cluster is allowed to have its own specific effect on the outcome that all its members share. However, this is not estimated separately for each cluster, but treated as an unobserved random variable (hence the name) drawn from a distribution with mean zero, so that only the standard deviation of that distribution needs to be estimated.

Such models allow simultaneous analysis of the effect of an exposure at the cluster and at the individual level (or even several levels of hierarchy), as well as exploration of correlations within levels before and after adding covariates.

Instead of assuming that the within-cluster slope is the same for each cluster and that just the intercept differs (modelled as a fixed or a random effect), random effects models can also let the slope differ between clusters (random slopes model).

If the within-cluster slope depended on a cluster characteristic, e.g. if the individual poverty gradient was steeper in richer clusters, this would be cross-level interaction, which can also be explored and accomodated in random effects models.

1.3 Literature review: Determinants of skilled attendance

1.3.1 Introduction

After having presented various important conceptual and measurement issues, I will now give an overview of the literature on determinants of skilled attendance. The term skilled attendance is not used here in its strict definition of a truly skilled provider in an enabling environment, but rather pragmatically as an umbrella term for any outcome definition aiming to approximate this, usually any health professional present at delivery. Where possible, I refer specifically to delivery attendant or place.

A large number of studies on determinants of skilled attendance at delivery have investigated a plethora of potential influential factors. In their review article “Too far to walk” Thaddeus and Maine [76] summarise these factors under their conceptual framework of the three delays. Their focus, however, is on factors “that affect the interval between the onset of an obstetric complication and its outcome” [76], i.e. on care-seeking for obstetric emergencies. Although their third delay can apply to all facility births, there is an implicit assumption in their framework that most births occur at home, which is the norm in settings with the highest maternal mortality, and that the first and second delay occur in response to the need to change the delivery venue because of a complication.

Behavioural theory stresses the importance of defining context for behaviour precisely, since the “substantive factors influencing one behaviour are often very different to those influencing another behaviour” and “the most effective interventions will be those directed at changing specific behaviours” [77]. For instance, the determinants of condom use with a regular partner differ from the determinants of condom use with a casual partner [77]. Similarly, we would anticipate that the determinants of preventive care-seeking for delivery (i.e. precautionary seeking of a skilled attendant as women go into labour for anticipated normal delivery) are not necessarily the same as those for emergency care-seeking in reaction to a developing complication.

The framework of the three delays of Thaddeus and Maine was expanded to conceptually distinguish emergency care-seeking and preventive care-seeking (Figure 6). While similar factors are involved, their relative importance may differ or they may act in a different way. Cost of transport, for instance, is likely to be a greater deterrent for preventive than for emergency care-seeking. Physical accessibility may exert its role on preventive care-seeking mainly through influencing the decision to seek care, while in the case of emergency care-seeking, reaching the facility in time may be the main problem.

Thaddeus and Maine clearly distinguish between the direct effect of actual accessibility on reaching a facility (second delay) and the indirect effect of perceived accessibility on the decision to seek care (first delay), and correspondingly for actual and perceived quality of care. In Figure 6, the effects of perceived factors are indicated by dashed arrows.

I also changed the categorisation of economic factors in the framework. Thaddeus and Maine grouped economic status and women's access to money among socioeconomic / cultural factors, a category that is thought to only influence decision-making but not the ability to reach a facility. Economic status was included in the accessibility category which influences both. The socioeconomic / cultural factors are thus reduced to sociocultural factors, from which I further separated those that influence perceived benefit / need of health facility use. I also split the accessibility category into economic and physical accessibility.

Concerning quality of care, I distinguished quality of emergency care from quality of preventive care. While quality of emergency care – in line with the original framework – is thought to influence the third delay (receiving adequate and appropriate treatment), good quality preventive care for facility deliveries is thought to prevent some complications from arising. Since this literature review investigates determinants of facility use rather than determinants of maternal mortality, the direct effect of quality on the third delay is not relevant here. For simplicity I therefore included the indirect effect of perceived quality of care into the category of perceived benefit / need.

While it is important to clarify conceptually how the various influential factors might affect the three delays for both preventive and emergency care seeking, I did not identify any studies that attempted to distinguish between preventive and emergency care seeking. However, some studies considered the role of complications in care-seeking and I grouped this determinant with the factors influencing perceived benefit / need.

This literature review has been published in BMC Pregnancy and Childbirth [78].

Figure 6: Delay phases and factors affecting use of delivery care and maternal mortality (adapted from Thaddeus & Maine)

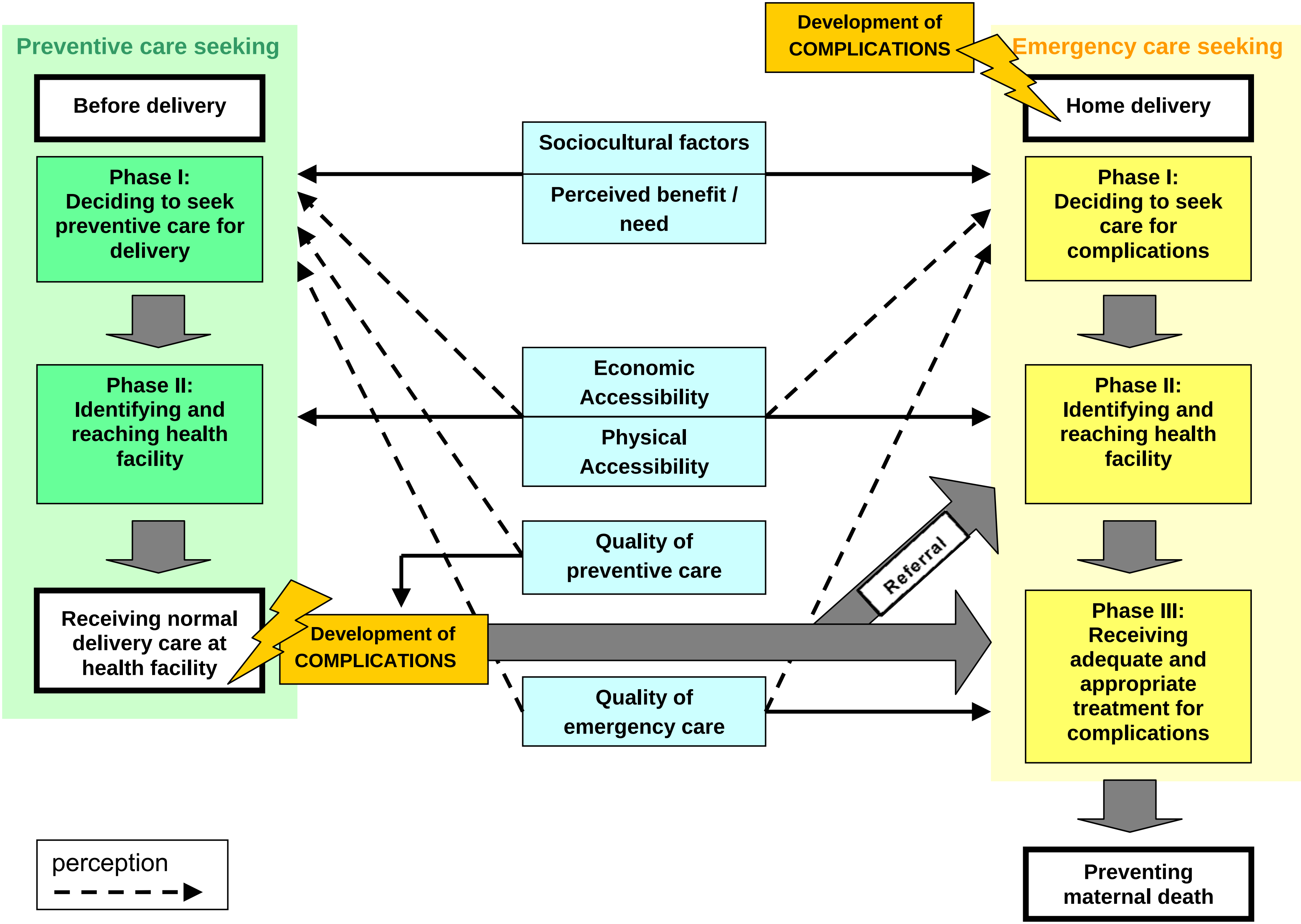


Table 1 summarises the determinants identified in the literature into the four categories of my framework, with their hypothesized mechanism of action and common findings on their effects. A detailed description follows below.

Table 1: Factors thought to be associated with skilled delivery service use in the literature

Determinant*	Rationale	Findings
Sociocultural factors		
Maternal age +++	Older women: more experienced in using services, more confident, more say in household. Young women: more modern.	No difference, or older women more likely to use services in all multivariate studies examined.
Marital status ++	Single mothers more autonomous: more use. But maybe poorer and stigmatized: less use.	No association or either direction.
Ethnicity, religion, traditional beliefs +++	Certain cultural backgrounds, beliefs, norms and values as well as discrimination may decrease care-seeking.	Mixed results. Large differences in some studies, none in others.
Family composition +	Small children at home and no extended family to help should decrease use.	Some found less skilled care if higher number of births in previous five years.
Mother's education +++	Knowledge, access to written information, modern culture, more confident, higher earnings, control over resources, better communication with husband and providers, etc. should all increase use.	Consistently strong and dose-dependent positive effect on delivery service use.
Husband's education ++	Knowledge, modern attitudes, better communication between spouses, higher autonomy for wife, higher earnings, etc. should increase service use.	Higher husband's education consistently increases skilled attendance; effect often smaller than effect of mother's own education.
Women's autonomy ++	Decision-making power, mobility, control over resources, access to transport should increase use.	Most found some aspects to increase skilled attendance, but others found no effect.
Perceived need		
Information availability +	Information about risks of childbirth and about service availability in radio or television should increase use.	Information access associated with more skilled attendance in some studies but not in others.
Health knowledge +	Knowledge about risks of childbirth and the benefits of skilled care should increase wish to use services.	Expected association in some but not in other studies.
Pregnancy wanted +	Higher value attached to desired child justifies expenses for skilled attendance.	Expected association in some but not in other studies.

Perceived quality of care +	Perceived poor personal and medical quality of care, clash with culture and fear of procedures may decrease use.	Qualitative studies generally find perceived low quality decreases use, some describe interaction with distance and cost. Very few quantitative studies.
ANC use ++	Familiarity with services, encouragement by health workers increases delivery service use.	Usually those attending ANC much more likely to receive skilled delivery care.
Previous facility delivery ++	Familiarity with services increases their use.	Nearly always very strongly associated with index facility delivery.
Birth order +++	First birth: more difficult, help from natal family, high value on pregnancy, or unplanned/unwanted. High order births: previous experience, confidence if no problems previously, difficulty to leave home with several small children, poorer families.	No difference or first births and lower order births more likely to have skilled attendance than high order births in the vast majority of studies examined.
Complications +	Pregnancy complications (→ ANC advice), complications during delivery, previous complications (→ women aware, medical risk) should increase use of skilled attendance.	Qualitative studies: important factor, decreases importance of other barriers. Few quantitative studies, several found that women with complications are more likely to seek skilled care.
Economic accessibility		
Mother's occupation +	Own earnings, range of movement, information should increase use. Decreased use expected if work is poverty-induced.	No effect in several studies, association in either direction. Often less use of skilled attendance among women farmers.
Husband's occupation ++	Higher financial resources and health insurance with some occupations should increase service use.	In several but not in all studies increased skilled attendance if higher status occupations.
Ability to pay +++	Costs for transport, care, opportunity costs decrease use by the poor.	Poorer women less likely to have skilled attendance, in some studies no effect.
Physical accessibility		
Region, urban / rural +++	Social and service environment differences between regions. In rural areas generally worse services and infrastructure, more poverty, more traditional beliefs, which all decrease use.	Nearly always moderate to large differentials with less service use in rural areas.
Distance, transport, roads ++	Distance as disincentive and actual obstacle to reach facilities, enhanced by lack of transport and poor roads.	Less service use when further away or no difference.

* Frequency of inclusion in quantitative studies: + rarely, ++ sometimes, +++ nearly always

1.3.2 Sociocultural factors

Sociocultural factors primarily influence decision-making on whether to seek care, rather than affecting whether women reach a facility. One could conceptually distinguish the mother's own motivation to use services from whether she can act on her wishes. However, I considered decision-making of both mother and her family and therefore included women's autonomy and husband's education in this category.

1) <u>Maternal age</u>

Age is often presented as a proxy for accumulated experience, including in the use of health services [23, 79-81]. Older women are also possibly more confident and influential in household decision-making than younger women, and than adolescents in particular [23, 81, 82]. Furthermore, older women may be told by health workers to deliver in a facility since older age is a biological risk factor [23, 80, 83]. On the other hand, older women may belong to more traditional cohorts and thus be less likely to use modern facilities than young women [81].

Age is highly correlated with parity, and, in some settings, with educational level. It is also associated with marital status, wantedness of a pregnancy, socioeconomic status and decision-making power [84].

Most studies on determinants of delivery service use consider age; those with a multivariate analysis (i.e. controlling for parity) find either no effect of age or a higher use of skilled attendance among older mothers compared to younger mothers.

2) <u>Marital status</u>

Marital status may influence the choice of delivery place, probably via its influence on female autonomy and status or through financial resources. Single or divorced women may be poorer but enjoy greater autonomy than those currently married. Young single mothers may be cared for by their natal family, which may encourage skilled attendance, especially for a first birth. On the other hand, single mothers may be stigmatised and prefer to deliver at home because they anticipate a negative provider interaction [85].

Several studies include marital status and find no association with skilled attendance [86-88], while some find less facility use among married women [89-91]. Studies used a variety of groupings and some did not adjust for confounders, making results difficult to interpret. One study looked separately at monogamously married, polygamously married, never married and formerly married mothers in six African countries. Results vary from showing no association (Tanzania, Ghana, Burkina Faso), to monogamous women seeking care more often than the other groups (Ivory Coast and Kenya), to formerly married and polygamous women seeking more care (Malawi) [92].

3) Ethnicity and religion, traditional beliefs

Ethnicity and religion are often considered as markers of cultural background and are thought to influence beliefs, norms and values in relation to childbirth and service use and women's status. Moreover, certain ethnic or religious groups may be discriminated against by staff, making them less likely to use services [80].

More specifically, women in some cultures may avoid facility delivery due to cultural requirements of seclusion in the household during this time of "pollution" [93] or because of specific requirements around delivery position, warmth, and handling of the placenta. In some cultural groups in Africa, the belief that obstructed labour is due to infidelity hinders care-seeking [76, 94]. Beliefs that birth is a test of endurance, and care-seeking a sign of weakness may be another reason for delivering alone in some contexts [95].

In many societies, ethnicity and religion are closely linked to socioeconomic position [80, 86] and place of residence; minority ethnic or religious groups may live in remote areas with worse health infrastructure and transport. Inadequate control for socioeconomic position, place of residence or access to services will lead to residual confounding.

Many studies include ethnicity and/or religion, with mixed findings. Most Latin American studies find that indigenous women are less likely to have skilled attendance at delivery [79, 80, 96-99]. Ethnic minorities in China [100], Kurds in Turkey [101], members of scheduled castes/tribes in India [81], Catholics in Vietnam [102] and non-whites in South Africa [23] are also less likely to receive skilled care. In Ghana, no ethnic differences were detected [86, 103], but members of traditional religions and Muslims are less likely to use delivery services as compared to Christians. Several other studies report no ethnic or religious differentials for their settings.

Fewer studies look at beliefs and attitudes directly. Those that do, find that women holding biomedical health beliefs [80], those who had used family planning [104] and those who did not mind being delivered by a male provider [91] are more likely to use skilled providers. Using traditional medicines is not associated with skilled care in two studies [81, 105], neither is the presence of ayurvedic providers and traditional birth attendants (TBAs) in the community in a study in Uttar Pradesh [106]. Another study used a high proportion of husbands in the community approving family planning as well as a lower average number of children as measures for modern attitudes and found these to be associated with higher use of facilities for delivery [92].

4) Family composition

Women with young children may have difficulties finding child-care while they deliver at a health facility, in particular if they live in a nuclear family. Sometimes women are accompanied by family members during their hospital stay, so that even these cannot take care of other children during the time [85]. In addition to influencing the ease of leaving home, living with an extended family may also influence decision-making power of the woman; and the number of small children at home may also be a proxy for socioeconomic status, which may be hard to control for.

Few studies consider family composition. Some find a significant influence of the number of births in the previous five years on whether the mother delivered the index birth in a health facility [87, 107]. Other studies however do not find any association of preceding birth interval (as a measure of age of the youngest preceding child) [104], of number of children under five in the household [108] or of the ratio children to adults in the household [109] with facility delivery.

5) <u>Mother's education</u>

There are multiple potential pathways that could explain why "maternal education is consistently and strongly associated with all types of health behaviour" [83]. These include increased knowledge of the benefits of preventive health care and awareness of health services, higher receptivity to new health-related information, socialisation to interact with formal services outside the home environment, familiarity with modern medical culture, access to financial resources and health insurance, more control over resources within the household and wiser spending, more egalitarian relationship and better communication with the husband, more decision-making power, increased self-worth and self-confidence, better coping abilities and negotiating skills as well as reduced power differential towards health care providers and thus better communication and ability to demand adequate services [23, 76, 110-112]. Education also reflects a woman's childhood background, including familiarity with health services and certain beliefs and norms, and some recommend this should be controlled for [79, 81, 112]. It has also been suggested that there may be community effects of education, with more highly educated communities organising themselves and demanding better public services and a higher position for health on the political agenda [111]. By contrast, better awareness of poor quality in many facilities and higher confidence in self-care may delay care-seeking among educated women. Furthermore where strong public health programs reach out to disadvantaged sectors of the population, the education gradient in health service use may be small.

Education is likely to be associated with wealth and even residence. Adjusting for current wealth will measure the direct effect of education, excluding its indirect effect through improved living standards [113]. It is also important to control for confounding by maternal age since average education levels may have changed substantially over time.

With few exceptions, all studies include maternal education and find a strong and dose-dependent positive effect of educational level on use of skilled attendance, but levels of education are classified differently. For example, in most African settings, effects of primary education versus no education are already well discernable. In Tajikistan, where most women have secondary education and 40% delivered at home in 1998, there is no differential in service use up to secondary education, but those with higher education are more likely to deliver in a facility than the rest [114].

Where the contextual effect of education is considered by including the percentage of women with secondary education in each cluster, it is highly predictive of an individual woman's facility use for childbirth in most of the African countries studied, more so than the also substantial individual education effects [92]. In Haiti and Mali the concentration of adults (not just women) with secondary education is also associated with facility delivery but is restricted to women who had lived in the area for at least 5 years in Mali [108], and in Haiti the association was weakened and lost significance when individual-level variables were added to the model [107].

6) Husband's education

Educated husbands may be more open toward modern medicine [79], aware of the benefits of skilled attendance and more able to communicate with health workers and demand appropriate care, as described for women's education. They may also put fewer constraints on their wives' mobility and decision-making, thus facilitating care-seeking.

Husband's education is associated with occupation and with household wealth. Some studies even use husband's education as their measure of household socioeconomic status [100]. Considerations concerning confounding and pathways are similar to those described for mother's education.

Nearly all studies that consider husband's education find that higher education of the husband is associated with skilled attendance at delivery, although the effect is often less than that of the mother's own education.

7) Women's autonomy

The various dimensions of autonomy, such as position in the household, financial independence, mobility and decision-making power regarding one's own healthcare, may all impact on health facility use. In many countries, women cannot decide on their own to seek care, but have to seek permission from a husband or mother-in-law. Furthermore, women may lack control over material resources needed to pay for expenses, their mobility may be restricted or they may lack access to vehicles or even bicycles or donkeys [76, 110]. However, women's informal power in the household may mitigate some of the above [76]. The interpretation of various measures of autonomy depends on the context – women who take decisions alone in a context where this is unusual, "might be relatively isolated, unsupported individuals, and not autonomous agents" [110]. As such they may have resource constraints and be less likely to use services.

Women's status, as it reflects on the importance attached to female health also plays a role. "Sex discrimination as a contributory factor to maternal mortality has been largely ignored, [and] has been hidden within the general issue of poverty and underdevelopment which is assumed to put everyone… at an equal disadvantage in health terms." [115]

Autonomy and status are likely to be modified by age, marital status, wealth and parity.

Several studies examine the effect of autonomy dimensions on use of skilled attendance at delivery [80, 85, 88, 91, 94, 104, 110, 116-120]. Most find significant associations for at least some dimensions, but which are important varies from study to study. Dimensions studied include freedom of movement, aspects of decision-making, control over earnings, communication and sharing of housework with the husband, sex of household head and presence of the mother-in-law in the household.

1.3.3 Perceived benefit / need

This category comprises factors influencing the perception of how a facility delivery with skilled attendance would benefit mother and newborn and/or how big the personal need for such care is. This perception is shaped by general awareness of the dangers of childbirth and interventions available at health facilities, by individual past experiences with pregnancy, childbirth and health services, as well as by risk assessment of the index pregnancy. As for the previous group, factors in this category are thought to primarily affect the decision to seek care.

8) <u>Information availability</u>

Having access to information through modern media could influence women's knowledge about delivery risks and availability of services.

It may be hard to disentangle access to information from possession of radio or television and the higher socioeconomic status that makes these more likely. Literacy is essential for access to written information.

Several studies examine exposure to radio or television and to family planning messages in the media [81, 92, 98, 106]. An association with increased use of facilities for delivery is found in some settings but not in others.

9) <u>Health knowledge</u>

Specific knowledge about the risks of childbirth and the benefits of skilled attendance should increase preventive care-seeking, while recognition of danger signs and knowledge about available beneficial interventions should increase care-seeking for complications.

The majority of studies of use of delivery care are cross-sectional and it is difficult to establish time sequence. Contact with a skilled attendant could increase specific knowledge on childbirth via health education. Specific knowledge may also be associated with educational level in general.

Few studies consider health knowledge. Women in Zambia who know danger signs in pregnancy are more likely to deliver in a health facility as compared to those without such knowledge [91] and a similar but not significant tendency was observed in Southern Laos [121]. Also, in Mali, women who are told about complications at antenatal care are more likely to give birth in a facility [108].

10) <u>Pregnancy wanted</u>

Women with unwanted pregnancies may be less likely to invest in skilled attendance at delivery than those who attach high value to the expected child. However, delivery care may be sought due to the risk for the mother rather than the child [112].

Wantedness may be associated with age, parity and social support or marital status.

Wantedness and its impact on uptake of care is rarely studied. A study specifically investigating this question found no association of wantedness with home deliveries in Bolivia or the Philippines, a 20% increase in the odds of home delivery in Peru, a borderline significant increase by 35% in Kenya and a borderline significant decrease by 20% in Egypt [122]. Another study found that wantedness at time of birth increases the odds of having a doctor at delivery by 30% in South Africa while there is no such association in Brazil [23]. In Kenya, the odds of home delivery are increased by 40% when pregnancy is either unwanted or not wanted at that time [104]. No association between wantedness and delivery care was found in Thailand [112].

11) <u>Perceived quality of care</u>

Perceived quality of care, which only partly overlaps with medical quality of care, is thought to be an important influence on health care seeking. Assessment of quality of services “largely depends on [people’s] own experiences with the health system and those of people they know” [76]. Although some elements such as waiting times can be measured objectively, the perception of whether these are a problem and affect quality is more subjective. Elements of satisfaction cover satisfaction with the outcome, the interventions and with the service received – including staff friendliness, availability of supplies and waiting times [76]. In many cases, the medical ‘culture’ may clash with the woman’s, for example, when family members are not allowed to be present, supine birthing position is imposed or privacy not respected; this may lead to perceptions of poor quality [76]. Some studies mention that women report better quality of care in private facilities, but that cost deters them from using those [93, 94, 123, 124].

Perceived interpersonal quality of care overlaps to some extent with traditional beliefs and possibly sometimes with ethnic discrimination. Concerns about quality interact with other barriers, for example with distance or cost. Objective measures of quality of care such as facility infrastructure, equipment and staffing are associated with physical accessibility, access to information and other aspects of remoteness such as poverty and traditional values.

Nearly all qualitative studies of service use in the literature report quality of care to be an important issue, with staff attitudes featuring prominently. Many women report dissatisfaction with rude, arrogant and neglectful behaviour at health facilities and prefer the care of a TBA or relative [94, 95, 123, 125-127]. In several settings women complain about culturally inappropriate care, for example in Hoima district in Uganda providers urge women not to express pain openly [95]. Shortcomings in personal care at facilities are often coupled with shortcomings in hygiene and medical care. Women criticise dirty toilet facilities, lack of water and aseptic practices as well as lack of necessary drugs or too early C-sections [93, 95, 124, 128, 129].

Few quantitative studies assess quality of care. A Vietnamese study found that women who delivered in a facility give a significantly higher average quality score for “health care delivery”, but not for “communication and conduct of personnel” as compared to women who delivered at home (and who judged these quality aspects from others’ experience or earlier contacts with the facility) [85]. Another study in a rural district of Zambia found no effect of perceived quality of care [91] on service use, however, service satisfaction levels were 96%. Facility delivery is associated with higher total number of doctors in the facilities of the area where the woman lives in Uttar Pradesh, but not with staffing levels or drug stock-outs in Paraguay, Uganda or Tanzania [130]. Studies in Morocco and Burkina Faso also found no significant effect of number of health workers or infrastructure on delivery in a facility [131, 132]. A survey in Afghanistan also failed to find an effect of presence of obstetric equipment, but equipment levels were shockingly low overall [133].

12) <u>Antenatal care use</u>

Antenatal care (ANC) services can provide opportunities for health workers to promote a specific place of delivery or give women information on the status of their pregnancy, which in turn informs their decisions on where to deliver. Risk assessment during ANC may explicitly recommend a place of delivery, for instance to deliver in a hospital for a twin pregnancy. On the other hand, women who are told their pregnancy is fine may feel encouraged to deliver without a skilled attendant. In Uganda, a study described that nurses abuse women without ANC cards and hinder their admission for delivery services; this deters women who did not use ANC from seeking delivery services [123].

ANC attendance can be a marker of familiarity in interacting with the health system and with the health facility. Women who use ANC may therefore be more likely to use facilities for delivery. Alternatively, use of ANC may signify availability of a nearby service, which may also provide delivery care. In many settings, however, ANC is also provided by mobile clinics and small facilities that do not offer delivery services. Moreover, while timing for ANC is flexible and the service free in most places, this is not true for delivery services.

Any observed association between ANC use and facility use for delivery is always suspect of arising from confounding by other factors, in particular availability of and access to services, since those women closer to facilities are more likely to go to both [92]. Other confounding factors may be knowledge of pregnancy risks and attitude towards health services [83], complications [134] and most other factors influencing service use. When examining the effect of other determinants on use of skilled attendance, controlling for ANC use may be inappropriate as it is likely to be on the causal pathway.

About a quarter of studies investigating determinants for skilled attendance at delivery assess the role of ANC use as a predictor. Some find no effect but most find that women who use ANC are much more likely to receive skilled attendance at delivery. The presence of a health worker providing ANC in the community can also increase use of skilled attendance, as described for Haiti [107]. A study in Mali found that the level of antenatal care uptake in the enumeration area is highly predictive of individual women's health facility use for delivery, even when controlling for individual ANC use [108], which suggests that area-level use may be a proxy for other factors including accessibility.

13) Previous delivery service use

Women who delivered with a skilled attendant previously become more familiar with this setting, which may make them more likely to use it again. Also most determinants, particularly those that do not change (e.g. education, place of residence, beliefs) which influence a previous place of delivery, are likely to operate in the same fashion again. Even more than for ANC, any observed association between previous and subsequent facility delivery use is likely to be confounded by availability of and access to services [92], attitude towards health services [83], previous complications, knowledge about pregnancy risks and various other factors. Naturally, the same determinants that played a role for previous use are likely to influence present use.

Qualitative studies indicate that women tend to deliver with the same provider if a previous delivery went well and tend to change when they are dissatisfied [85, 123, 125]. Two quantitative multi-country analyses of Demographic and Health Survey (DHS) data found very strong associations between previous and current facility delivery [83, 92]. Most odds ratios found by Bell and colleagues are between 20 and 50, while those found by Stephenson et al are not as extreme, probably because the latter controlled for community-level percentage of women who ever had a facility birth as a proxy for service availability and norms [92]. This community level factor is highly associated with place of delivery in five out of six African countries studied [92].

14) Birth order

The first birth is known to be more difficult and the woman has no previous experience of delivery. Often a high value is placed on the first pregnancy and in some settings the woman's natal family helps her get the best care possible [81]. Furthermore, health workers may recommend a facility delivery for primipara. By contrast, women of higher parity, can draw on their maternity experiences and may not feel the need to receive professional care if previous deliveries were uncomplicated [106]. Very high-order births, however, are more risky. Additionally, women with several small children may have greater difficulty in attending facilities due to the need to arrange child care [79, 106]. In one setting, referrals for free tubal ligation in public hospitals after delivery were seen as an incentive for older women to seek a facility birth [99], but I interpret this as an effect of higher parity rather than age. In China, the one-child-policy deters women with higher order pregnancies from using services for fear of punishment [100].

High parity may reflect a lack of access to family planning services which may be associated with lack of access to delivery care. High parity can also indicate traditional attitudes, and sometimes lower socioeconomic status which is hard to control for adequately [106].

Most studies in the field consider the effect of parity on delivery service use. The vast majority find higher levels of service use for the first and lower order births as compared to higher order births.

15) Complications

Complications experienced during previous deliveries or loss of the newborn can make women aware of the dangers of childbirth and the benefits of skilled interventions and thus make them use skilled attendance for subsequent deliveries. Furthermore, women with specific medical interventions in a previous delivery, e.g. a Caesarian section, will be encouraged by health workers to seek skilled care for subsequent deliveries since there is an increased risk for rupture with a scarred uterus.

Another possible pathway is that problems experienced during the index pregnancy can make women seek health services antenatally and health workers may then recommend health facility delivery. Finally, complications during an attempted home delivery often influence women and their families to seek professional care, even though the original intention was to deliver at home. Alternatively, a precipitate labour may mean a woman intending to deliver in a facility ends up delivering at home or on the way.

The type and severity of complications that lead to a change in place of delivery depend on the perception of what is abnormal and what is amenable to medical treatment [76]. As mentioned earlier, the factors involved in decision-making are likely to differ for preventive facility deliveries and for emergency care-seeking of attempted home deliveries that run into problems. In the latter case, the severity of complications may override the perception of barriers like distance and cost [76]. Presence of complications could thus be an effect modifier for other barriers. People who consider "normal deliveries" or minor problems as not justifying cost, time and travel to a facility may attempt to overcome those barriers if there is danger to life, even if the cost is much higher [76].

Many studies in settings with low levels of skilled care find that a large proportion of women say they have facility deliveries because they experienced complications [93, 128, 135]. While few quantitative studies investigate the role of complications, those that do mostly find that at least some types of current or previous complications are associated with health service use for delivery [23, 80, 99, 105, 106, 116, 118, 127, 131, 134, 136]. In one study, facility delivery is associated with prolonged labour [105], while another study did not detect any association with prolonged labour or bleeding, but found one with breech delivery [99]. A study in Chiapas found that while distance was an important deterrant to care-seeking in uncomplicated cases, this was much less so when complications occurred [96].

1.3.4 Economic accessibility

Economic accessibility refers to the relation between financial capability of the family and costs of a facility delivery including transportation costs. While directly affecting whether a woman can actually reach a facility for delivery (second delay), the anticipation of high costs will affect whether a decision for a facility delivery is made in the first place (first delay). I grouped mother's and husband's occupation and other measures of ability to pay in this group, including community-level poverty, although some obviously also measure other aspects.

16) <u>Mother's occupation</u>

Women who are working and earning money may be able to save and decide to spend it on a facility delivery. However, in many settings women either do not earn money for their work or do not control what they earn. An increased range of movement and better access to information are suggested as reasons why formal work may promote women's use of health facilities for childbirth. On the other hand, working may be poverty-induced and indicate resource constraints, which would make working women less likely to use health services for delivery.

Variables associated with occupation may include education, wealth and place of residence and these may act as confounders.

Relatively few studies include women's occupation. Several find that farming women are less likely to have skilled attendance at delivery than women in other occupations [88, 103, 117]. This may stem from limited financial resources and health services in rural areas – wealth and place of residence were not always adjusted for. A number of studies do not find any effect of maternal working status or occupation [79, 85, 87, 102, 137], while others find that formally employed women are more likely to use delivery services [91, 98]. In two Southern Indian states [81] and in Nepal [138], however, working women are less likely to use services than non-working women, which may signify that working is poverty-induced in that context. Another study in Bangladesh [139] found an interesting interaction effect: There is a large differential in delivery service use favouring gainfully employed women among those living more than 1 hour travel time from a health centre, while employment status does not play a role among those within 1 hour travel time. This could be due to employed women being better equipped to overcome access barriers including transportation costs or female mobility limitations.

17) Husband's occupation

Wives of husbands with higher status occupations could be more able to use facilities for delivery. High status occupations are associated with greater wealth, making it easier for the family to pay costs associated with skilled delivery care. Certain professions include health insurance benefits, making care-seeking less costly.

Occupation is associated with education and wealth, and these may thus be confounding the relationship. Some studies use husband's occupation as a measure of household economic status [88], but the majority also include other measures such as household assets.

Most studies find that higher status occupation of the husband is associated with skilled attendance at delivery. In rural Haiti, however, a mother is less likely to deliver in a facility when her partner contributes all or part of the household expenses, after controlling for household wealth [107], possibly because she has less autonomy in that situation. A study in Turkey did not find any effect of paternal occupation in itself but when the father had household health insurance, the last birth was more likely to have occurred in a health facility [101].

18) Ability to pay

The cost of care-seeking may include costs of transportation, medications and supplies, official and unofficial provider fees as well as the opportunity costs of travel time and waiting time lost from productive activities [76] (although women in the late stages of labour are unlikely to do any production other than reproduction). Where women do not travel alone, accompanying adults or children for whom no caretaker can be found increase opportunity costs, transportation costs and costs for staying over night in the town where the health facility is located [76]. Households on a tight budget will have great difficulties to pay these costs and therefore be less likely to use a health facility for delivery.

Another reason for greater use of services is that “households with higher living standard are more modern and therefore more receptive towards modern health care services” [81]. On a larger scale, communities with less economic development are likely to be more traditional, give women less autonomy and have less positive attitudes towards service use [106]. An alternative mechanism how economic status affects care-seeking is that the “characteristics of the health facilities serving the poor … may discourage use” [76]. This may stem from inferior quality of care or worse availability of services in poor areas thus requiring users to travel long distances. “Cost and distance [from a facility] often go hand in hand… as longer distances entail higher transportation costs.” [76]

Ability to pay for care-seeking may be associated with modern attitudes and women’s autonomy and, on a community scale, with service availability and quality; all these factors are likely to act as confounders.

Nearly all qualitative studies mention cost as an important barrier to formal care. TBAs are usually deemed affordable for poor families since their payment is negotiable in terms of amount and timing and can be in kind [123]. However, Thaddeus and Maine found to their surprise that “the literature indicates that compared to other factors, the financial cost of receiving care is often not a major determinant of the decision to seek care” [76]. On the other hand, they quoted data from Nigeria where a “drastic decline in hospital births” was observed after user fee introduction in the 1980s, while “the admissions of complicated obstetric cases increased” [76]. This suggests that costs deter poorer women from using delivery services for preventive purposes, while they play a lesser role in case of complications where the cost-benefit ratio is different [76]. A study in Afghanistan also found that women living in the catchment area of a fee-charging facility were less likely to deliver with skilled attendance than those living near free facilities, even after controlling for other factors [133].

Nearly all quantitative studies include some measure of household wealth. Most use an asset index; others use single assets such as television possession or housing material, land size or food sufficiency. While the majority find that richer households are more likely to have skilled delivery care (up to five times more likely), others do not detect an association. This may be partly due to the choice of wealth indicator and of other variables in the model, and partly to household wealth not playing a big role in certain contexts, for example where wealth gradients are shallow, where services are free or where quality is the overriding concern [80, 140]. A recent systematic review of the effects of economic status on delivery service use in the literature [141] came to similar conclusions.

A few researchers investigated community-level poverty effects. A study on geographic aspects of poverty and health in Tanzania found that poorer communities (higher percentage of households in the poorest asset tercile) in both rural and urban areas are further away from a hospital, that staffing, equipment and drug supplies in their closest health centre are worse, and that delivery at facilities and with skilled providers is less common [142]. Unfortunately, the authors did not disentangle the effects of infrastructure, community poverty and household poverty. Another study in Haiti found that neighbourhood-level poverty, determined as the percentage of households in the lowest wealth quintile, is associated with decreased use of skilled attendance [107]. In Guatemala, women living in communities with a sewer system, as a measure of community infrastructure, have five times the odds of receiving formal delivery care of those in communities without, controlling for family socioeconomic status, ethnicity, distance to the nearest clinic and various other variables [98]. Similarly, an analysis of urban data in 85 DHS countries found that in most countries, cluster-level living standard strongly influences skilled birth attendance even when controlling for household living standard [143]. Interestingly, this study found that women from poor households living in non-poor clusters have a similar probability of receiving skilled attendance to women from non-poor households living in poor clusters [143], suggesting independent effects of household- and cluster-level poverty.

1.3.5 Physical accessibility

Like economic accessibility, physical accessibility affects indirectly the first and directly the second delay. I have included region and place of residence in this category, but realise this is an arbitrary choice since such complex variables also comprise aspects of all the other categories.

19) Region and place of residence

Since "service and social environments are typically very different in urban and rural areas, … strong urban-rural differences in use of delivery care are expected" [83]. Similar reasoning applies to differences between regions within a country and it can be difficult to know which factor to ascribe any differences in service use to.

Place of residence may be associated with education, ability to pay, parity, ethnicity/religion, beliefs, information availability, autonomy, availability and quality of services and accessibility of services. Its inclusion in an analytic study is therefore questionable if the goal is to disentangle these factors.

The vast majority of studies on delivery care use include region or urban/rural residence among their variables. Virtually all these studies find a large advantage for urban women compared to rural, and even larger for those living in large cities or in the capital. Differentials between regions within a country are usually moderate to large in size. A particularly extreme case is Ethiopia, where the odds of urban women to deliver with a skilled attendant are more than 8.5 times, and those of women in Addis Ababa nearly 40 times, those of rural women [87]. A systematic literature review by Say and Raine [141] on the rural-urban difference in delivery service use came to similar conclusions. They identified only two studies not showing higher facility use in urban compared to rural women: one in Kerala [81], where the differential is smaller than in other Indian states (OR 1.7) and not significant, and one that compared urban to peri-urban women in the Kathmandu valley [140]. Mekonnen found evidence for an interaction by place of residence in Ethiopia: while sociodemographic factors influence delivery care in urban Ethiopia, in rural areas distance and travel time are the crucial determinants [144]. Addai suggests a potential interaction of social influence by place of residence: “While all such [individual] choices are bounded by social context, they are probably more so for rural women for whom social, cultural and family ties frame many major decisions” [103].

20) Distance and transport

Distance to health services exerts a dual influence on use, as a disincentive to seeking care in the first place and as an actual obstacle to reaching care after a decision has been made to seek it [76]. Many pregnant women do not even attempt to reach a facility for delivery since walking many kilometres is difficult in labour and impossible if labour starts at night, and transport means are often unavailable. Those trying to reach a far-off facility often fail, and women with serious complications may die en route [76].

The obstacle effect of distance is stronger when combined with lack of transport and poor roads, and its disincentive effect is less pronounced if women have serious complications or the reputation of the provider is good [76]. Even where facilities are conveniently located, they are underused if their quality is considered bad. Where people have the choice between several facilities, they may well travel further if the target facility is perceived to offer superior quality care [76, 145]. It would thus be useful to consider distance together with service quality and transport options.

It has been argued, that in common with rural place of residence, "distance to hospital also captures other aspects of remoteness such as poor road infrastructure, poor communication between communities, poverty, limited access to information, strong adherence to traditional values and other disadvantages that are difficult to measure quantitatively" [132].

Despite general acknowledgement of its importance and an intuitive feel that it is likely to matter, distance or travel time to health facilities is not regularly considered in studies on determinants of skilled attendance, partly due to inadequate data [76, 106, 107, 146]. “Few surveys that collect information on respondents also collect it on the health services to which they have access and [on other] attributes of their areas of residence.” [107].

Occasionally, the role of distance is assessed by examining facility records on the proportion of users that came from further away in the catchment area or “by looking at the severity of the condition in which patients arrive at the facility and relating it to how far they had to travel” [76]. Some large national household surveys added a community questionnaire to gather information on distance to the closest facility [98, 100, 104, 107], but mostly data originate from smaller-scale surveys or surveillance sites. Stephenson and Tsui lament in their study in Uttar Pradesh: “To take these services [in neighbouring communities] into account would require access to geo-referenced data, concerning the location of each health-care facility in the survey area. The absence of such data has restricted analysis to the use of the facilities in the respondent’s immediate community.” [106]

A small number of studies in the field of maternal health have made use of GIS technology to determine distance, for example Chowdhury and colleagues in the Matlab surveillance site in Bangladesh [147]. I have not identified any studies looking at skilled attendance at delivery that have used GIS to merge data from national or large-scale household surveys with facility census data, although Heard, Larsen and Hozumi used this approach to look at the effect of distance to family planning services on use of modern contraception in Malawi [48].

The way distance is measured differs between studies. When information is gathered through community questionnaires, either distance or time needed to travel to the closest facility is asked. Some researchers collected information on both [85, 104]. Travel time has the advantage of taking the usual mode of transport as well as road quality and the difficulty of the terrain into account. As a downside, a single measure for time assumes that everybody uses the same transport mode and that there are no differences by season. Adding covariates for means of transport and season of birth should help deal with this problem to some extent. Several of the studies examining the effect of distance also considered road quality, bus services or household transportation means [80, 99, 107, 108].

When using GIS to calculate distance, straight-line distance is the most commonly used measure and was employed by Chowdhury and colleagues and by Heard and colleagues in their studies [48, 147] arguing it is simple, and often good, approximation. Heard et al also investigated ease-of-passage grids to take natural obstacles into account, thereby making assumptions on transport mode, but found that this did not differ much from straight-line distance in Malawi [48].

Many qualitative studies mention distance as an important deterrent from delivering in facilities, in particular when labour starts unexpectedly or at night and in the absence of transport options [85, 93, 123-125]. A study in Maharashtra [124], however, reported that unexpectedly, two women from the remotest village had delivered at a distant private hospital, because “the distance from their village to the primary health centre made them sceptical about delivering at home in the village in case complications occurred” [124].

The vast majority of quantitative studies that include distance report less use of skilled attendance at delivery in women living far away from a facility. I attempted a simple synopsis of the methods and results among studies adopting a multivariable method in Table 2. In the most extreme cases, the odds of having skilled attendance are only one fifth for women in the most distant category as compared to women close-by [105, 147]. The matter is complicated by the variety of distance and transport measures used and the variation in how skilled attendance was defined.

Some studies however find no effect of distance. One such study in Cambodia [105] found that distance from both health centre and hospital had a strong deterrent effect on health facility use for childbirth in bivariate, but not multivariate analyses. The study controlled for birth attendant at the preceding delivery, which is likely to be a very good proxy for physical access to services, potentially better than distance itself which does not contain information on transport options or whether the facilities are functional at all. This may partly explain the loss of significance of the distance variables in the multivariate model. In two other settings where distance does not seem to play a role, the authors reported that health care and transport infrastructure in the area are good [85, 127], and thus distance differentials are probably small and unimportant. Even small distances can pose a barrier, however, as shown in Bangladesh [147], when transport difficulties and cultural barriers augment their effect.

Two studies report interactions with distance. Potter found in rural Mexico that road quality ceases to matter when a village is more than 25km away from a market [99] and Pebley described an interaction with ethnicity in Guatemala [98]: Ladino women living far away from a clinic are less likely to use formal delivery care than those nearby, while there is no such effect for indigenous women. The latter seem to rely on TBAs no matter how close a clinic is, probably due to other barriers. In fact, non-Spanish speaking indigenous women have only 1/100 and Spanish speaking indigenous women 6/100 the odds of ladinas of having formal delivery assistance [98].

Table 2: Multivariate studies examining the effect of distance and transport on skilled attendance at delivery

* Abbreviations: MvLR = multivariable logistic regression, RE = random effect, SE = standard error, “birth (5y, recent)” = most recent birth in previous five years, n.s. = not significant, LSMS = Living Standards Measurement Survey, S.A.= % deliveries assisted by skilled attendant; in *italics* if outcome is % facility delivery. “No delivery care info” means no information on whether facilities provide (acceptable) delivery care.

Nr.	Author (year), study site	Data and methods*	Limitations	S.A.*	Results: Association with skilled attendance*	Any effect
1 [145]	Anson (2004), Rural China	Survey in HeBei Province 32 villages 4273 births (ever, recent) MvLR	Included births >10years ago (no control for year, change in facilities?). No delivery care info. No cluster adjustment.	*28%*	Distance (as continuous variable, per km?) from township health centre not significant (OR 1.0) , from county hospital OR 0.97, from city hospital OR 1.01. Presence of MCH worker in village OR 0.74, village doctor commissioned for MCH in village OR 1.36.	yes
2 [148]	Anwar (2004), Rural Bangladesh	Matlab 1997-2001 surveill. 11555 births (1997-2001) MvLR	Small area. Adjusted for ANC use. No cluster adjustment.	26%	Distance to health subcentre (ref:<=1km) 1.1-2km: OR 0.45, 2.1-3km: OR 0.50, 3.1-4km: OR 0.42, >4km: OR 0.18	yes
3 [136]	Anwar (2008), Rural Bangladesh	Community survey in two intervention areas 2164 births (1y, recent) MvLR	Small areas. Adjusted for ANC use. No cluster adjustment.	35%	Distance to nearest government hospital >5km vs 0-5km: OR 0.66 (35% S.A.= 13% at private facility, 10% at government/ NGO facility, 12% at home)	yes
4 [96]	Brentlinger (2005), Chiapas, Mexico	Community survey 18 selected villages 1146 births (2y) MvLR with robust SE	Specific study in conflict region. No delivery care info. Adjusted for ANC use.	*13%*	Hospital > 1h away vs <1h away: OR 0.4. In subgroup without reported complications: distance OR 0.2, subgroup with complications: not significant (OR 0.8). (Clinics rarely staffed, travel time to hospital up to 6h, infrequent bus services, ambulance drivers charge horrendous sums, armed roadblocks, unsafe at night)	yes
5 [147]	Chowdhury (2006), Rural Bangladesh	Matlab 1987-2001 surveillance data GIS data 41419 births (15y) MvLR, adjustment for clustering by area, time and mother.	Small area.	5% in 1990, 25% in 2001	Distance to basic health facility (ref:<1km) a) facility-based care: 1-2km: OR 0.43), 2-3km: OR 0.34, >3km: OR 0.21; b) home-based care by midwife: 1-2km: OR 0.46, 2-3km: OR 0.41, >3km: OR 0.27. (Midwife has to travel to woman’s house, family needs to send someone first to get her, night-time transport dangers, cultural problems for women to travel)	yes

Nr.	Author (year), study site	Data and methods*	Limitations	S.A.*	Results: Association with skilled attendance*	Any effect
6 [85]	Duong (2004), Rural Vietnam	Community survey + qualitative methods 1 district, 200 births (3m) Case-control: selected by delivery place. MvLR.	Small area. Small sample size. No cluster adjustment.	- (60% in area)	Little difference, not significant. Both groups had easy access: average distance to commune health centre (lowest level, providing delivery care) 1.7km for home deliveries and 1.85km (larger SD) for facility deliveries, average travel time about 20 min for both.	no
7 [114]	Falkingham (2003), Tajikistan	LSMS + community questionnaire 2214 births (ever, recent) MvLR	Included births >10years ago (facilities may have changed). No delivery care info. No cluster adjustment.	89%	Polyclinic present in community vs not: a) skilled vs unskilled attendant: not significant (OR?), b) facility delivery vs home delivery (but some with skilled attendant): OR 1.4.	yes
8 [110]	Furuta (2006), Nepal	DHS: reported problem 4694 births (3y, recent) MvLR with robust SE	Only distance problem perception in general. No mv OR for factors other than autonomy.	13%	Distance to health facility reported as a big problem versus small / no problem in case of illness: not significant (OR?, bivariately 8% vs 19% skilled care).	no
9 [107]	Gage (2006), Rural Haiti	DHS + community questionnaire 169 rural Enum. Areas 4533 births (5y) 2-level RE MvLR	No delivery care info. Adjusted for cluster secondary education (proxy for access?).	*10%*	Distance to hospital (ref:<5km): 5-14km: OR 0.34, 15-19km: OR 0.32, 30+km: OR 0.30. Health centre with ANC <=5km vs >5km: n.s. (OR 0.9). Mountainous vs not: OR 0.5. Road conditions: n.s. (ORs all close to 1). Household transportation (ref: none): horse/mule n.s. (OR 1.2), bike/motorbike/car/truck n.s. (OR 1.2).	yes
10 [108]	Gage (2007), Rural Mali	DHS + community questionnaire 264 rural Enum. Areas 6178 births (5y, recent) 2-level RE MvLR	EmOC judged from community informants. Adjusted for cluster education and ANC use. Included several access variables and distance interactions in model.	*26%*	Distance to nearest delivery care (ref: in enum. area): 1-4km: n.s. (OR 0.53), 5-9km: OR 0.49, 10-14km: OR 0.42, 15-29km: OR 0.40, 30+km: n.s. (OR 0.62). Distance to EmOC <=5km vs >5km: n.s. (OR 0.69). Time to public transport <15 vs 15+ min.: n.s. (OR 1.4). Emergency auto transport n.s. (OR 1.1). Index of no. of facilities within 5km n.s. (OR 1.1).	yes

Nr.	Author (year), study site	Data and methods*	Limitations	S.A.*	Results: Association with skilled attendance*	Any effect
11 [80]	Glei (2003), Rural Guatemala	Community + provider interviews within 20km. 4 selected rural departments 3350 births (3y) 3-level RE MvLR	Outcome is biomedical pregnancy care (incl. 9th month) vs other care (omitting no care). No info on delivery care.	(43%)	Health centre/post in community: n.s. (OR?) Private doctor/clinic in community n.s.(OR?) Distance from municipal capital to Guatemala city per km: OR 0.95. Community had bus service in past 5 yrs: n.s. (OR?) Community had open road all year round: n.s. (OR?)	(yes)
12 [109]	Hodgkin (1996), Rural Kenya	Survey in 60 villages and 86 surrounding facilities in a rural district. 149 births (1y, recent) Multivar. probit regression	Small area, few births. No data on mother, only on household. Not adjusted for education. No cluster adjustment.	*48%*	Distance to nearest facility with delivery service: Per 1km increase (for average household) → 3.4% decrease in probability of facility delivery.	yes
13 [149]	Hotchkiss (2001), Nepal	LSMS + community questionnaire 1434 births (3y, recent) Multivar. probit regression	No delivery care info. No cluster adjustment. Probit hard to interpret.	13%	Travel time to public health facility (incl. sub health posts) <=1h vs >1h: significantly higher probability of using trained delivery assistance, coefficient 0.356.	yes
14 [132]	Hounton (2008). Rural Burkina Faso	Household survey and facility census in 2 districts 81536 births (4y) MvLR with robust SE	Small area.	*38%*	Distance from assigned health centre: per km up to 7km: OR 0.77, per km over 7km: OR 0.97. Distance from assigned hospital: per 10km: OR 0.83. Health centre characteristics (staff, equipment): n.s.	yes
15 [119]	Li (2004), China	Survey in Diandong county 1334 births (3y) MvLR	No delivery care info. Adjusted for village location (mountains etc). No cluster adjustment. 14% missing outcomes.	17%	Distance to the nearest clinic per km: n.s. (OR 1.02). Village location (ref.: plains): mountainous area: OR 0.25, hilly area n.s. (OR 0.67).	no
16 [104]	Magadi (2000), Kenya	DHS + community questionnaire 5290 births 3-level RE MvLR	Adjusted for ANC use.	*42%*	Distance to nearest delivery facility (ref: <5km): 5-10km: OR 0.5, >10km: OR 0.4 Travel time to nearest delivery facility: (ref: <1h): 1-2h n.s. (OR 0.9), >2h: OR 0.6	yes

Nr.	Author (year), study site	Data and methods*	Limitations	S.A.*	Results: Association with skilled attendance*	Any effect
17 [133]	Mayhew (2008), Afghanistan	National survey of 617 facilities, and villages within 90min walking time 9917 births (2y) MvLR with robust SE	Sampling excluded very remote women.	13%	Walking time to nearest facility (ref: <=30min): 31-60min n.s. (OR 0.8), 61-90min: OR 0.7, >90min: OR 0.6 (unclear why any further given sampling). Mode of transport, type of health facility, availability of obstetric equipment: n.s.	yes
18 [134]	Mishra (2006), India	DHS + community questionnaire 25499 births (3y) Multinomial MvLR	Adjusted for ANC use. No delivery care info. No cluster adjustment. Multinomial regression hard to interpret.	*25%*	For facility delivery vs no assistance at home (third category was skilled attendant at home): Hospital within 5km vs not: relative RR 1.31 Village has all-weather road vs not: relative RR 1.32	yes
19 [120]	Mistry (2009) Rural India	DHS + community questionnaire 11648 births (3y) 2-level RE MvLR	No delivery care info. Adjusted for village economic development and electricity.	*27%*	Distance to health facility (ref: <2km): 2-5km OR 0.71, >=6km (only 10% of sample) OR 0.68. Presence of all-weather road n.s. (OR 1.06)	yes
20 [127]	Paul (2002), Rural Bangladesh	Survey in 39 villages in small rural area 2334 births (2y) MvLR	Very small area. TTBA (7%) included as skilled attendant. No cluster adjustment.	11%	Distance to nearest hospital/ clinic/ TTBA: >2miles vs <2miles: not significant bivariately (12% vs 11%). (Area well connected in terms of transport and several facilities located in proximity.)	no
21 [98]	Pebley (1996) Guatemala	DHS + community questionnaire 3490 births (5y) 3-level RE MvLR (model building with robust SE)	No delivery care info. No model formal vs all other care.	26%	1) Formal vs TBA assistance (given any assistance): Distance to nearest clinic per km: For ladino: OR 0.95, for indigenous women: n.s. (OR 1.02). 2) Formal/TBA vs family/no assistance: Distance to nearest clinic per km: For ladino: OR 0.91, for indigenous women: OR 0.92	yes
22 [121]	Phoxay (2001), Southern Laos	Survey in one district. 205 births (5y) MvLR	Small area, few births. No delivery care info.. Adjusted for knowledge and delivery cost. No cluster adjustment.	53%	Distance to health facility (ref: >15km): <3km: OR 4.5, 3-15km: n.s. (OR 1.5). Transportation cost “high” vs “low”: n.s. (OR 0.6).	yes

Nr.	Author (year), study site	Data and methods*	Limitations	S.A.*	Results: Association with skilled attendance*	Any effect
23 [99]	Potter (1988), Rural Mexico	National survey in communities with <2500 inhabitants. 1579 births (13m) MvLR	Outcome is hospital birth (health centre?). No delivery care info. No distance effect shown. No cluster adjustment.	36%	Health centre in community: n.s.? (no mv result given) Good road (=partly paved) from community to market vs no good road: OR 2.15, good road vs no good road if community far off (>25km): n.s. (OR 0.7), Public transport: n.s.? (no mv result given)	(yes)
24 [112]	Raghupathy (1996), Rural Thailand	DHS + community questionnaire, rural areas. 1680 births (5y, recent) MvLR	No delivery care info. No cluster adjustment.	? rural (77% total)	Distance to nearest hospital per km: OR 0.97. Education effect stronger at further distances (but interaction not significant).	yes
25 [139]	Rahman (2008), Bangladesh	National prospective survey 961 births (followed up) 2-level RE MvLR	TTBA included as skilled attendant. No delivery care info. Interaction wrongly interpreted.	13%	Travel time to health centre <=1 hour (74% of births) vs >1h: OR 7.7 for not employed women with low SES, OR 1.6 for employed women with low SES, OR 2.1 for not employed women with high SES, OR 0.44 for employed women with high SES.	(yes)
26 [146]	Rose (2001), 7 countries	DHS + community questionnaire 1458 - 7314 rural births (3y/5y) Limited MvLR	Inadequate control for confounding, only adjusted for education. No cluster adjustment.	4% - 64%	Distance from delivery facility: >=5km vs <5km: OR 0.24 in Benin, OR 0.63 in Mali, OR 0.42 in Uganda, OR 0.63 in Zimbabwe, OR 0.70 in Indonesia, OR 0.70 in CAR, n.s. (OR 0.73) in Haiti. Uganda (ref: <5km): 5 -14km: OR 0.5, >15km: OR 0.25	yes
27 [100]	Short (2004), Rural China	DHS + community questionnaire 4485 births (10y, recent) 3-level RE MvLR	Outcome is delivery by doctor (excluded midwives due to unclear skill levels)	40%	Distance from township (maternity services): >5km vs <5km: OR 0.63. Distance from county town (hospital) (ref: <11km): 11-30km: OR 0.68, 31+km: OR 0.55.	yes
28 [106]	Stephenson (2002), Uttar Pradesh	Community survey with facility questionnaire in 5 districts, 3106 births (3y) 3-level RE MvLR	Small area. No descriptive data. No info on distance to facilities outside community.	? *(no info)*	Secondary health facility in community: OR 2.23, Tertiary health facility in community: n.s. (OR 1.48), Number of doctors in community: (linear?) OR 1.08, Health infrastructure index (=presence of modern healthcare providers in the community): n.s. (OR 1.14),	yes

Nr.	Author (year), study site	Data and methods*	Limitations	S.A.*	Results: Association with skilled attendance*	Any effect
29 [130]	Tsui (2001), Uganda Tanzania Paraguay	Various population and facility surveys linked. U: 846 (3y), T: 4171 (5y), P: 1186 (5y) births MvLR (RE or robust SE?)	Facilities sampled in different ways. No info on delivery care.	*U53%* *T49%* *P82%*	Distance to nearest health facility (per km): Uganda OR 0.92, Tanzania OR 0.92, Paraguay to hospital n.s. (OR 1.0), to health centre n.s. (OR 0.97), to health post: OR 0.92. Staff levels and stock-outs at facilities: n.s.	yes
30 [150]	Van den Broek (2003), Rural Malawi	Survey in catchment area of one large health centre. 2179 births (1y) MvLR	Small area. Inadequate control for confounding. No mv distance OR. No cluster adjustment.	63%	Distance to health centre (per km): OR ?, highly signif. Bivariate results for attendance by midwife vs TBA: OR 0.60 per km, for attendance by midwife vs female relative: OR 0.82 per km.	yes
31 [151]	Van Eijk (2006), Kenya	Surveillance system (HDSS) in rural area 635 births ("recent") MvLR	Small area. 13% non-response. No info on delivery care. No cluster adjustment.	*17%*	Travel time to ANC (ref: walking time <1h): Walking time 1h n.s. (OR 0.58), walking time >1h: OR 0.36, used bus or bicycle n.s. (OR 0.81).	yes
32 [152]	Wagle (2004), Nepal	Urban-rural survey near capital with only hospital 308 births (45d) MvLR	Small area, few births. Adjusted for ANC use. No cluster adjustment.	*"about half"*	Travel time to the hospital: >1h vs <=1h: OR 0.13. Univariate finer categories show decreasing trend from <30 min to >3h travel time.	yes
33 [105]	Yanagisawa (2006), Rural Cambodia	Community surveillance system in rural district 980 births (3m) MvLR	Small area. Adjusted for ANC use and for attendant at previous delivery. No cluster adjustment.	*11%*	Distance to health centre (BEmOC) (ref: <2km): n.s. (OR ?, bivariate: 2-5km: OR 0.8, >5km: OR 0.3), Distance to district hospital (CEmOC) (ref: <10km): n.s. (OR ?, bivar.: 10-19km: OR 0.7, >20km: OR 0.3)	no

CHAPTER 2

METHODS

In this chapter I first introduce the three data sources that are being linked in this study – individual/household data, health facility data and population distribution data – and then explain in detail how I used these data to achieve the study objectives. I first describe how I classified health facilities according to their Emergency Obstetric Care functioning, and then how I determined population service coverage, including revising the urban/rural status of wards. Thirdly, I provide detail on distance measurement, including information on errors in the geographic data and how I dealt with these. Finally, I describe the steps leading to the multivariable analysis of the effect of distance on facility use for delivery, including: 1) the conceptual framework; 2) information on the distance variables and some important confounders; 3) the statistical model; 4) the model fitting procedure and 5) the calculation of population attributable fractions.

2.1 Data sources

This study links different datasets using geographic coordinates. Health facility data are linked to individual and household data to study the influence of distance on delivery service use while controlling for determinants like education and household wealth. Furthermore, health facility data are linked to population distribution data to investigate population coverage with delivery services.

The best individual and household data available with geographic coordinates are from the Demographic and Health Surveys. While DHS have been done in more than 80 countries, many of which have high maternal mortality, a search of data sources revealed that few such countries also have data on all their health facilities with geographic coordinates. Zambia is one of the few countries where these data exist. In the following I will describe my three data sources, the DHS, the Health Facility Census and the Zambian Population Census.

2.1.1 Demographic and Health Survey (DHS)

Demographic and Health Surveys are nationally-representative household cluster surveys with sample sizes usually over 5000 households in several hundred clusters, conducted with technical assistance from the MEASURE DHS project, funded by the U.S. Agency for International Development (USAID). The clusters are usually villages in rural areas and suburbs in urban areas. The respondents are women of reproductive age (15-49 years) and often a subsample of men is also interviewed. The surveys include questions on household and individual characteristics, fertility and family planning, maternal and child health. In particular they inquire about women's entire (live) birth history and collect details of antenatal and delivery care for births in the previous five years. [153]

In most recent DHS, the location of communities that participated in the survey is georeferenced using a GPS receiver. Where a GPS reading is missing, the location of the centre of the survey cluster is approximated using a gazetteer or a map. Data on the location of these communities, or clusters, is released as a separate DHS data file. In general, the coordinates reported in most surveys without HIV testing are accurate to 15-20 meters with respect to the centre of the cluster. If HIV testing was done however, the GPS data is "scrambled" which means a random error in any direction of up to 2 km is added to cluster locations in urban areas, and up to 5 km in rural areas, in order to protect confidentiality. [154]

The representative nature of the DHS data, their wide coverage, which includes many of the poorest countries, and their comparability over settings make them well suited for this study. However, unscrambled GIS data are available only for few DHS, which is a severe limitation. Furthermore, since the GPS readings are done in a central point of the cluster, the exact position of each household is not known. In places where villages are very spread out, this could lead to misclassification of distance of several kilometres. The DHS include most of the information needed for controlling for confounders when studying the effect of distance, being particularly strong on reproductive history, knowledge and women's decision-making power. However, there is no information on specific knowledge and decision-making power related to delivery and neither do we know where women originally intended to deliver and whether they changed their decision due to complications. DHS tried to address the latter problem with information on self-reported complications in some surveys, but Zambia is not one of these. Furthermore, since delivery information in DHS is only collected on live births, complicated cases that resulted in a stillbirth are missed.

2.1.2 Health Facility Census (HFC)

2.1.2.1 Health facility information needs

For my analysis, I either need information on all the health facilities of different types available in the proximity of the clusters where the household survey was conducted, or information on all the facilities in the region or country.

To avoid misclassification, the facility database should ideally be

1) complete and include non-public facilities,
2) give information on the facilities during the time period to which the household survey relates,

3) have information on which services are available at each facility (delivery care, emergency obstetric care), and on personnel and equipment in order to allow a judgement if those services are really functioning,
4) include information on the precise location of each facility in order to be able to calculate distances from the households to the facilities.

My strategy to identify suitable facility data included searching the websites of WHO, MEASURE DHS and other organisations, as well as contacting key people there directly. I also searched the Ministry of Health websites of various countries. The MEASURE Evaluation / USAID document "Profiles of Health Facility Assessment Methods" [155] provided further information on available data and contacts.

The Service Provision Assessment (SPA) surveys by MEASURE DHS take a nationally representative sample of health facilities. However, except for some older SPAs, this is not done in spatial relation to the Demographic and Health Surveys. Therefore they cannot be used to link household and facility data. WHO's Service Availability Mapping (SAM) collects national information on service provision of all facilities but in most countries *detailed* health facility information with GIS coordinates is only available in a few districts.

2.1.2.2 Health Facility Census (HFC)

The Health Facility Census, developed by the Japanese International Cooperation Agency (JICA), is a national-level assessment of the functionality of health system assets and provides extensive information useable for health system planning [155]. It can be used as a baseline on which a national Health Management Information System (HMIS) builds. A Health Facility Census has so far been conducted in Malawi and Zambia.

The HFC aims to cover all public and semi-public (mission, NGO, etc) health facilities as well as major private facilities. There is no sampling; information is collected on every facility. The information includes the precise location (using GPS), availability and condition of physical infrastructure and equipment, availability of services and headcounts of health workers.

In Zambia, a HFC was carried out in 2005. Box 2 summarises the information available in the Zambian HFC datasets.

Box 2: Summary of information in the Zambia HFC datasets

- JICA-assisted Health Facility Census 2005/06
- Around 1400 health facilities visited: GPS of location + questionnaires
- Only some private facilities included in some districts (plan to capture later)
- Separate questionnaires and datasets for the 24 second/third-level hospitals

Facility information
- ID, Name, province, district, type, ownership, GPS, road access

Type: 24 second/third-level hospitals, 76 first-level hospitals, 235 urban health centres, 978 rural health centres, 108 health posts.

Human resources
- Staff category (administration&support/medical/paramedical)
- Staff cadre (medical doctor, clinical officer, nurse, lab technician, pharmacist,…)
- For second/third-level hospitals additionally: department (e.g. Obstetrics / Gynaecology), midwives separate from nurses
- Numbers for each cadre: registered, on duty/headcount at day of visit
- Separate for male and female staff

Services
- Child health, family planning, HIV, malaria, tuberculosis, sexually-transmitted infections, sterilisation, water and sanitations, antenatal care, postnatal care, post-abortion care

Delivery service yes/no (82% yes)
- Midwife/doctor present/on call 24h, health professional with midwifery skills present/on call 24h
- All 8 EmOC signal functions yes/no, resuscitation of newborns yes/no
- Referral for EmOC yes/no, communication tool used for referral, provide transportation for referral yes/no, if so type of transport, which facility referred to
- For second/third-level hospitals additionally: Anaesthesist on call 24h, neonatal unit, vacuum extraction and forceps deliveries (yes/no and numbers), number of C-sections.

Utilities
- Communication (landline, cellphone, high-frequency radio, very-high-frequency radio, fax: working or not)
- Electricity (power grid, generator, solar: working or not)
- Water supply (council mains, borehole electric/manual/solar, other: working or not, storage, capacity, reliability, hot water)
- Waste disposal (sewer, septic tank, pit latrine etc)
- Transport (motor vehicle, motorcycle, bicyle: working or not); >10% missing data

Infrastructure
- For each building: name, storeys, construction materials, rooms
- Condition for each element (walls, foundations, roof, etc)

Equipment
- By department (general, operating room, neonatal,…): type of equipment (blood pressure machine, fridge, microscope, scale, delivery bed, thermometer, ambubag, etc - not numbercoded)
- For each equipment: numbers working / not working (major repair/minor repair)

2.1.2.3 Limitations

The HFC provides limited dimensions of service quality. There is no information on quality of care practices, nor on educational or training background of personnel [155]. The information on medical quality is limited to adequacy of staffing and equipment and to presence or absence of signal functions such as injectable antibiotics, C-sections and blood transfusions. There is no information on drug availability or stock-outs. Moreover, no information is available on staff attitudes or patient satisfaction / perceived quality of care, which are likely to influence service use at least as much as medical quality.

In terms of judging presence of EmOC signal functions, the HFC merely asks yes/no questions on whether these are provided. It does not check whether they actually have been performed in the last 3 months as recommended in the UN guidelines and practiced in AMDD needs assessments [26, 31].

The HFC did not capture all private (for-profit) facilities in 2005 but planned to do this later. Since most of these are located in urban areas anyway, this is not a serious limitation for my analysis of delivery care focussing on rural Zambia (see 2.5.1). There is also no information available on cost of service use (e.g. fees, drugs, consumables). Health facility user fees were introduced in Zambia in 1993 as part of the structural adjustment programs and removed in April 2006 for rural health facilities [156].

Another problem is that facilities open and close, staff come and leave, equipment breaks or is acquired over time, while a census just shows the situation at one point in time. It is a big simplification to extrapolate this cross-sectional information from the time of data collection to the five year time period for which the DHS provides information on births, especially if the time point is not even during the period of interest (as is the case for the DHS 2001/02 in relation to the HFC 2005). Furthermore, some facilities might have been missed by the census or their geographic location is missing, which introduces further error.

2.1.3 Population Census

In 2000, the latest decennial Zambian “Census of Population and Housing” was conducted by the Central Statistical Office [157]. The census contains population numbers down to ward level with geographic data on administrative boundaries (provinces, districts, constituencies, wards). It furthermore provides figures of annual population growth rates by district, calculated by projecting growth between 1990 and 2000, and thus projected mid-year population figures can be calculated for the years following the census. The census also contains information on fertility, including crude birth rates for each province.

2.2 Health facility classification

2.2.1 Dataset merging and cleaning

The HFC used separate questionnaires for “first-level hospitals and facilities below” and for “second- and third-level hospitals” and the data was recorded in different component datasets. The datasets were examined for missing values and cleaned before they were merged. Detailed information is available in Appendix A.

The dataset for second- and third-level hospitals contains 24 records, and information on facilities, GPS coordinates, human resources, utilities and equipment is complete. Information on availability of delivery services is also complete with the exception of the University Teaching Hospital in Lusaka. External information indicates that as the largest hospital in Zambia, it provides all services, therefore I coded all CEmOC functions as present.

The datasets from the census of “first-level hospitals and facilities below” contain 1397 records with basic information of which 1346 also contain information on delivery service availability and human resources. These 1346, together with the 24 records from the second- and third-level hospitals, add up to 1370 facilities with delivery service and human resource information necessary for the classification of EmOC status.

Twelve facilities out of 1370 (0.9%) had missing data on one of eight EmOC signal functions and one facility had missing data on four signal functions. In the classification, I assumed that those missing functions were not provided and used the information on the remaining functions.

Three medical licentiates, who are experienced clinical officers with an additional two-year training in surgery and thus can perform C-sections, were counted as doctors. When there were multiple responses for the same staff cadre, I chose the higher number. Where the number of staff registered was lower than the number present, I set the number registered equal to those present.

The number of facilities claiming to provide referral transport is much higher than those having a vehicle. As it is likely that vehicles are sent from higher-level facilities to collect patients [158], the information on transport provision for emergency referral given in the delivery dataset was used, rather than requiring functional vehicles to be present in the utilities dataset.

Only facilities reporting the use of a communication tool (phone, fax, radio, internet) for EmOC referral and that had such a tool available and working were classified as functioning in terms of EmOC communication.

The equipment dataset was not used since there is no precoding and there are thousands of items with various spelling versions. The additional information available for the 24 second- and third-level hospitals (e.g. numbers of C-sections and of vacuum and forceps deliveries) was also not used except to conduct consistency checks.

2.2.2 Classification by obstetric function

As highlighted previously, actual (and not just theoretical) provision of signal functions implies sufficient numbers of staff qualified and trained to perform these, 24 hour availability as well as presence of necessary equipment and drugs. While AMDD needs assessments aim to ascertain actual performance of signal functions, the Zambia HFC just used simple yes/no questions for each function. Therefore, I used a combination of criteria to determine EmOC functioning, including reported presence of signal functions, staffing, 24 hour service, utilities and referral capacity. The 1370 Zambian health facilities with sufficient data were classified into 6 EmOC categories, or as substandard if not fulfilling even the lowest criteria (Tables 3a and 3b which are showing the same in different ways). In the following, I describe and justify the criteria used.

For a facility to be considered as offering Comprehensive Emergency Obstetric Care (CEmOC), all 8 signal functions need to be present. This includes C-section capability and thus availability of a doctor 24 hours and working electricity. Therefore, working electricity and 24 hour presence of a midwife or doctor and at least one doctor found on duty at the day of visit were used as criteria. Given that doctors usually take shifts and may leave the facility at times, a minimum of 3 doctors registered at a facility was thought to be desirable to ensure continuous functioning.

Considering the fact that assisted vaginal delivery may not be consistently promoted and are rarely performed in Zambia [21, 38], I also constructed a CEmOC-1 category that does not require this function. For this category, the criterion of 24 hour availability of a doctor or midwife was relaxed to allow "on call" providers besides presence at the facility. While it is sufficient to have someone on call 24 hours in places where this person lives close-by and/or reliably turns up when called, this is not always the case and therefore this criterion is somewhat weaker. Furthermore, the required number of doctors registered was reduced to two for this weaker category.

Basic Emergency Obstetric Care (BEmOC) implies the availability of the 6 basic signal functions. These can be performed by a midwife or similarly qualified health professional. Therefore, at least one health professional found on duty at the day of visit and at least 3 registered was used as criteria. As health professionals I counted doctors, nurses and clinical officers, in line with the DHS classification of skilled attendants [6]. Not all nurses and clinical officers possess midwifery skills, so the estimate is probably over optimistic. Additionally, 24 hour presence of a doctor or midwife at the facility was used as requirement for full BEmOC status, which helps ensure that some midwifery competence is available at the facility 24 hours. Facilities that do not provide surgery or blood transfusion themselves need to be able to refer patients in need of these functions. Therefore, referral capability and provision of a vehicle for transport were deemed necessary requirements for a fully functioning BEmOC facility.

A BEmOC-1 category was constructed that – as for CEmOC-1 – does not require the capability to perform assisted vaginal deliveries and allows 24 hour on call availability instead of provider presence. Instead of ensuring transport provision by vehicle, only possession of a functioning communication tool was required (mostly telephone or radio) to contact a referral institution.

Given that the vast majority of health facilities in Zambia do not meet the above strict criteria but nevertheless provide some useful emergency obstetric services, two more categories were created, BEmOC-2 and BEmOC-4, allowing two and four signal functions to be absent, respectively.

Furthermore, two registered health professional were deemed sufficient for BEmOC-2 and no requirements on numbers of staff registered were made for BEmOC-4. However, for both, at least one health professional had to be seen on duty at the day of visit. Concerning 24 hour presence / on call, for the BEmOC-4 category, any health professional with midwifery skills was allowed instead of the restriction to midwives or doctors.

When subsequently referring to ‘EmOC facilities’ or ‘BEmOC facilities’ in general, limited services are not included and only facilities offering at least BEmOC-1 functions are meant.

Table 3a: EmOC classification of Zambian health facilities

Criteria	Full CEmOC	CEmOC minus 1	Full BEmOC	BEmOC minus 1	BEmOC minus 2	BEmOC minus 4
SIGNAL FUNCTIONS						
Injectable antibiotics	yes	yes	yes	yes	4+*	2+*
Injectable anticonvulsants	yes	yes	yes	yes		
Injectable oxytocics	yes	yes	yes	yes		
Manual removal of placenta	yes	yes	yes	yes		
Manual removal of retained products	yes	yes	yes	yes		
Assisted vaginal delivery	yes		yes			
Caesarian section	yes	yes				
Blood transfusion	yes	yes				
UTILITIES						
Electricity / generator	yes	yes				
REFERRAL						
EmOC referral offered			yes[#]	yes[#]	yes[#]	yes[#]
Vehicle for referral			yes[#°]	yes[#°]	yes[#°*]	yes[#°*]
Communication tools						
24 HOUR SERVICE						
Midwife/doctor present 24h	yes	yes*	yes	yes*	yes*	yes*
Midwife/doctor on call 24h						
Health professional with midwifery skills on call 24h						
STAFFING						
Doctors registered	3+	2+				
Doctors on duty at visit	1+	1+				
Health professionals registered			3+	3+	2+	
Health professionals on duty			1+	1+	1+	1+
How many facilities qualified in each category	30	24	42	39	155	375
How many qualified in each category or above	30	54	96	135	290	665

* any of the criteria in the rows

[#] not required if having CEmOC functions themselves

° not required if next door to a facility with CEmOC functions

Table 3b: EmOC classification of Zambian health facilities

EmOC level	Signal functions[1]	24h service every day	Staffing[2]	Referral
CEmOC	All 8 functions (+ electricity)	Midwife/doctor present 24h	≥ 3 doctors registered, ≥1 doctor on duty	Not required
CEmOC-1	All 8, or all except assisted vaginal delivery (+ electricity)	Midwife/doctor present or on call 24h	≥ 2 doctors registered, ≥1 doctor on duty	Not required
BEmOC	All 6 basic functions	Midwife/doctor present 24h	≥ 3 health prof. registered, ≥1 health prof. on duty	Offer referral[3], provide vehicle for referral[4]
BEmOC-1	All 6 basic, or all except assisted vaginal delivery	Midwife/doctor present or on call 24h	≥ 3 health prof. registered, ≥1 health prof. on duty	Offer referral[3], provide vehicle[4] or have communication tool
BEmOC-2	At least 4 functions	Midwife/doctor present or on call 24h	≥ 2 health prof. registered, ≥1 health prof. on duty	Offer referral[3], provide vehicle[4] or have communication tool
BEmOC-4	At least 2 functions	Any health professional with midwifery skills present or on call 24h	≥1 health professional on duty	Offer referral[3], provide vehicle[4] or have communication tool

1 Six basic signal functions: Injectable antibiotics, injectable anticonvulsants, injectable oxytocics, manual removal of placenta, manual removal of retained products, assisted vaginal delivery. Two comprehensive signal functions: C-section, blood transfusion.

2 Health professional: doctor, nurse, midwife or clinical officer
Registered: recorded as working in the facility. On duty: present at day of visit

3 not required if having CEmOC functions themselves

4 not required if next door to a facility with CEmOC functions

2.3 Population coverage calculation

2.3.1 Census ward population geographic data

The Zambian population census 2000 provides information on population counts by ward and information on the higher-level administrative units that the wards belong to, constituency, district and province. The Central Statistical Office provided us with geographic data (shapefiles) on ward locations and population numbers, as well as on the location of national parks and water bodies. From the ward file I created higher-level administrative shapefiles for constituencies, districts and provinces in the GIS platform ArcView (http://www.esri.com/software/arcgis/arcview/index.html).

I have no information on population distribution inside wards, therefore I had to make the unrealistic assumption that the population is distributed evenly inside wards. This assumption is most unrealistic for wards that contain both (semi)urban and rural areas such as around Chipata (Fig. B2, Appendix). As very few people live in national parks or on small islands that are not covered in the water body data, I excluded these areas and assumed an even population distribution in the rest of the ward areas.

To get population numbers per district and province for the year 2005 when the HFC was conducted (for the comparison to EmOC benchmarks in section 3.2), I projected the annual district growth rates between 1990 and 2000 five years further. To estimate birth numbers in 2005, I applied the Crude Birth Rates (births per 100,000 population) that the Census provides by province to all districts in a province.

All 1286 Zambian wards are classified as rural or urban in the census ward dataset, thus allowing examination of EmOC coverage separately by urban and rural residence. Checks on this classification were performed in Google Earth after importing the ward and district shapefiles using the freely available function “Export to KLM” of the GIS platform ArcGIS (http://www.esri.com/software/arcgis).

In order to validate and improve the urban-rural classification of the ward dataset, I used Map 2.5 from the Zambian Census 2000 report [157] which provides information on all Zambian cities with approximate size, and then checked the built areas on Google Earth for all cities and towns and their surrounding wards. In many places, it was difficult to decide on the urban-rural classification, e.g. whether to consider a small town in a rural district as urban, whether to consider the distant outskirts of large cities as rural or whether to consider a ward urban that just contains a small part of a town or city while the rest of the ward is clearly rural. (Examples are shown in Figures B1 and B2 in the Appendix).

I used a conservative approach to classify urban and rural areas, by leaving the classification as it was when I was in doubt and by creating a semiurban category where I disagreed with the classification but wanted to be more cautious than changing it completely. Of 1286 wards, I changed the classification of 67 wards: 2 rural wards were reclassified as urban, and 13 rural wards as semiurban, 2 urban wards were reclassified as rural and 50 urban wards as semiurban. This resulted in 233 urban, 63 semiurban and 990 rural wards in my revised classification.

2.3.2 Coverage calculation

For the coverage analysis comparing to international benchmarks, I used natural administrative units (provinces and districts) and related their populations and/or estimated birth numbers to the availability of delivery care, EmOC facilities and health professionals. EmOC facilities are defined as those facilities offering at least BEmOC-1 according to my classification.

In order to take spatial proximity into account, I furthermore examined what proportion of the population lives within reach of a facility offering delivery care and within reach of a facility offering EmOC. This was done by mapping both health facilities and ward areas in the GIS platform ArcGIS. I created circular buffers of a certain radius (e.g. 15km) around facilities and calculated the ward area covered by these, the proportion of ward area covered, as well as the population covered (assuming even distribution). Then I exported the dataset into Excel and Stata, where the proportion of the total population covered nationally and by province, separate for rural and urban areas, was calculated and graphs produced.

Furthermore, a 50km radius buffer around CEmOC(-1) facilities was computed in ArcGIS, and the ward areas and populations within and without computed. An indicator was created for all delivery facilities whether they lie within or without that area and the resulting table exported into Excel and Stata, where the numbers and levels of facilities were summarised for both groups.

2.4 Distance measurement

2.4.1 General issues

Ideally, one would like to use more sophisticated distance measures that take roads and surface into account, given that straight-line distance is only a crude proxy for true travel time. However, I decided to use only straight-line distance in this work for two reasons.

Firstly, in order to be able to calculate distance along roads or over the terrain, one needs detailed geographical data of good quality which are currently not easily available. WHO and partners have been working on harmonising geographic data in Zambia for several years, but still have not made enough progress to release them [159, 160].

Secondly, in the DHS 2002, there are unintentional errors in the geographic coordinates and in the DHS 2007 error has been purposefully added through the scrambling procedure to protect confidentiality (see 2.4.2 and 2.4.3). Given that my distance measures already contain substantial errors due to these mistakes in the geographical coordinates, it does not make sense to refine them further on a smaller scale. For example, we may add travel time for crossing a river while in reality the cluster is really on the other side of the river anyway.

How well straight-line distance approximates true distance depends on the geography of the country, such as rivers, altitude and physical barriers to travel. Travel time also depends on the means of transport used. Unfortunately I don't have information on public transport, but it is known to be very infrequent in rural Zambia. Furthermore, the availability of public transport is likely to vary by time of day or night – which is important for delivery care. In a situation where most people can be assumed to walk along small paths, straight-line distance may be a reasonable proxy. I also include information from the DHS on household transportation means and season of birth as possible effect modifiers for distance.

2.4.2 Health Facility Census geographic coordinates

I received two different versions of GPS coordinates for the Zambian health facilities, one in Excel tables and one in the ACCESS database. In the first, latitude and longitude are in decimal degrees while in the latter they are recorded in "degrees", "minutes" and "thousands". Usually, GPS coordinates are either decimal or in degrees, minutes and seconds (DMS).

For most records, the two versions correspond to each other, when interpreting “thousands” as thousands of minutes. However, for about 10% of records, this is not the case. It appears that the decimal version in these cases was not derived from the other version but from external information. Furthermore, for some records it seems that the "thousands" are rather conventional seconds or seconds multiplied by ten (as they contain decimal points and never exceed 60 or 600).

This means there are four potential ways the GPS coordinates could be read:

1. "thousands" = minutes/1000 (1/60000 degrees)
2. "thousands" = seconds (1/3600 degrees)
3. "thousands" = seconds*10 (1/36000 degrees)
4. using the decimal version if different from the above

Unfortunately, I did not manage to get any metadata from the Zambian authorities on how the coordinates were manipulated. In order to find out which reading is correct, I checked facility locations for all hospitals, facilities with C-sections and a large number of other facilities using Google Earth, maps, internet searches and personal emails to mission facilities. While it is often difficult to tell which version is correct, in many cases, in particular in towns where detailed maps are available and where Google Earth has good resolution, this is well possible. In other cases, one can tell at least which version must be wrong (e.g. across the border or in the middle of a forest).

It became clear that for different facilities, different ways of reading the coordinates were correct. A pattern emerged that for consecutive facilities (in the same district) usually the same reading was correct. Therefore, I came up with an algorithm (Appendix A, Box A1) to determine which reading to use for each facility.

The final "best guess" version was compared to the facility coordinates in the two districts where WHO's Service Availability Mapping (SAM) was done. Facilities were matched by name and type. 32 facilities existed in both the SAM and the HFC dataset and had GPS coordinates recorded in both. 29 of those had virtually identical coordinates. Of the 3 that differed, the SAM version seemed to be correct in two while the HFC appeared to be off by 4km and 7.5km respectively. For the third one, an urban health centre in Kafue, the HFC located it correctly inside Kafue centre, while the SAM version located it 42km further east in a forest which seems highly implausible. Some other checks also highlighted that the "best guess" version of the HFC coordinates is good but not perfect.

Of the 1419 health facilities that had facility information and geographic information recorded, the geographic data were non-existent for 26 (coded as 999, many of these defence facilities). So in total 1393 facilities could be used in the GIS analysis.

The final corrected version of the GIS coordinates for all the facilities was merged to the main health facility dataset. Both contained facility ownership information and there were several inconsistencies. I used the health facility listing from the Zambian Central Board of Health [161] as a gold standard to decide ownership. I used the classification system explained in section 1.2.2.2 to classify all health facilities into one of the EmOC categories. A simple dataset containing only basic facility information (identity number, name, district, etc.), the EmOC classification and the GIS coordinates was created and imported into the GIS platform ArcView. There, I projected it into Universal Transverse Mercator (UTM) zone 35 and saved it as a shapefile for further use.

2.4.3 Demographic and Health Survey geographic coordinates

The geographic coordinates for the 320 clusters from the DHS 2001/02 were downloaded from the Macro International DHS website (www.measuredhs.com) in early 2007 after receiving permission. Besides cluster numbers and geographic coordinates, the file also contains information on the four administrative levels of each cluster: province, district, constituency and ward. The coordinates for 44 clusters were missing including all 36 clusters in Luapula Province.

I used the same procedure for checking locations as described for the HFC data (maps and Google Earth) and found a number of inconsistencies in the DHS 2001/02 dataset, e.g. two clusters with different names in the same location, coordinates of clusters located in a different district to that detailed in the dataset or located outside the Zambian border.

In the GIS platform ArcView, I used the administrative data from the Zambian Census 2000 to check whether the DHS geographic coordinates were located in the province, district, constituency and ward specified in the DHS file. 54 of 276 (20%) clusters with coordinates were found to be located outside their ward, of which 27 were located outside their constituency, of which 14 were located outside their district, of which 2 were located outside Zambia.

Further checks on these were performed in Google Earth after importing the cluster locations into Google Earth using the “Export to KLM” function in ArcGIS and also displaying ward and district borders for orientation. In Appendix C I provide further detail on the procedure and explain why the administrative information from the DHS 2001/02 was in general considered more reliable than the its geographic coordinates.

Upon further examination, 37 clusters (of 276, i.e. 13%) were found to be clearly located in a ward different to that indicated by the administrative information and at least 3 km from the border. 14 of the 37 clusters were 50 km or more away from their supposed location.

While some cases were easily corrected, for most clusters with misplaced coordinates it was difficult to know where the coordinates should actually be located. Similarly, it was difficult to find the location for the 44 clusters for which the DHS data did not provide any coordinates (all Luapula clusters and some others). For small wards, it seemed reasonable to guess the coordinates, but for larger wards I could not attempt to place them anywhere and thus had to exclude those clusters.

Finally, I checked the urban-rural status of the DHS 2001/02 clusters by projecting the original and modified ward classification (see above) in Google Earth (without using any other information on the cluster from the DHS data). This allowed me to view the precise location of a cluster in the ward, which is important if a ward is not homogenously urban or rural. As with the modification of the ward classification, I used a conservative approach, leaving the classification unchanged in cases where there was doubt. Furthermore, I tended to leave dubious urban locations unchanged while recoding dubious rural locations into urban, because I considered a potentially false inclusion in my analysis (of rural births) more harmful than false exclusion. For 15 clusters I changed the urban-rural classification: 13 rural to urban (5 of which were excluded for other reasons anyway) and 2 urban to rural.

The geographic coordinates for the 320 clusters from the new Zambia DHS 2007 were downloaded as soon as that survey became available in April 2009, but are only available in the scrambled version (details in section 2.4.5). There are no missing coordinates in the 2007 survey and no checks (or corrections for the scrambling) are possible since administrative information on cluster locations is not provided (only province).

The geographic DHS datasets were imported into ArcView, projected into UTM zone 35S and converted into shapefiles for further analysis.

2.4.4 Distance to EmOC calculation

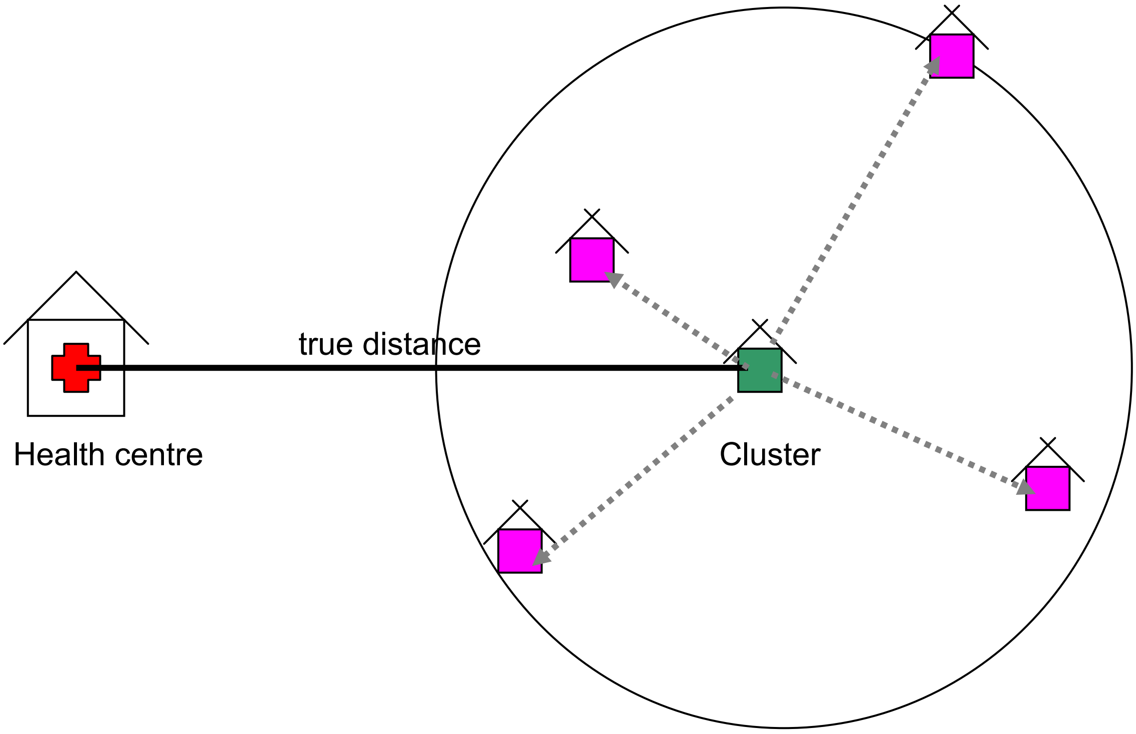
The shapefiles of both the health facilities and the DHS clusters were mapped in ArcView and separate shapefiles created for each type of facility using the EmOC classification. Using the freely available ArcView extension "Nearest Neighbor 3.6", I calculated the distance from each cluster to the nearest health facility of each type, i.e. for each cluster the distance to the closest CEmOC facility, closest CEmOC-1, closest BEmOC, etc. This was done both for the corrected 2002 clusters and the 2007 clusters. The resulting tables with the various distance variables were then exported and transformed into Stata datasets for future merge with the main DHS birth datasets. Distance was calculated in meters, so while categories seem overlapping (2-5 km, 5-10 km, etc.), they are not in fact as distance was never exactly 5.000 km.

2.4.5 Error in distance measures due to DHS geodata scrambling

The precision of the DHS cluster geographic coordinates is usually very high, within 15-20 meters. However, if HIV data is also collected, extra error is added in order to “ensure that it is impossible to identify specific communities” to protect individual confidentiality. In these surveys (and more recently this is planned to be extended to all surveys) “up to 2 kilometers of random error in any direction is added to cluster locations in urban areas, and up to 5 kilometers of random error is added to cluster locations in rural areas.” [154] Additionally, every 100th rural cluster is randomly displaced by 10km.

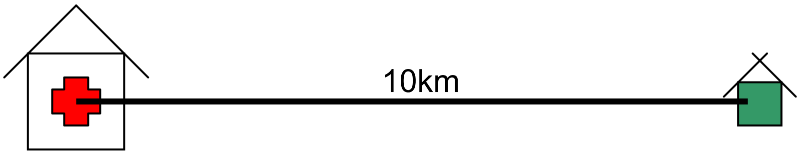
This procedure is called “geo-scrambling” by DHS. It is done after converting the original GPS coordinates (decimal degrees) into UTM grid references (to have a flat plane instead of a surface of a sphere). A random direction of 0-360 degrees is chosen and a random displacement radius of 0-5,000m for rural and 0-2,000m for urban points, with every 100th rural point being given a 0-10,000m radius. The new point is then reconverted into decimal degree values.

For my study, this leads to misclassification of distance from clusters to their closest health facility. In the following I will describe the resulting error distribution of distance measurements. The size of the error is not straightforward as it depends on the displacement radius chosen and also on the angle with which the cluster coordinate is displaced. The following sketch shows the mechanism of displacement (in pink possible displaced cluster locations).



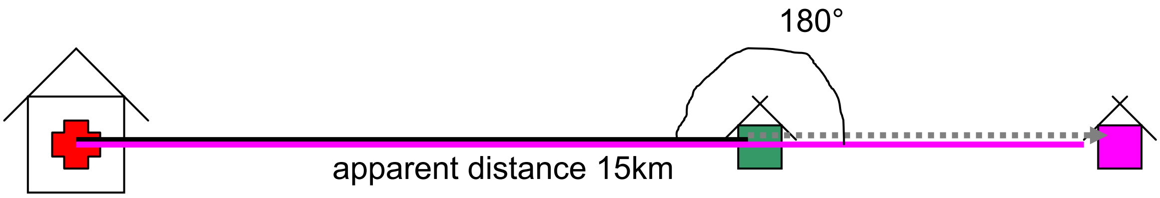
I will consider the situation for a fixed displacement by 5 km first and assume a true distance from village to health centre of 10 km.

1) True situation: Cluster located 10 km from health centre.

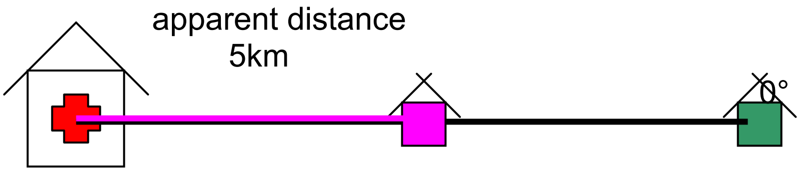


The simplest error cases are a displacement angle of 0° or 180° which will lead to an underestimate or overestimate by exactly 5 km respectively.

2) Displacement of cluster by 5 km in 180°

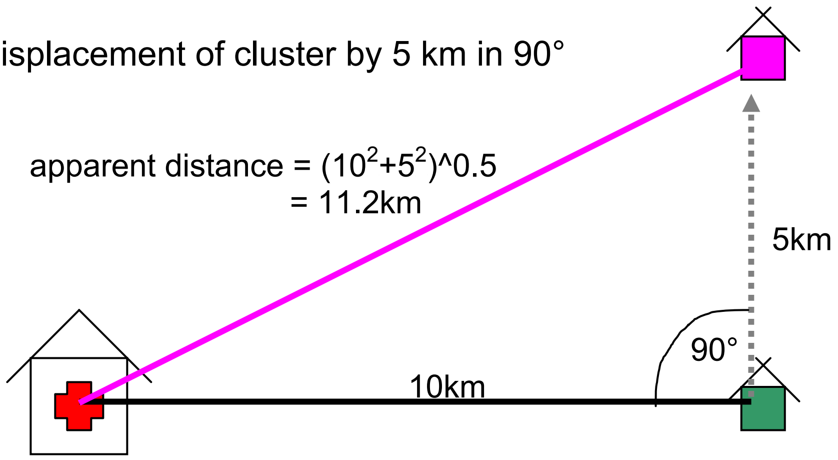


3) Displacement of cluster by 5 km in 0°



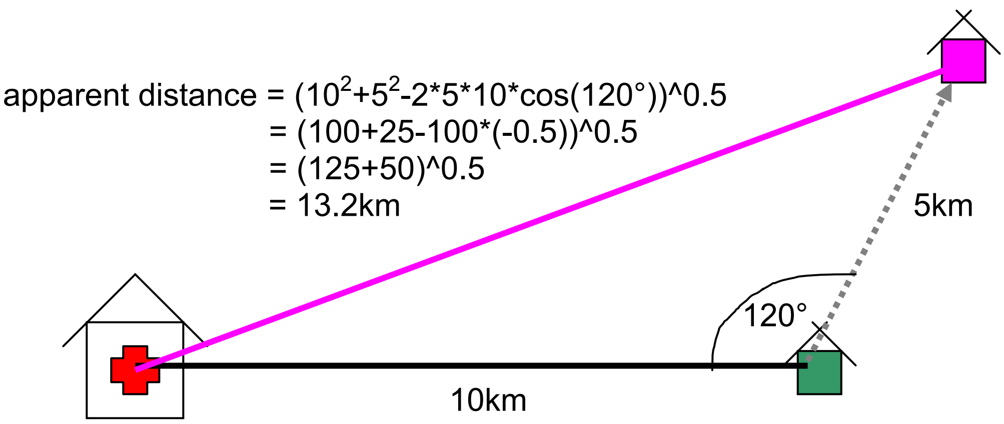
If the displacement is by 90° (or by 270°), one can use Pythagoras' theorem to calculate the apparent distance: $a^2 + b^2 = c^2$

4) Displacement of cluster by 5 km in 90°



For angles between the true distance and the displacement radius other than 90°, one needs to use the law of cosines, a generalisation of Pythagoras' theorem: $a^2 + b^2 - 2ab\cos(phi) = c^2$ (with phi being the angle)

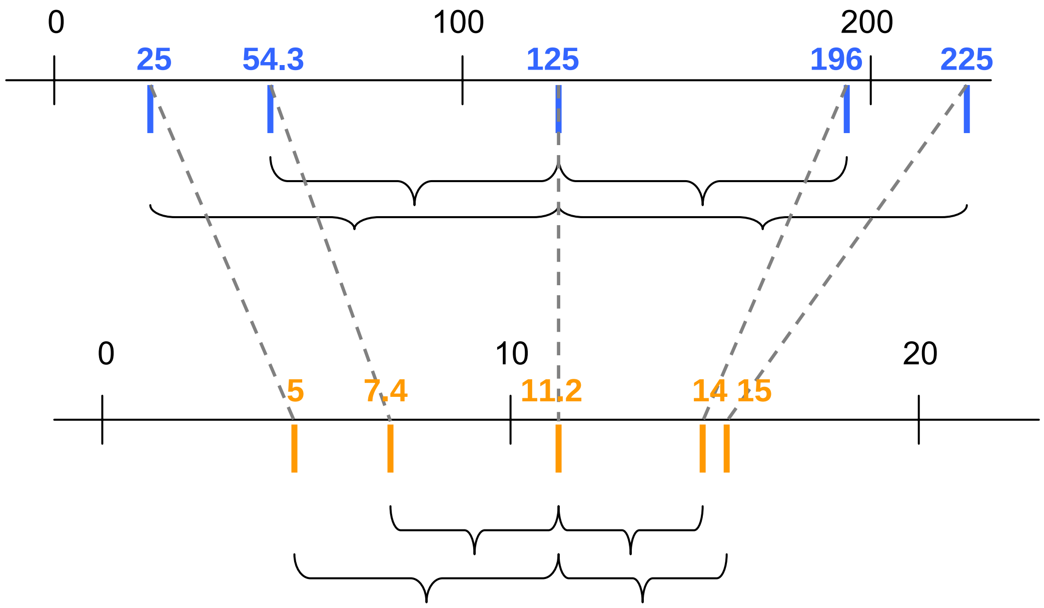
5) Displacement of cluster by 5 km in 120°



While the term under the square root is symmetrical (i.e. the cosine makes it on average larger or smaller to the same extent), its square root is not, since larger numbers get shrunk relatively more.

Still considering the 10km true distance and 5km displacement example:

cos(180°)=-1 → c=(125-100*(-1))^0.5 = **225**^0.5 = **15**
cos(135°)=-0.707 → c=(125-100*(-0.707))^0.5= **195.7**^0.5 = **14**
cos(90°)=0 → c=(125-100*0)^0.5 = **125**^0.5 = **11.2**
cos(45°)=0.707 → c=(125-100*0.707)^0.5 = **54.3**^0.5 = **7.4**
cos(0°)=1 → c=(125-100*1)^0.5 = **25**^0.5 = **5**

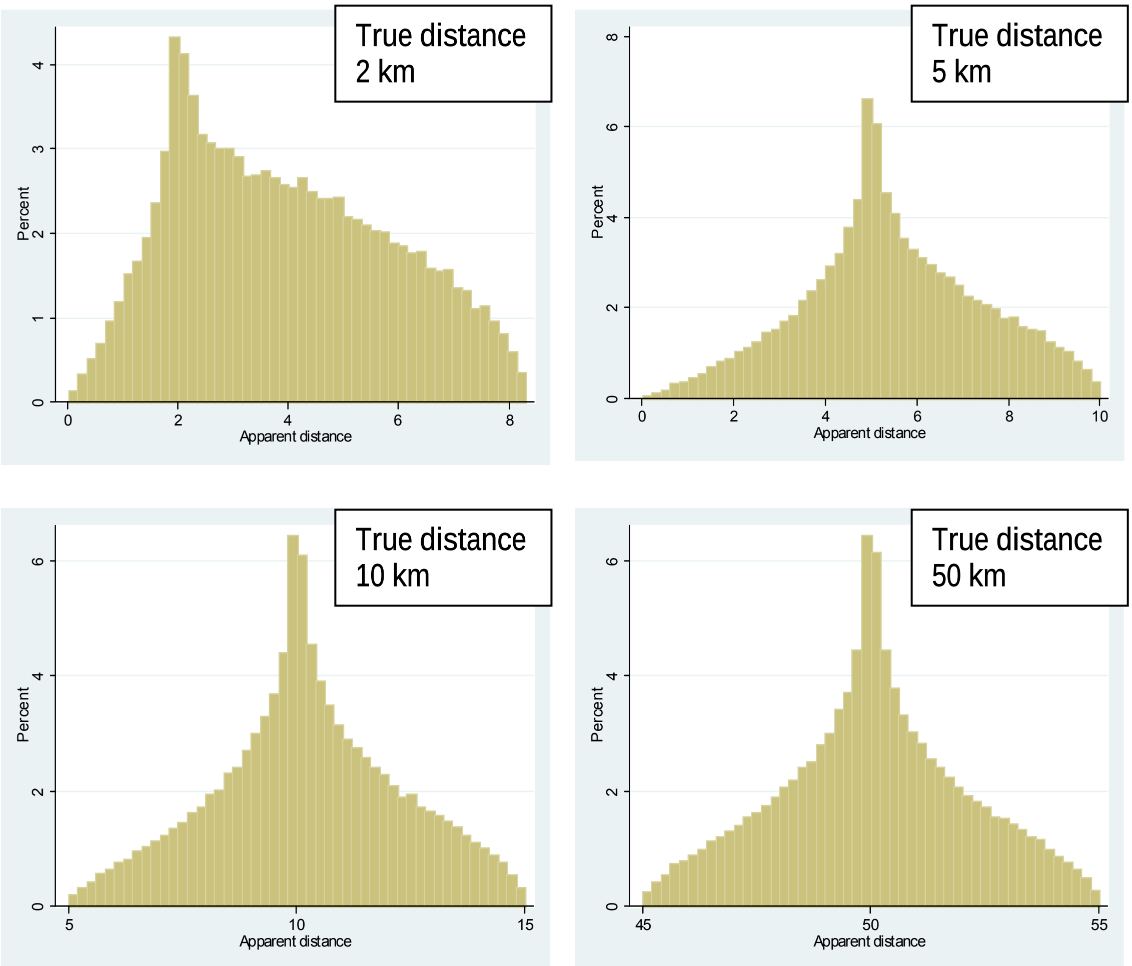


However, since there is also an error radius added (in this example the maximum of 5 km), this pushes the distance on average above the true distance (here the median apparent distance is 11.2 km). This is more so if the error is large in relation to the true distance (with the most extreme case being a true distance of 0 km where only overestimation can occur). Overall, this leads to an asymmetric error distribution, which overestimates the distance, especially for small distances.

I simulated the error in Stata using a random number generator to produce a random angle between 0° and 360° (or rather a random radian between 0 and 2π, called randrad) and a random distance between 0 and 5 km (called randdist), using the law of cosines to calculate the apparent distance (appdist), as explained above. For true distances (truedist) of 2 km, 5 km, 10 km and 50 km, the apparent distance distributions are shown in Figure 7.

*generate appdist=(truedist^2+randdist^2-2*truedist*randdist*cos(randrad))^0.5*

Figure 7: Apparent distances after scrambling for various true distances



2.5 Analysis of the effect of distance on service use

2.5.1 Conceptual framework

The opportunity to link health facility data with the DHS household survey data allows me to not only include contextual factors derived from aggregate properties, but also information on service availability in my framework. A simple conceptual model is shown in Figure 8a, using the same categories as introduced in the literature review and Fig. 6 and adding a category of cluster-level influences that are thought to act by creating a more or less encouraging environment concerning care-seeking for delivery. Figure 8b shows the variables sorted by their level of hierarchy (birth, mother, household, cluster).

As the aim of this analysis is to investigate the effect of geographical access to health facilities of a certain level, all other variables are merely of interest as confounders. The framework is therefore not a full representation of all the hypothesised associations between variables, but rather focuses on the relationship of other variables with distance and with health facility use. Urban or rural place of residence is not considered in the framework as the analysis is restricted to rural births to avoid confounding by place of residence, and as distances in urban areas are homogenously short anyway (Fig. 50) and other factors such as cost are the main concern [129].

I did not include variables in my analysis that measure infrastructure at the same time (such as electricity) in order to not control implicitly for distance. Similarly, I avoided variables that may be extremely good proxies for access to the next town and thus to a health facility, such as average educational level in the cluster. Furthermore, variables that could be important determinants for care seeking, but at the same time could be influenced by care seeking, such as health-related knowledge, were not included, since controlling for variables downstream of the outcome would introduce bias.

The framework shows that when trying to quantify the effect of distance on health facility use for delivery, it is necessary to consider a wide range of other determinants as potential confounders.

Figure 8a: Conceptual framework of influences on health service use

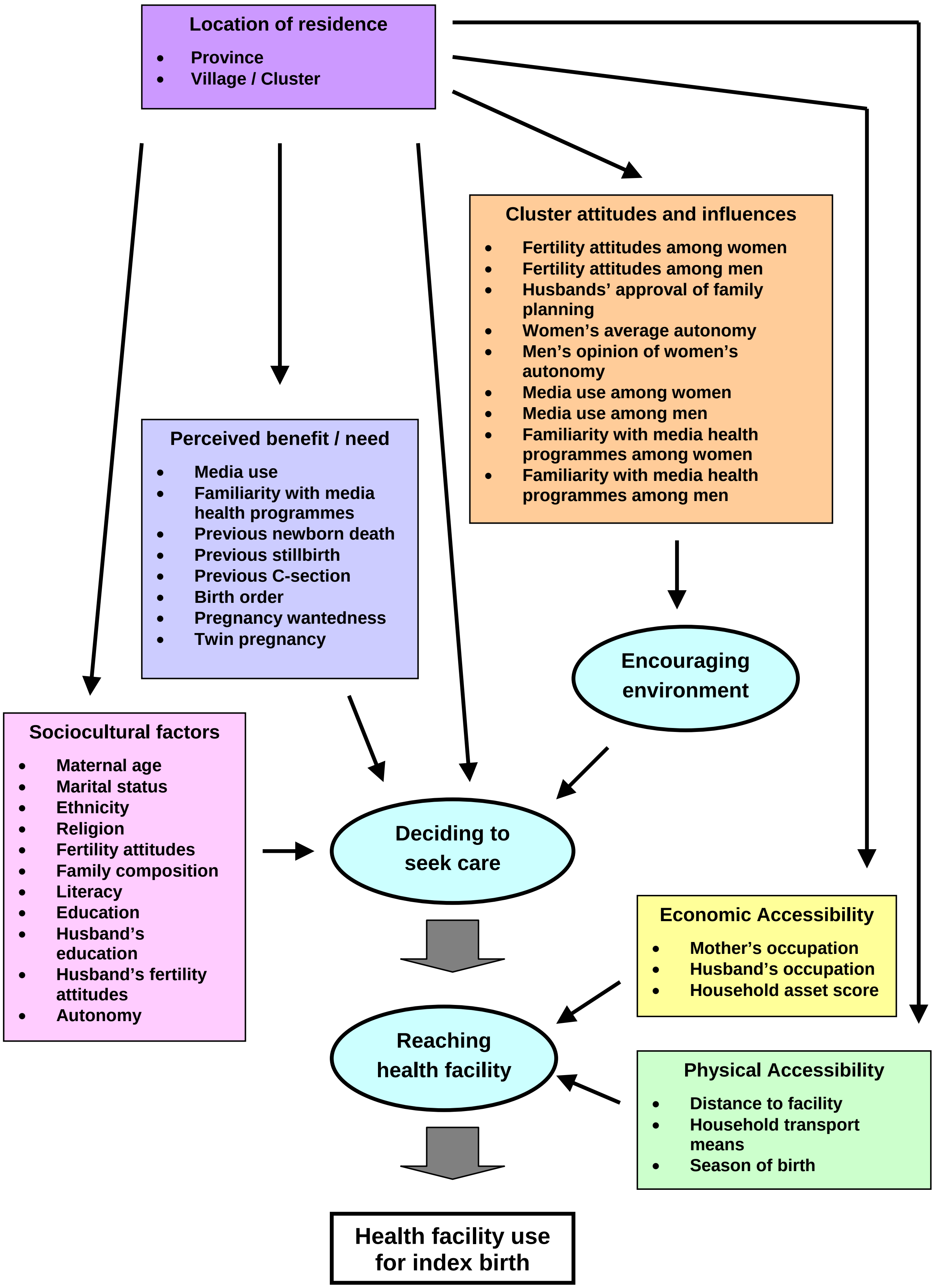
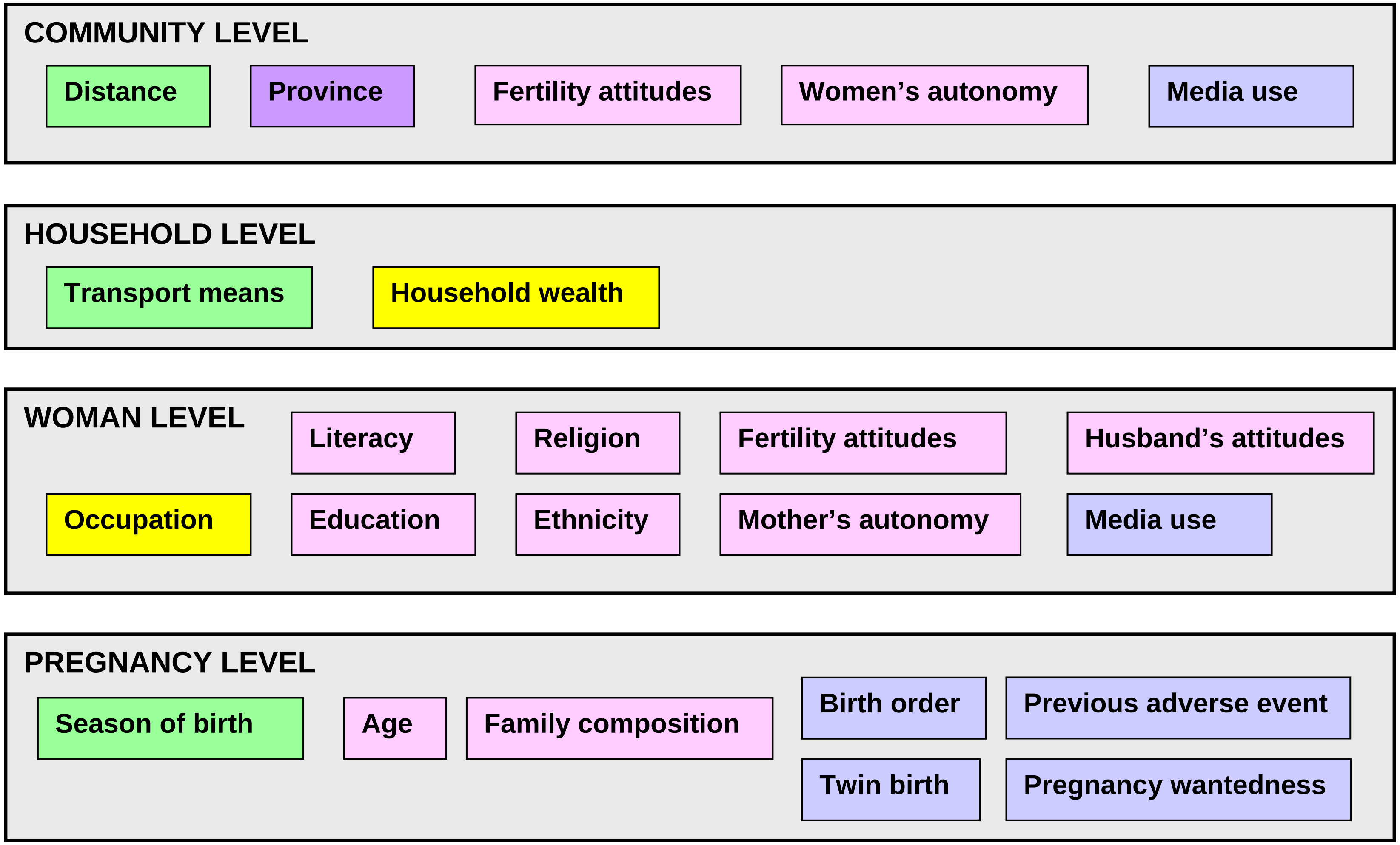


Figure 8b: Hierarchy of explanatory variables (colours corresponding to the factors in Figure 8a)



2.5.2 Data cleaning and missing data

Macro International already performs extensive checks and cleaning procedures before releasing the DHS datasets. I have read their documents explaining these procedures (Guide to DHS Statistics, DHS Data Editing and Imputation and DHS Recode Manual) and have also performed consistency checks on the datasets myself. While I did not discover any inconsistencies in the birth, individual or household datasets, I identified serious errors in the GIS dataset. This has been described in the previous section (2.4), along with the cleaning and processing of the Health Facility Census datasets.

There are few missing values for the outcome and for the various possible confounders and I have documented these with the details of the variable construction, as well as my assumptions in dealing with missing values in some of the composite variables (see Appendix D). Given that only a few single values are missing, advanced analyses taking account of missing data such as multiple imputation were not deemed necessary for the confounders.

Distance information is lacking for a substantial number of births for two reasons. In some cases (over 10% of the sample, see section 3.3.1), the mother moved since the birth or is just visiting at the place of interview, so we do not have any information on the relevant cluster at time of birth, and thus all cluster-level variables including distance are lacking. The second reason is that in the DHS 2002, cluster locations in Luapula Province and elsewhere were missing, and I could only identify their location reliably in a small number of cases. Similarly, for those clusters where the GIS coordinates were found wrong in the 2002 DHS, only few could be corrected and most had to be left missing.

I have restricted the analysis to births where distance information is available and analysed and documented differences between those with available and lacking distance information.

For twin and triplet births, only the first record is used for the analysis.

2.5.3 Operationalising skilled attendance

Demographic and Health Surveys attempt to ascertain both where a woman delivered and the qualifications of all the persons who assisted in the delivery. In Zambia, as in most countries, this is being asked for all births in the previous five years. The response categories are shown in Table 4 and were exactly the same in the DHS 2001/02 and DHS 2007.

Table 4: DHS questions and answer options on place of delivery and assistant in Zambia (DHS 2001/02 and DHS 2007)

Where did you give birth to (NAME) ?	Who assisted with the delivery of (NAME)? Anyone else? (record all persons present)
Home: - Your home - Other home **Public Sector:** - Govt hospital - Govt health centre - Govt health post - Other public (specify) **Private medical sector:** - Pvt hospital/clinic - Mission hospital/clinic - Other private medical (specify) **Other (specify)**	**Health Personnel:** - Doctor - Clinical officer - Nurse/midwife **Other person:** - Traditional Birth Attendant - Relative/friend - Other (specify) **No one**

The following binary outcome variables were constructed:

1. Facility delivery (main outcome): Use of a health facility for delivery (public hospital or health centre, mission, private) versus delivery at home or at any other place.

2. Skilled attendant: Assistance of a trained health professional at birth (doctor, clinical officer, midwife, nurse) versus other health personnel, TBA, relatives or nobody.

As discussed earlier, these are just approximations for skilled attendance (which can be defined as a skilled attendant in a facility providing at least basic emergency obstetric care) given that no information is available on the actual skills of the health professionals or how enabling the facility environment really is.

As the main focus of this work is the role of distance to a facility, the main focus of the analysis will be on facility delivery. In Zambia, the categories of facility delivery and presence of a skilled attendant overlap to a very large extent (>98%). Place of delivery and delivery attendant were cross-tabulated to show the most common combinations and the overlap (Tables 9 and 10 in section 3.3.2).

2.5.4 Constructing distance / level of care variables

I constructed the following eight distance variables according to the levels of care defined in section 2.2.2:

- Distance to closest facility of any kind
- Distance to closest facility offering delivery care,
- Distance to closest facility offering at least BEmOC-4,
- Distance to closest facility offering at least BEmOC-2,
- Distance to closest facility offering at least BEmOC-1,
- Distance to closest facility offering at least full BEmOC,
- Distance to closest facility offering at least CEmOC-1,
- Distance to closest facility offering full CEmOC.

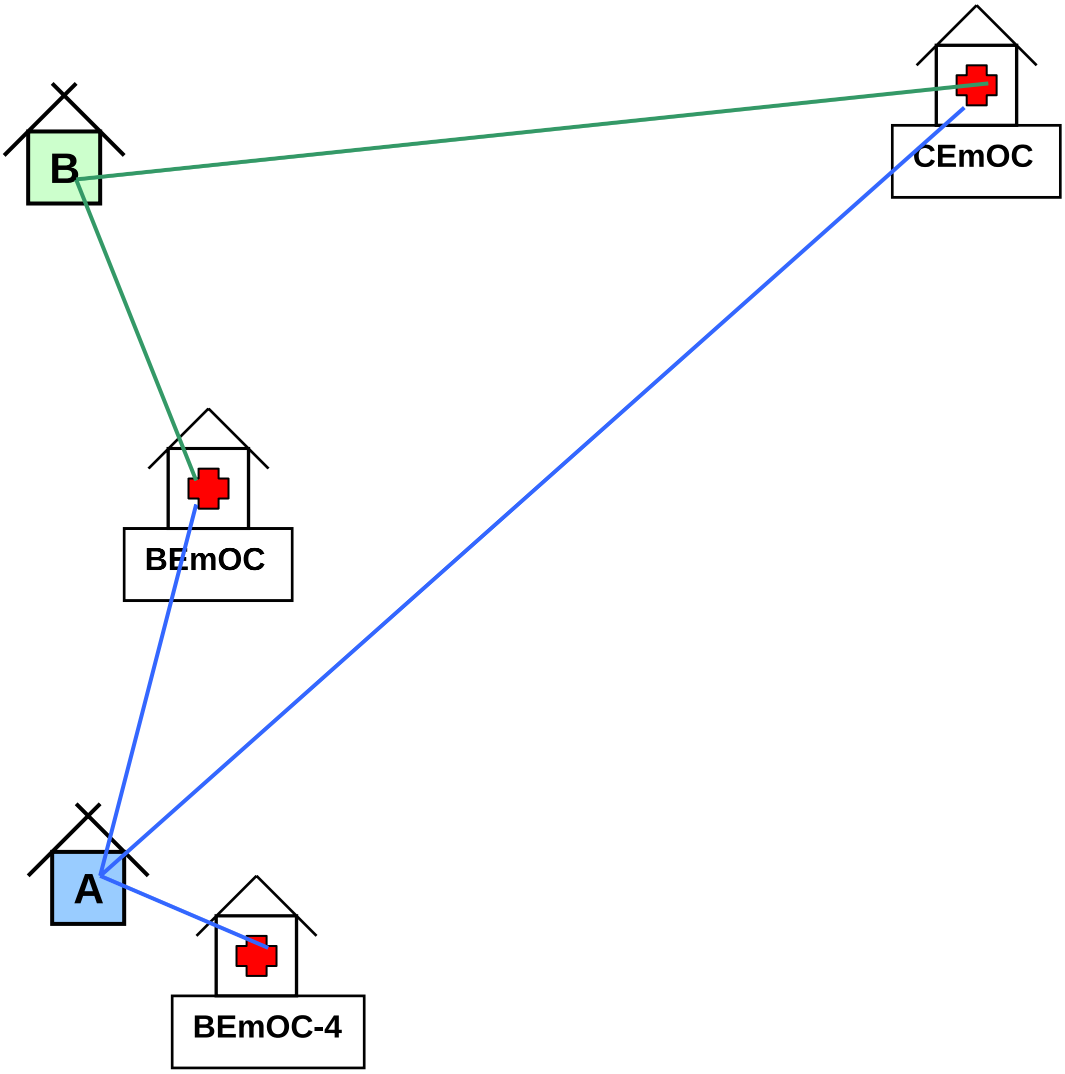
For presentation in the descriptive results (Table 11), distances were categorised, but for the analysis I used the continuous variables to not lose information. The distribution of the births over the various distance categories was displayed graphically.

In order to explore the shape of the relationship of the distance effect on health facility delivery, I first constructed very fine categories and also used the Lowess smoother in Stata (a locally weighted regression that calculates the proportion of facility births at each distance and plots a smoothed line graph) for visual exploration. There did not seem to be a particular threshold distance beyond which distance ceased to matter and the effect of distance did not appear to be linear either, but rather level off with large distances, as would be expected as the difference between 5 km and 10 km is anticipated to play a larger role than the difference between 45 km and 50 km. Therefore, I decided to use a logarithmic transformation as this shrinks large values disproportionally. Distances of less than 1 km were rounded to 1 km in order to not give too much weight to differences at this very close distance. The shape of the relationship of the resulting log-transformed distance variables was again examined (Fig. 60 and 61) and appeared to be approximately linear, so the models were built using a linear effect of log-distance on facility delivery.

I also constructed a variable of the best level of care available within 15 km within the following categories: no facility, a facility offering delivery care but not fulfilling BEmOC-4 criteria (termed substandard), and the various EmOC categories mentioned above.

The above variables either keep level of care constant and look at distance (e.g. distance to a BEmOC facility) or keep distance constant and look at level of care (e.g. best type of facility within 15km). Thereby, one does not take account of whether other facilities are available in the surroundings as well. For example, village A and B could be at similar distance from a BEmOC facility, but village A has a lower-level facility close-by, while village B is not as far away from the hospital offering CEmOC as village A (Figure 9). If we just use distance to closest BEmOC or better, we do not take the rest of the service environment into account.

Figure 9: Example of different service environments



In order to take distance and level of care into account simultaneously, I constructed an indicator variable to add to the model with distance to any delivery care. This indicator has four levels: whether the facility at that distance (or within 10 km of that distance) offers (1) substandard delivery care, (2) BEmOC-4 / BEmOC-2, (3) BEmOC-1/BEmOC or (4) CEmOC-1/CEmOC. It is expected that for the same distance to a facility, higher level of care at that facility should increase use.

Finally, there are two variables measuring whether women felt distance and transport were a big problem or not. I used both variables on the individual mother level, and also as a cluster aggregate, i.e. proportion of women in a cluster who consider distance a big problem. These variables were cross-tabulated with actual distances.

2.5.5 Constructing other explanatory variables

In order to control for confounding, I constructed a number of variables at individual, household and community level from variables available in the DHS dataset. An extensive documentation of variable construction and coding can be found in Appendix D. Below I give a summary, with some more detail only on those variables that are more complex: ability to pay, women's autonomy and community-level variables. For variables that were constructed from a variety of measured aspects, I developed a simple a priori scoring system instead of using Principle Component Analysis (PCA) because PCA is problematic with discrete data [64] and also because this scoring is more transparent.

Variables were left continuous where possible and reasonable, and in these cases a categorised version was only constructed for ease of presentation in Table 14. Categorisation of variables was done along naturally occurring splits, trying to represent the spread without creating too many categories or too small categories. This often meant creating smaller groups at the extremes than at the centre of the distribution.

2.5.5.1 Measuring ability to pay

Since I am interested in the ability of households to pay for costs associated with facility delivery in the previous five years, it is medium-term availability of cash I attempt to measure. Using household assets as a proxy is obviously not ideal, but in line with most other researchers I felt this was the best possible measure available. The household must have spent some cash to purchase household items such as a radio or phone and for non-natural floor materials and cooking fuel, and this may correspond to their ability to pay for costs associated with facility delivery.

The DHS wealth variable also includes electricity, electricity-driven assets such as fridge and television, as well as bikes, motorbikes and cars, and thus captures aspects of infrastructure and geographical access as well as financial means. Therefore, I created my own asset index excluding these components. The way the DHS constructs its index using PCA with binarised variables has also been shown to be suboptimal [64], another reason for not using it. I decided to use simple weights instead of PCA given that this is more transparent and does not perform worse [162].

Household water source and sanitation type are likely to be dependent on what is available where the household resides and may thus also to some extent capture infrastructure. However, I felt this is probably less strong than for electricity, and applies mostly to piped water and flush toilets, which are uncommon in rural areas anyway. Therefore I included these variables in the asset score. I also included food sufficiency of the household, a variable available in the DHS 2002, assuming that not having enough food to eat is a good proxy of ability to pay for accessing health services.

In the DHS 2007, a variety of new asset items were collected (e.g. furniture, cassette player, watch, sewing machine) as well as information on whether the household owns a bank account, all of which were included in the index. Furthermore, the DHS 2007 collected detailed information on farmland and livestock, important assets in rural areas, and I also included these in the 2007 asset index.

There is also a separate variable on whether money is considered a big problem for health care seeking. I did not include this variable in the index but analysed it as a separate variable.

2.5.5.2 Measuring women's autonomy

There is an abundance of questions in the DHS that may relate to women's autonomy. I summarised them into a smaller number of relevant aspects:

1) Woman's position in the relationship: combining information on age at marriage, age at first birth, age differential relative to the husband, communication between the spouses and the questions about the woman's opinion on the justification of wife-beating and refusal of sex.

2) Woman's financial independence: using the question about decision-making on larger purchases and whether they can decide about their earnings for women with paid occupation.

3) Woman's mobility: using information on her decision-making power concerning visits to friends and relatives.

4) Woman's decision-making power regarding her own health care: using the specific question asking about this.

Furthermore, I constructed community-level aggregate variables of female autonomy for these four aspects in order to explore potential contextual effects.

2.5.5.3 Community-level variables

I constructed a variety of cluster-level aggregates of individual-level variables, e.g. on modern versus traditional fertility attitudes of men and women (using their ideal number of children) and the female autonomy aspects, in order to capture the influence of surrounding opinions on the mother. This was done using the datasets of all women interviewed and not just those who had given birth in the last five years, and using the men's dataset.

I did not include community-level use of health facilities for delivery (as representing norms) since this would adjust for exactly all the accessibility issues that I want to elucidate.

2.5.6 Analysis of hierarchical data

The DHS data used in this analysis are clustered at several levels as there can be several births from one mother within the previous five years, sometimes several mothers share a household and many households make up a village/cluster.

Births are thus not independent and the hierarchical nature of the data must be taken into account. As the main interest of this analysis is a cluster-level variable, distance, and as there are hundreds of clusters in the dataset, a random effects model was considered the most adequate choice. This was done using the xtmelogit command in Stata10 that performs multilevel logistic regression using maximum likelihood.

A simple correction of standard errors, as is done with the survey commands in Stata (svyset and svy) or with the robust standard error command will lead to biased results when effects are different at the various levels. The svy-commands would allow me to weight observations according to their over- or under-representation in the national survey. However, since this analysis only considers rural women who did not move after the birth of their child in the previous five years, it is not nationally representative anyway.

There are usually only a few mothers per household and therefore the four-level model containing births within mothers within households within clusters was compared to a simpler three-level model excluding the household level. This was done for models without covariates and for the final models containing distance to the closest delivery care, an indicator variables for level of care and all the confounders, using one-sided Likelihood Ratio Tests (LRT). There was no strong evidence that adding a household-level random intercept improved the model: LRT p=0.17 for the null model and LRT p=0.19 for the final model in the 2002 dataset, and LRT p=0.09 for the null model and LRT p=0.15 for the final model in the 2007 dataset. There was strong evidence (p<0.001) that both mother and cluster random intercepts improved model fit in all four models. 1

Intra-cluster correlation (ICC) can be used to describe how correlated an outcome is among members of a higher-level unit. For linear outcomes the proportion of the total variance that is due to differences between clusters is straightforward to calculate:

$ICC = \sigma^2_{between} / (\sigma^2_{within} + \sigma^2_{between})$

Or more general:

$$\text{Correlation at level k} = \frac{\text{Sum of variances at that level and above}}{\text{Sum of all variances}}$$

For models with binary outcome it is not straightforward as there is no level-1 variance and the variance depends directly on the mean. There are different approaches to calculate an ICC nevertheless and in line with Stata, the

[1] Note that these results are only approximate because in this setting the statistics do not follow an asymptotic null Chi-square distribution.

figures were computed using $\pi^2/3$ for the level-1 variance. The ICC of the null model (no covariates) was compared to a model containing all explanatory variables that independently influence health facility use in at least one of the surveys, and this was repeated stratified by distance to the closest health facility.

2.5.7 Univariable analysis

Frequency distributions of all physical accessibility variables and all potential confounding variables in the sample were computed and are presented in Tables 11 and 14a-d, as well as the percentage of facility deliveries in each category and a crude Odds Ratio from a univariable model taking account of clustering at cluster and at mother level. P-values from Wald tests of all categories simultaneously are shown.

For convenience of presentation, continuous variables were categorised, however, the continuous variables were used in all further analysis. For categorical variables, the baseline was chosen so as to represent a natural baseline and/or to be not too small (less than 10% of the sample).

2.5.8 Multivariable analysis / Model building

All potential confounding variables that seemed at all associated with facility delivery and with any of the distance measures (even if only weakly, i.e. $p<0.15$), were examined for their confounding effect on the distance variables. This was done one variable at a time using a model with random intercepts for clusters and mothers. Age and parity were considered together as they are mutually confounding. Continuous variables were used in their categorical form and as linear effects and if the shape of the relationship (judging from categories and Lowess plots) suggested so, additionally using quadratic effects. Those variables that caused a change of at least 10% in the logOR of distance were considered to be confounders.

The multivariable models were built starting with education and household wealth as *a priori* confounders and then adding other variables in the order of the strength of their separate confounding effects, and keeping them in the model if they still changed the distance logOR by at least 10%. First, a model was built that did not include confounders at the cluster-level and then a second model was built including these. For the sake of consistency, all distance models from each dataset contain the same variables, even if some of these are not confounding all of the distance effects.

The indicator variable on level of care at the closest facility (or at a similar distance) was also used as a linear effect and the adequacy of that assumption was judged by looking at the increase in OR and by using a Likelihood Ratio Test.

Finally, effect modification of the distance effect was explored by performing interaction tests of the final models for the following variables that were a priori considered potential effect modifiers: level of care, season of birth, availability of household transport means, mother's education and household wealth. Additionally, interactions were explored for mother's fertility attitudes and relationship autonomy. The potential effect modifiers were collapsed into binary variables or into three categories in order to increase the power of the interaction tests.

2.5.9 Population attributable fractions

To estimate the proportion of home births that could be averted if all women had good geographical access to delivery care (assuming a causal relationship), I computed the population attributable fraction (PAF) of distance to health facilities as well as PAFs of other important determinants for comparison. This was done using an explanatory model with a cluster random intercept containing all variables that independently influence health facility use in at least one of the surveys in order to control for mutual confounding.

Distance was in the model a priori and variables were added in the order of their effect sizes and significance in univariable analysis, starting with individual-level variables and then adding variables on the household and cluster level, keeping and eliminating variables according to a cut-off significance level of p=0.05 in Wald tests.

A Stata user-written ado-file provides the command "aflogit" that can be run following multivariable logistic regression and that calculates PAFs for each factor adjusted for all other variables. Unfortunately, this command cannot be used after multilevel models, so I had to omit the cluster random effect and instead use robust standard errors. It also cannot be used after survey commands taking account of stratified sampling, but this is of less relevance here as my sample is not representative of Zambia anyway (only rural non-movers). “Aflogit” provides asymptotic standard errors and 95% confidence intervals for all PAF estimates, taking into account both the uncertainty of the relative risk and that of the proportion exposed.

The “aflogit” command does not make the “rare disease assumption” since it does not use the odds ratios for the calculation but rather calculates the number of cases one would expect if the exposure was absent and compares that to the number actually observed:

$$\text{PAF} = \frac{\text{number of observed cases} - \text{number of expected cases on removal of exposure}}{\text{number of observed cases}}$$

The number expected is calculated by predicting the probability of the outcome for each individual with the new covariate values but under the same logistic model. This approach is equivalent to using the formula:

PAF = (proportion of cases exposed) (1 – 1/Risk Ratio).

Population attributable fractions were calculated for distance to a facility offering at least BEmOC-1 services, using as the baseline (“unexposed” stratum) those within 5 km of such a facility. For comparison, PAFs for education and household wealth were calculated. For education, complete secondary or higher education was joined with incomplete secondary education to form the baseline category, since the former group is very small (only around 1% of rural births are to mothers with complete secondary education) and thus estimates become unstable. Furthermore, the PAF of average women’s relationship autonomy in the cluster was calculated as this variable showed a strong association with place of delivery in both datasets.

CHAPTER 3

RESULTS

The results comprise three main parts. In the first part I describe how Zambian health facilities are functioning in terms of Emergency Obstetric Care (EmOC) and which capabilities are most commonly absent, showing this separately for hospitals and health centres / health posts. In the second part I examine the distribution of EmOC facilities and health professionals in Zambia at national and subnational level, comparing to international benchmarks. Furthermore, I present the percentage of urban and rural populations living within 15 km of delivery care or EmOC. In the third and main part of the analysis I investigate the effect of distance on health facility use for delivery, presenting results from univariable and multivariable analysis and exploring effect modification. Finally, I calculate population attributable fractions to estimate the proportion of home births that could be avoided if all births were close to facilities, assuming a causal relationship.

3.1 Emergency Obstetric Care functions

3.1.1 Delivery service and staffing

Overall, of 1397 health facilities with facility information in the dataset of “first-level hospitals and below”, 1110 (79%) are recorded as offering delivery services: 69 first-level hospitals, 117 urban health centres, 873 rural health centres and 50 health posts.

Of the 24 second- and third-level hospitals, 21 offer delivery services while 3 do not according to the information in the HFC. These are Chainama Mental Hospital in Lusaka, Roan Antelope Hospital in Luanshya and Arthur Davison Hospital in Ndola. In all three cities, there are other hospitals offering delivery services.

In the human resources dataset from the “first-level hospitals and below”, 80 facilities were found to have only administrative and support staff recorded but no paramedical or medical staff. A further 79 facilities had no medical staff (doctors, nurses/midwives, clinical officers) but only paramedical staff such as environmental health technicians or lab technicians. In total, 246 doctors, 1047 clinical officers and 6018 nurses are registered at the 1365 facilities with human resource information in this dataset.

Table 5: Distribution of medical staff (health professionals: doctors, nurses/midwives, clinical officers) registered per facility in first-level hospitals and facilities below

Medical staff number registered at facility	Number of facilities	Percentage of facilities
0	159	12 %
1	438	32 %
2	259	19 %
3	111	8 %
4	59	4 %
5 or more	339	25%
Total	1365	100 %

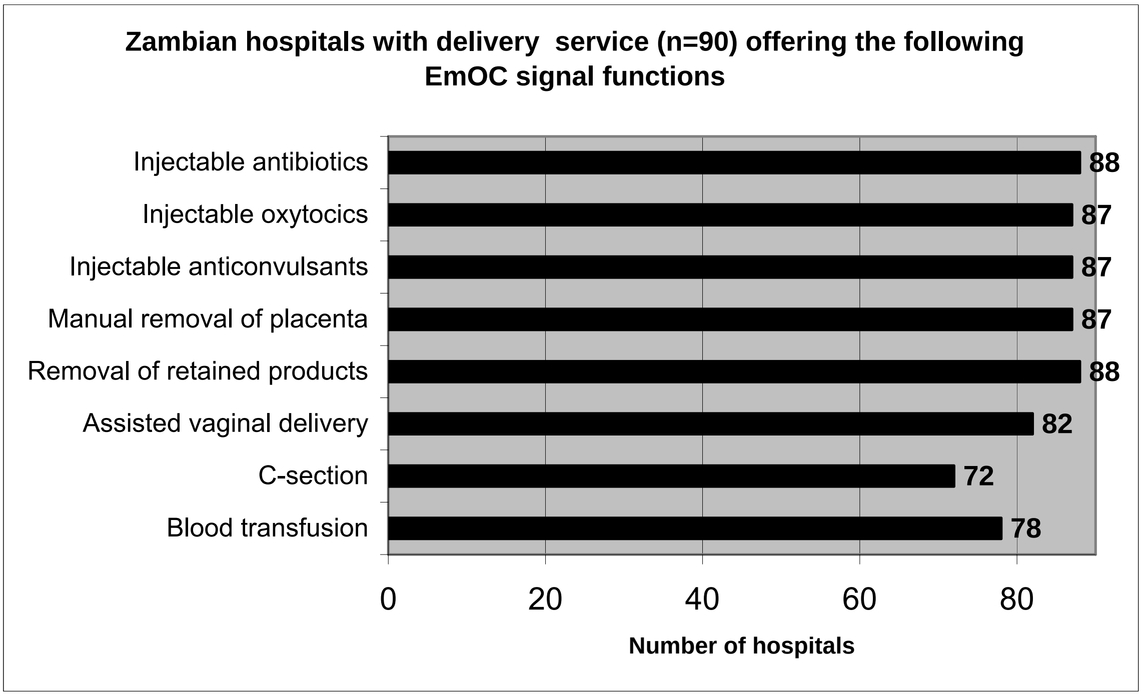
In the 24 second- and third-level hospitals, altogether 697 doctors are registered, with 398 alone at the University Teaching Hospital in Lusaka and ranging from 2 to 72 in the other 23 hospitals. Furthermore, 1897 nurses, 605 midwives and 150 clinical officers are employed in these 24 hospitals. The median numbers per second-/third-level hospital are 10 doctors, 60 nurses, 20 midwives and 5 clinical officers.

In the following, I grouped the first-level hospitals with the other hospitals instead of with the health centres and health posts as done in the datasets and the description above. Facilities that do not offer any delivery services are not considered below.

3.1.2 Hospitals

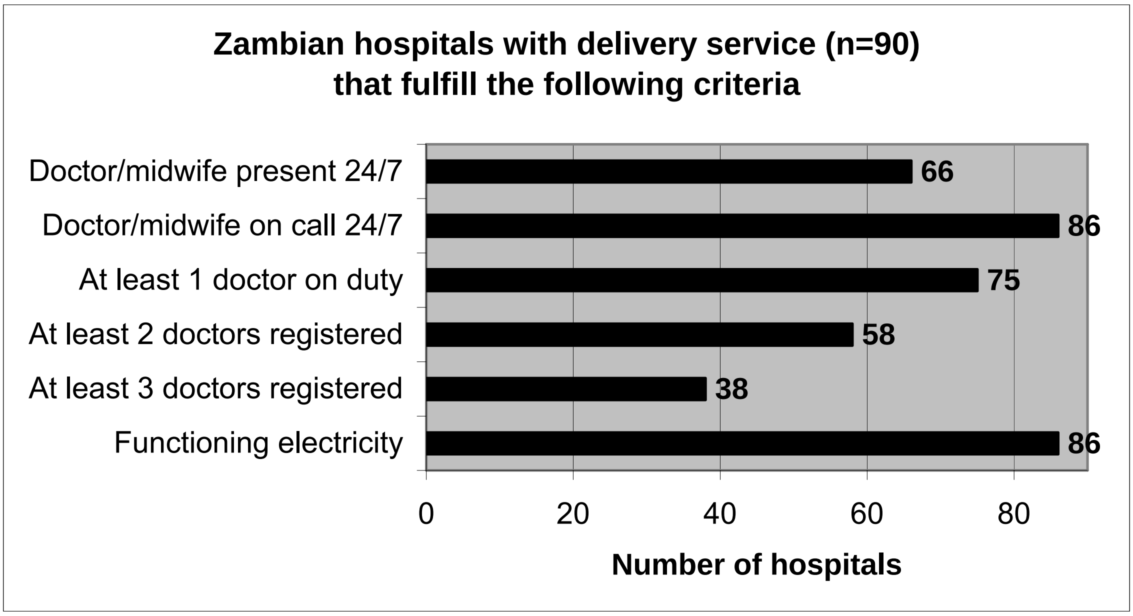
Except for assisted vaginal delivery, all basic signal functions are present at nearly all 90 hospitals in Zambia that offer delivery services. However, 20% do not offer C-section and 13% do not offer blood transfusion.

Figure 10: Signal functions offered in hospitals



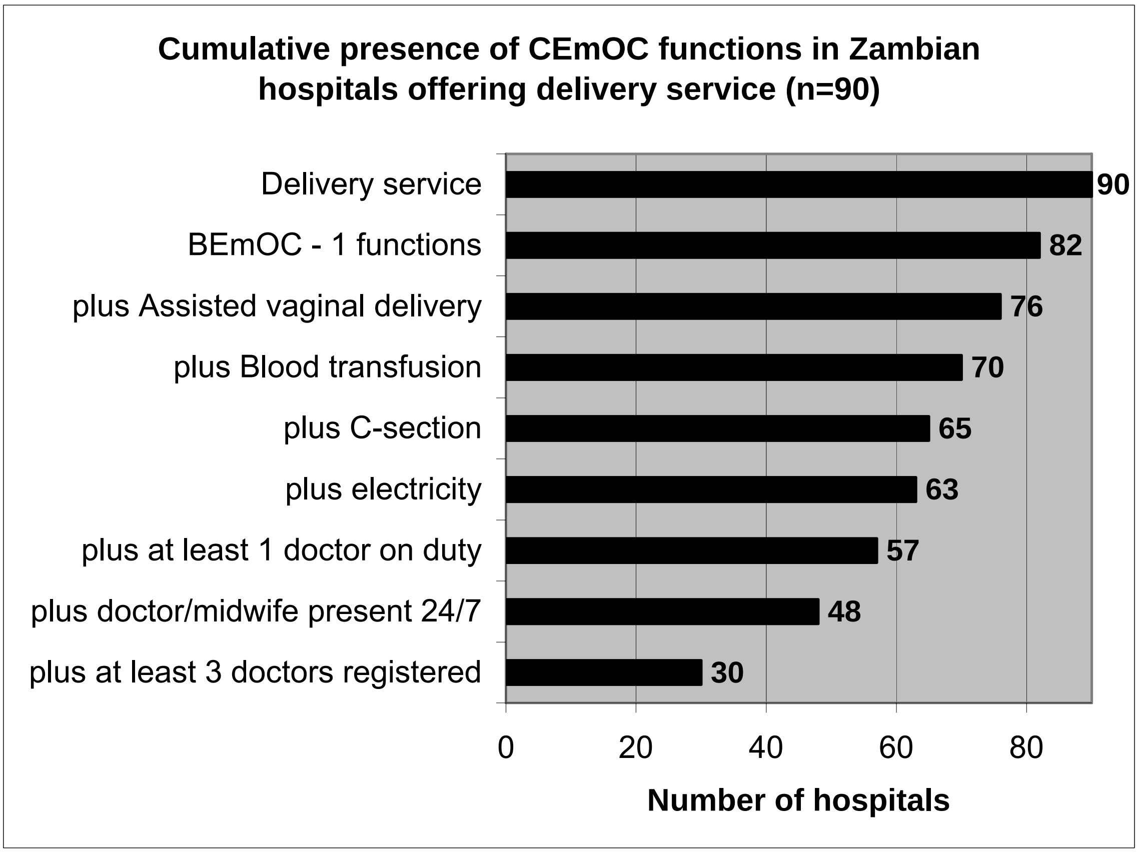
Nearly all hospitals have functioning electricity and a doctor or midwife on call 24 hours 7 days a week. However, only 66 hospitals (73%) have a doctor or midwife actually present 24 hours, and at the day of visit a doctor was found on duty in only 75 of the 90 hospitals (83%). More than half of the 90 hospitals have less than 3 doctors registered.

Figure 11: Other functions offered in hospitals



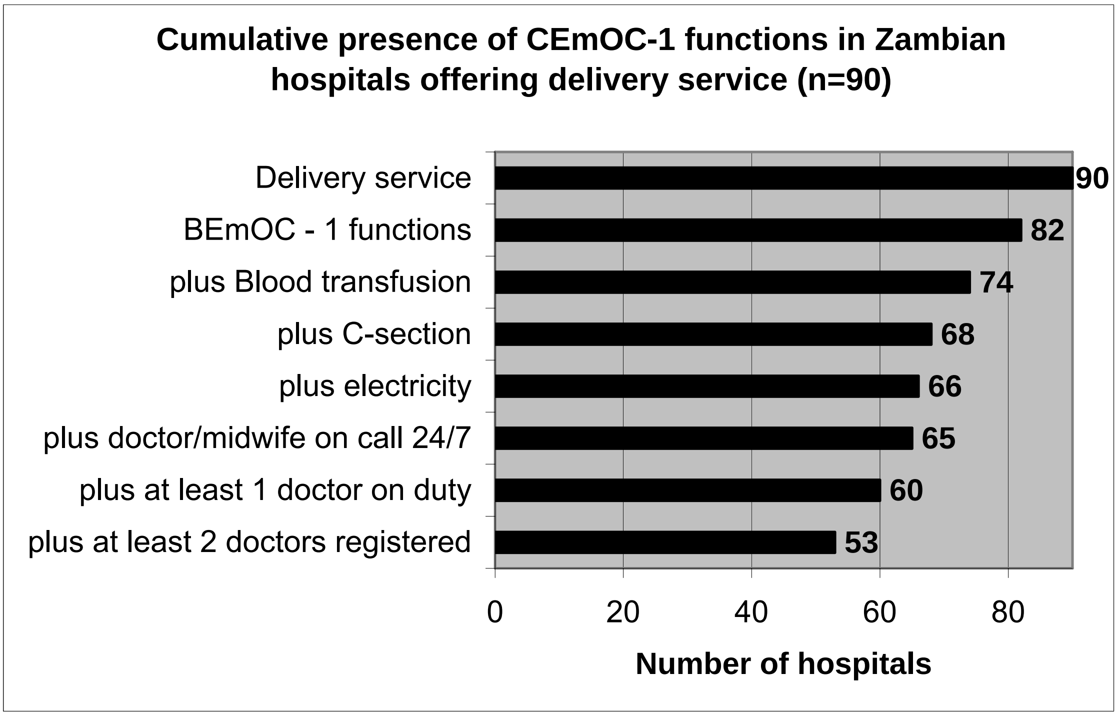
When considering all the criteria cumulatively, 82/90 hospitals offer all signal functions except assisted vaginal delivery (BEmOC-1 functions) and 65 offer all 8 signal functions. However, only 30 also fulfill the additional criteria for full CEmOC.

Figure 12



Using the more lenient CEmOC-1 criteria, of the 68 hospitals claiming to provide at least the 7 signal functions except assisted vaginal delivery, 53 also fulfilled the other criteria for this category.

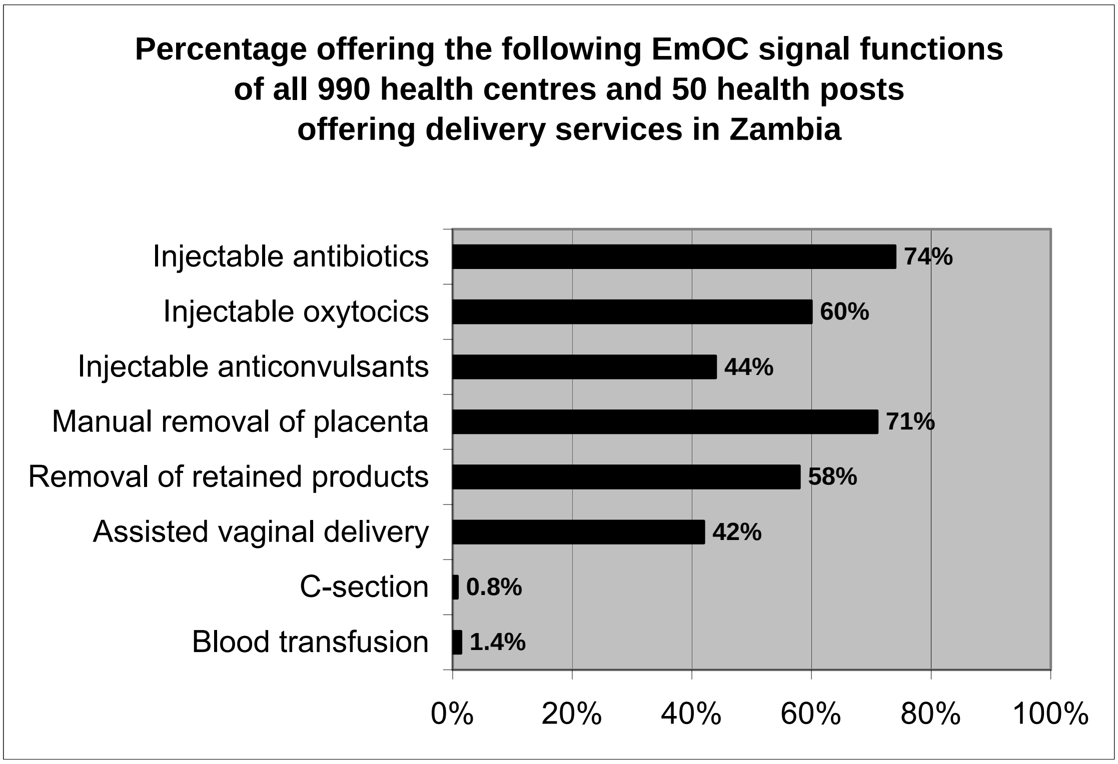
Figure 13



3.1.3 Health centres and health posts

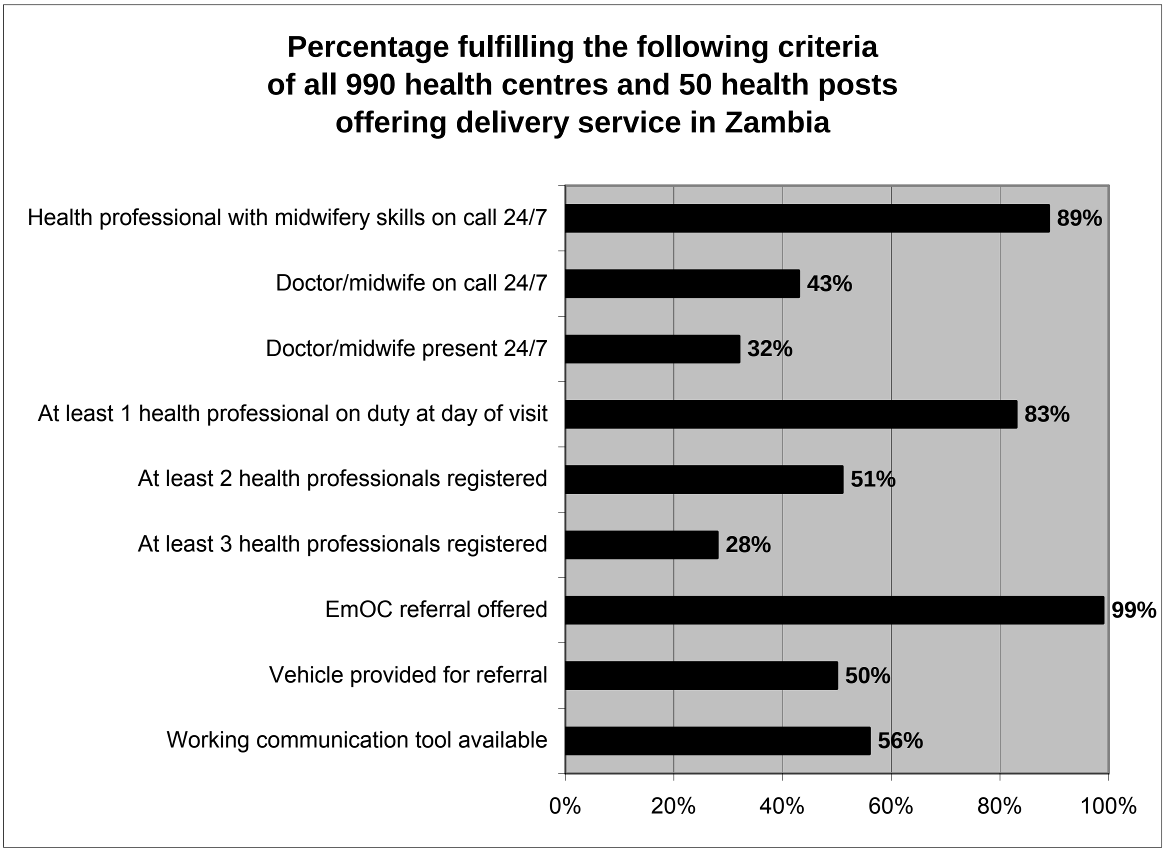
Among the 990 health centres and 50 health posts offering delivery services, the signal functions most prevalent are parenteral antibiotics and manual removal of placenta with 74% and 71% of all such facilities offering these services respectively. Parenteral anticonvulsants (44%) and assisted vaginal delivery (42%) are less commonly offered. Naturally, only a small number of health centres offer C-sections or blood transfusions.

Figure 14: Signal functions offered in health centres and posts



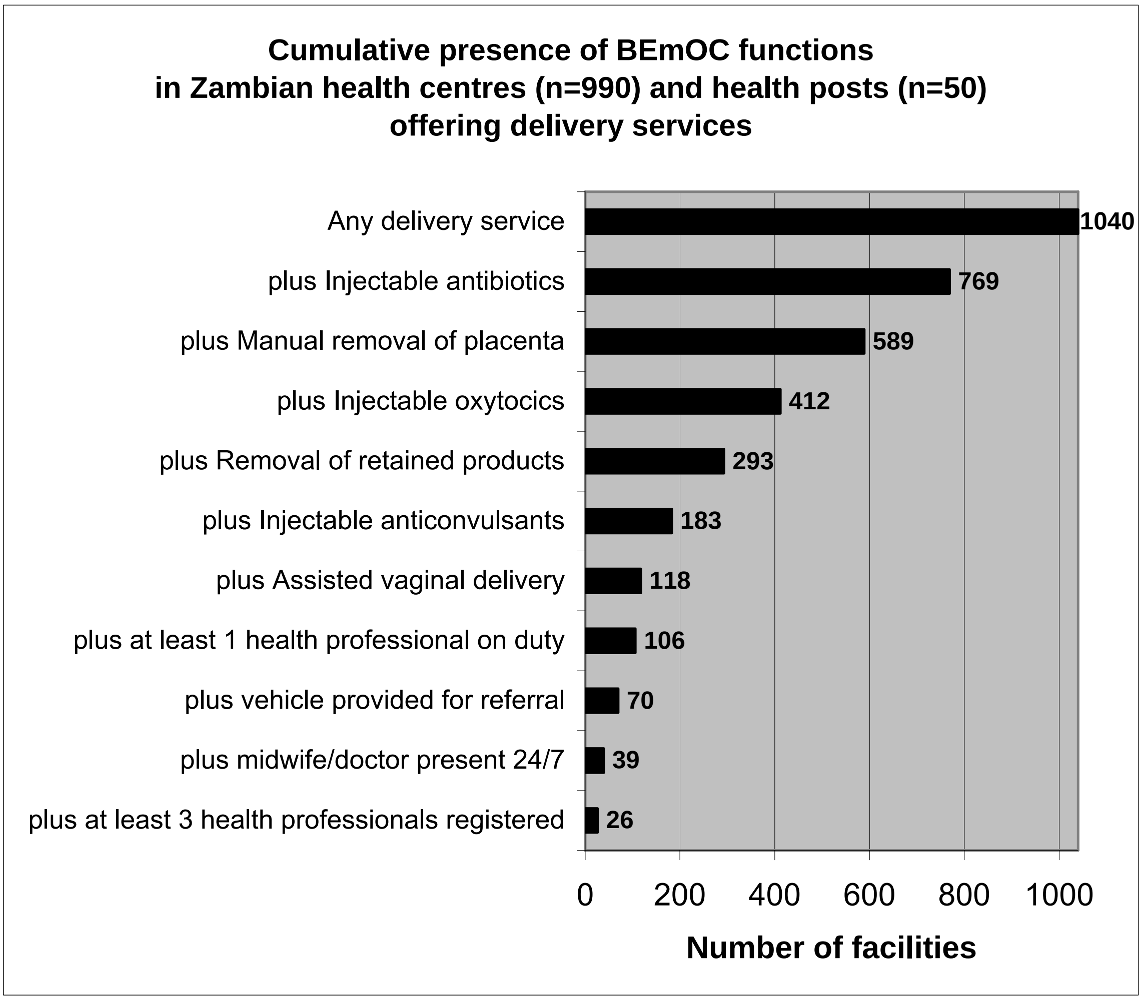
Of the additional criteria, 24 hour availability of a doctor or midwife and sufficient numbers of health professionals (doctors, nurses/midwives or clinical officers) are those most likely to be absent. While virtually all health centres and posts claim to refer patients for emergency obstetric care not offered at their facility, only half provide a vehicle for transport and only 56% have a functioning communication tool to contact the referral institution. A few of the latter may have a working communication tool but not use it since they are close enough to a referral institution to communicate directly.

Figure 15: Other functions offered in health centres and posts



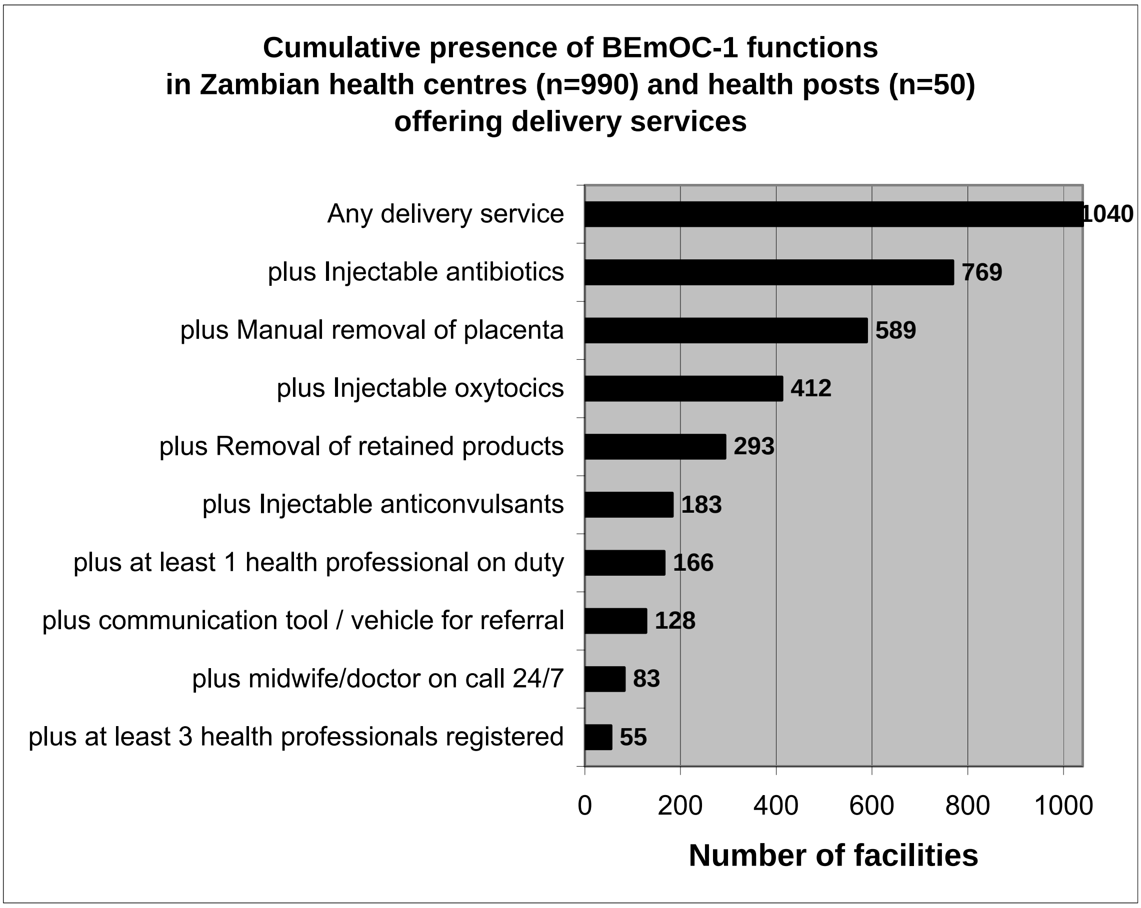
When considering all criteria cumulatively, only 118 (11%) of the 1040 health centres and health posts offering delivery services offer all 6 basic signal functions. Only 26 health centres (2.5%) fulfill all the criteria for BEmOC. Another 2 facilities (not shown) lacked referral means but were still classified as BEmOC because one was next door to a hospital and the other provided C-section and blood transfusion but employed one doctor only.

Figure 16



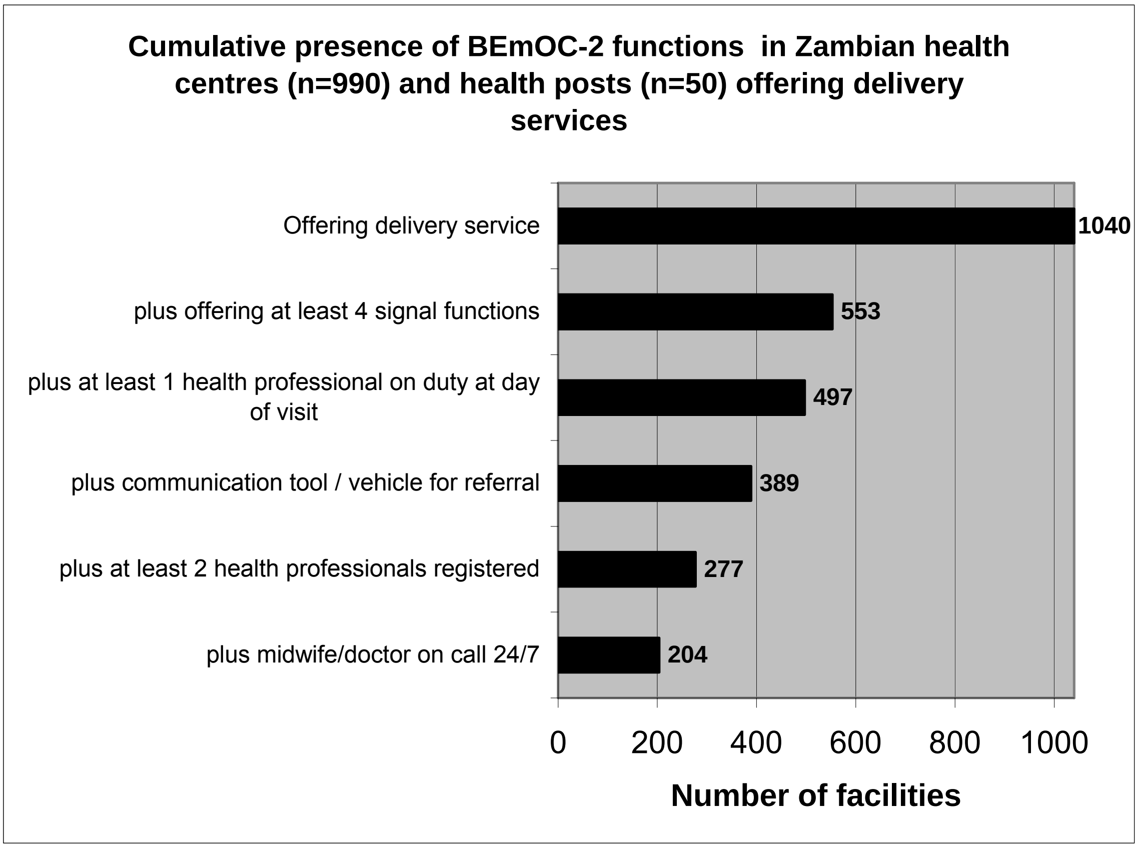
When using the less strict criteria of BEmOC-1, there are 183 facilities (18%) stating that they offer all basic signal functions except assisted vaginal delivery. Only 55 facilities (5.3%) of 1040 fulfill all the criteria for BEmOC-1 (plus the additional two mentioned above).

Figure 17



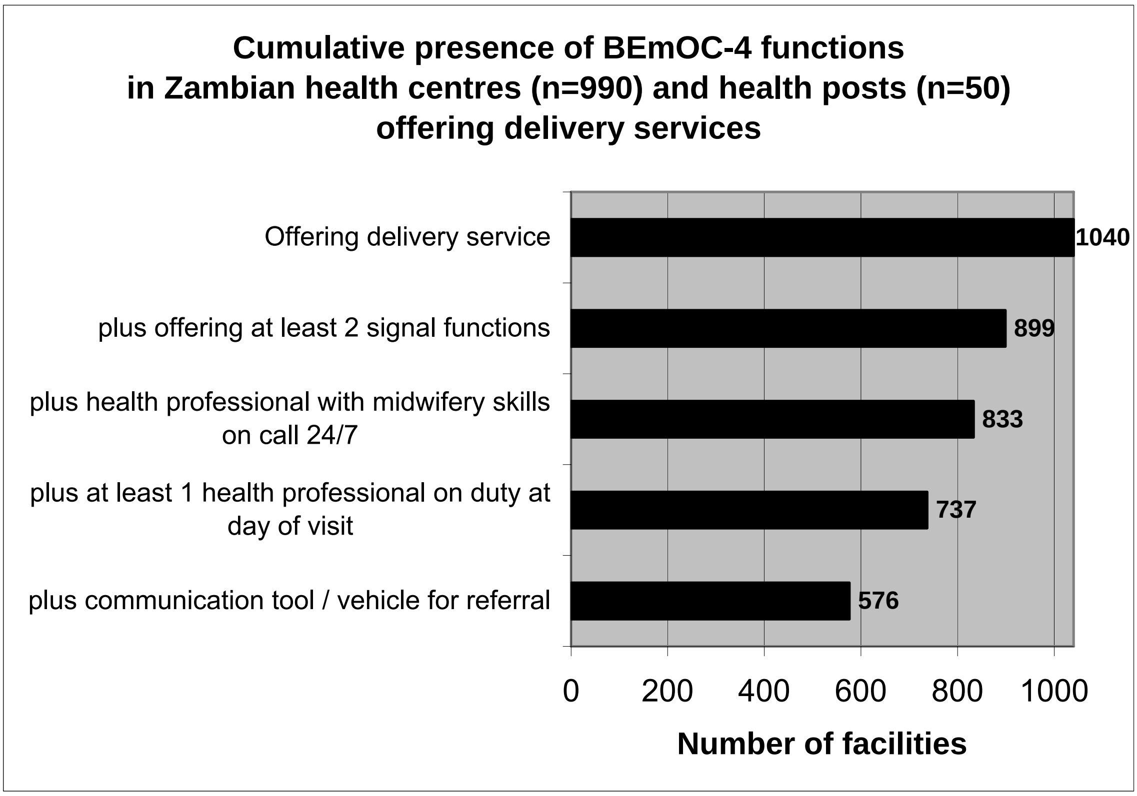
As the Figure 18 shows, only 20%, or 204 of the 1040 health centres and posts meet the more lenient criteria of the BEmOC-2 category (plus an additional 3 facilities that did not offer referral but were either next door or provided CEmOC functions themselves).

Figure 18



Finishing with the least strict category, BEmOC-4, the following cumulative graph (Fig. 19) shows that still only just above half, or 576 of the 1040 facilities fulfill even those minimal criteria of offering at least 2 signal functions, having a health professional with midwifery skills (not necessarily a midwife) on call 24 hours and at least one health professional on duty at day of visit, as well as being either able to provide a vehicle for referral or to contact the referral institution by phone or radio. This means that 464 facilities offering delivery services in Zambia fall short of those criteria according to the health facility census information.

Figure 19



3.1.4 EmOC classification results

When applying the criteria in Table 3 to all the health facilities in the datasets (hospitals, health centres and health posts), of the 1131 facilities that offer any delivery services, 30 fulfill the criteria for CEmOC and another 24 for CEmOC-1. 42 facilities of the remaining ones qualify for full BEmOC and 39 for BEmOC-1. These are altogether 135 or 12% of all facilities offering delivery services in Zambia. The following two graphs show the numbers of facilities in each category (Fig. 20) and the cumulative percentages (Fig. 21).

Figure 20

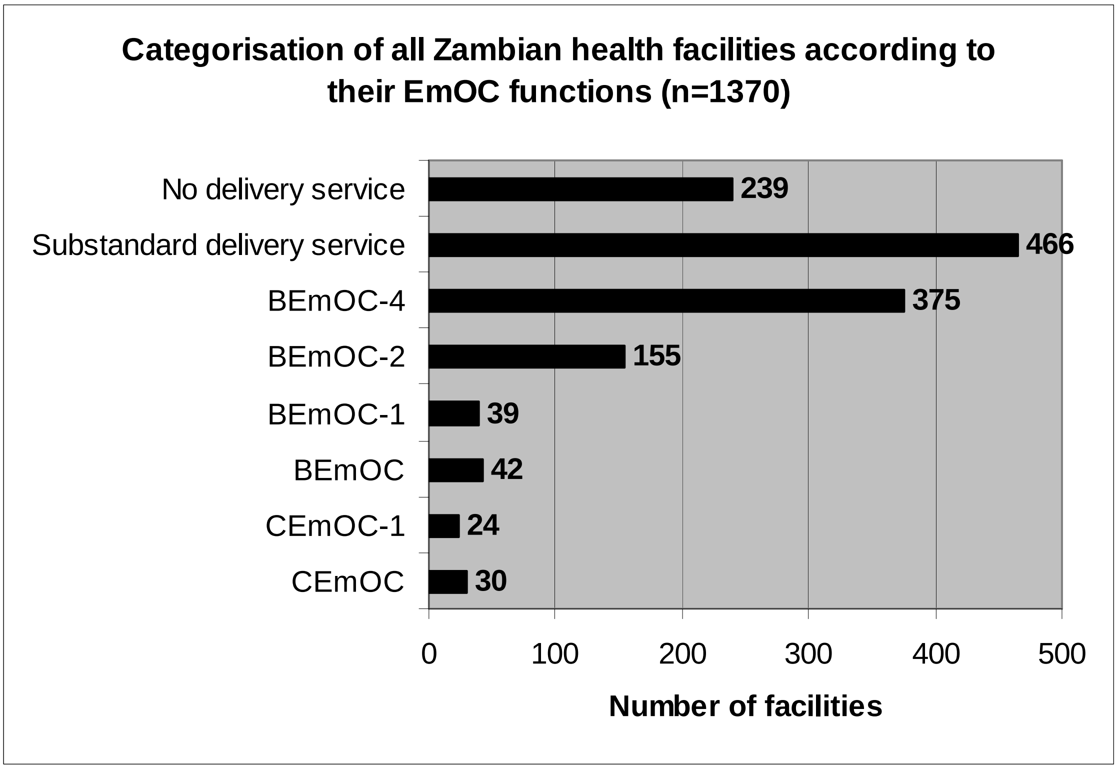
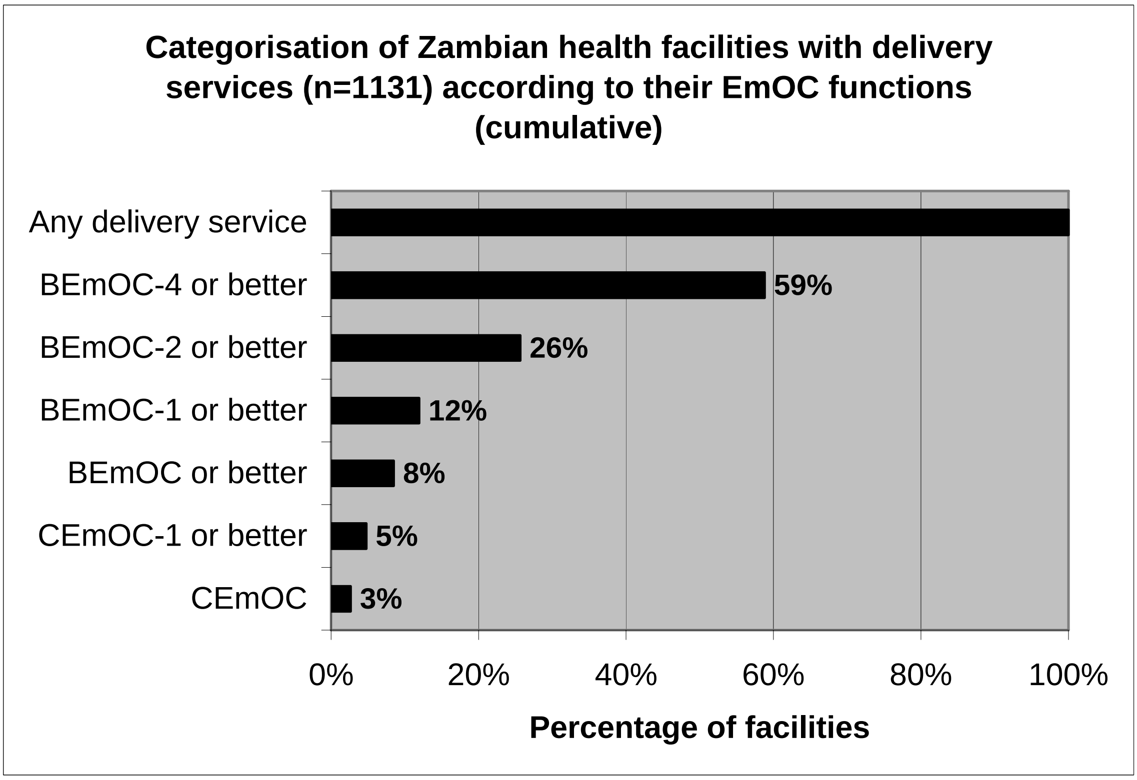


Figure 21


Categorisation of Zambian health facilities with delivery services (n=1131) according to their EmOC functions (cumulative)
Any delivery service
BEmOC-4 or better
BEmOC-2 or better
BEmOC-1 or better
BEmOC or better
CEmOC-1 or better
CEmOC
59%
26%
12%
8%
5%
3%
0%
20%
40%
60%
80%
100%
Percentage of facilities

3.2 Emergency Obstetric Care coverage

The following analysis aims to quantify how delivery services, in particular EmOC services, and health professionals are distributed in Zambia. For this purpose, the information from the Health Facility Census with the EmOC classification described above was linked to administrative level and population data from the Zambian Population Census 2000. EmOC was defined as at least BEmOC-1.

Three different types of analyses were performed. Firstly, the number of EmOC facilities per 500,000 population or per 20,000 births by province and by district was compared to the benchmarks from the UN process indicators of at least 5 EmOC facilities of which at least 1 CEmOC. Secondly, staffing levels were compared to the benchmarks set in the World Health Report 2005 of 3 doctors and 20 midwives per 3600 births, also by province and by district. Thirdly, I used the geographical information of where exactly facilities are located and how densely different wards are populated in order to calculate the proportion of population that lives within 15km of a facility offering delivery care or BEmOC respectively. This was summarised on the national, provincial and district level, overall and separately for urban and rural wards.

3.2.1 EmOC facilities

3.2.1.1 By province

Figures 22 and 23 show that all Zambian provinces meet the CEmOC benchmark of at least 1 CEmOC facility per 500,000 population or 20,000 births (assuming a Crude Birth Rate (CBR) of 40 births per 1000 population – which is approximately the Zambian average). Except for Eastern Province, all provinces also meet the EmOC benchmark of a minimum of 5 EmOC facilities (CEmOC or BEmOC) per 20,000 births. Lusaka Province falls short of the EmOC benchmark in terms of population but meets that benchmark in terms of births, due to its lower than average birth rate.

Figure 22

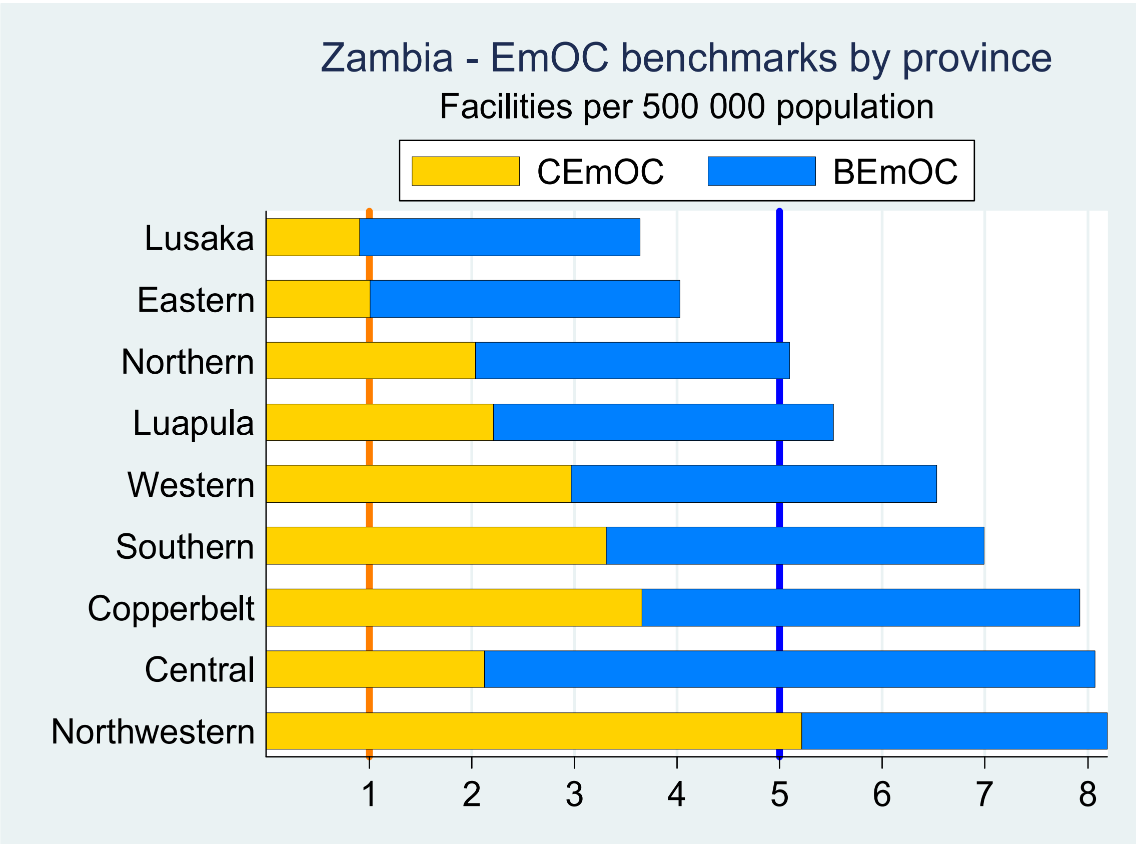
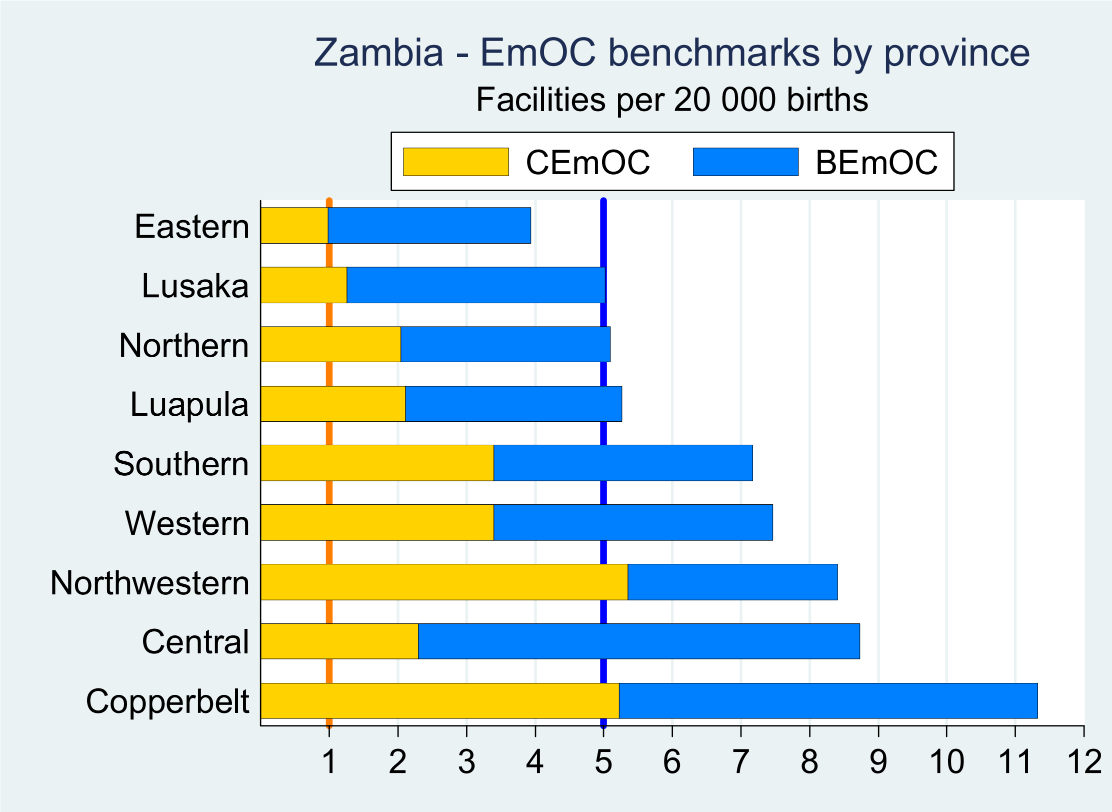
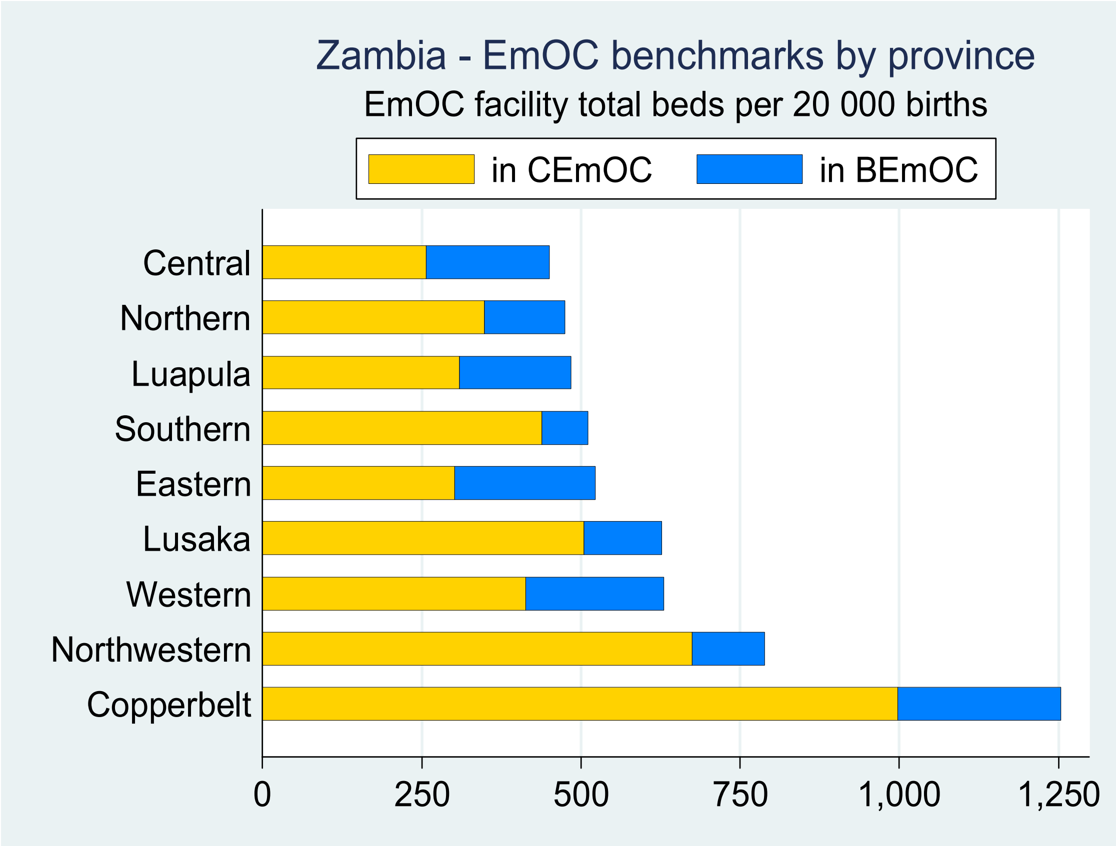


Figure 23



It should also be noted that the capacity of a facility is not considered which may distort the picture: The University Teaching Hospital (UTH) in the capital Lusaka has over 1000 beds and approximately 400 doctors and 500 nurses registered, while a third of the other CEmOC facilities and virtually all BEmOC facilities have less than 100 total beds. Therefore the picture changes somewhat when looking at EmOC beds instead of facility number (Fig. 24).

Figure 24

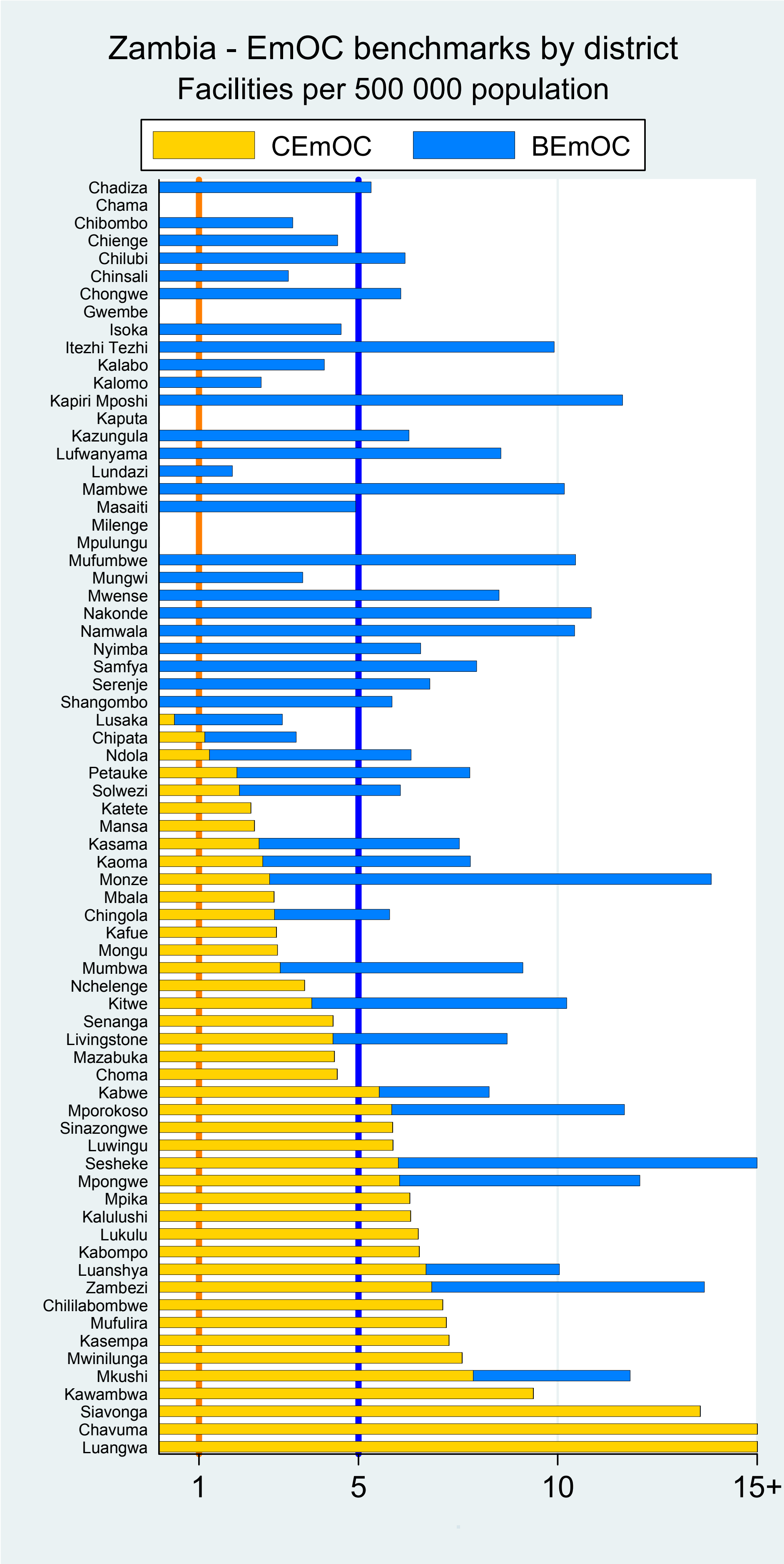


3.2.1.2 By district

When examining the distribution of EmOC facilities by district, it can be seen that nearly half of the 72 Zambian districts provide no comprehensive EmOC services (Fig. 25) and about a third have less than the recommended minimum 5 EmOC facilities available per 500,000 population, with 5 districts not having any facilities that were classified as EmOC (Fig. 26).

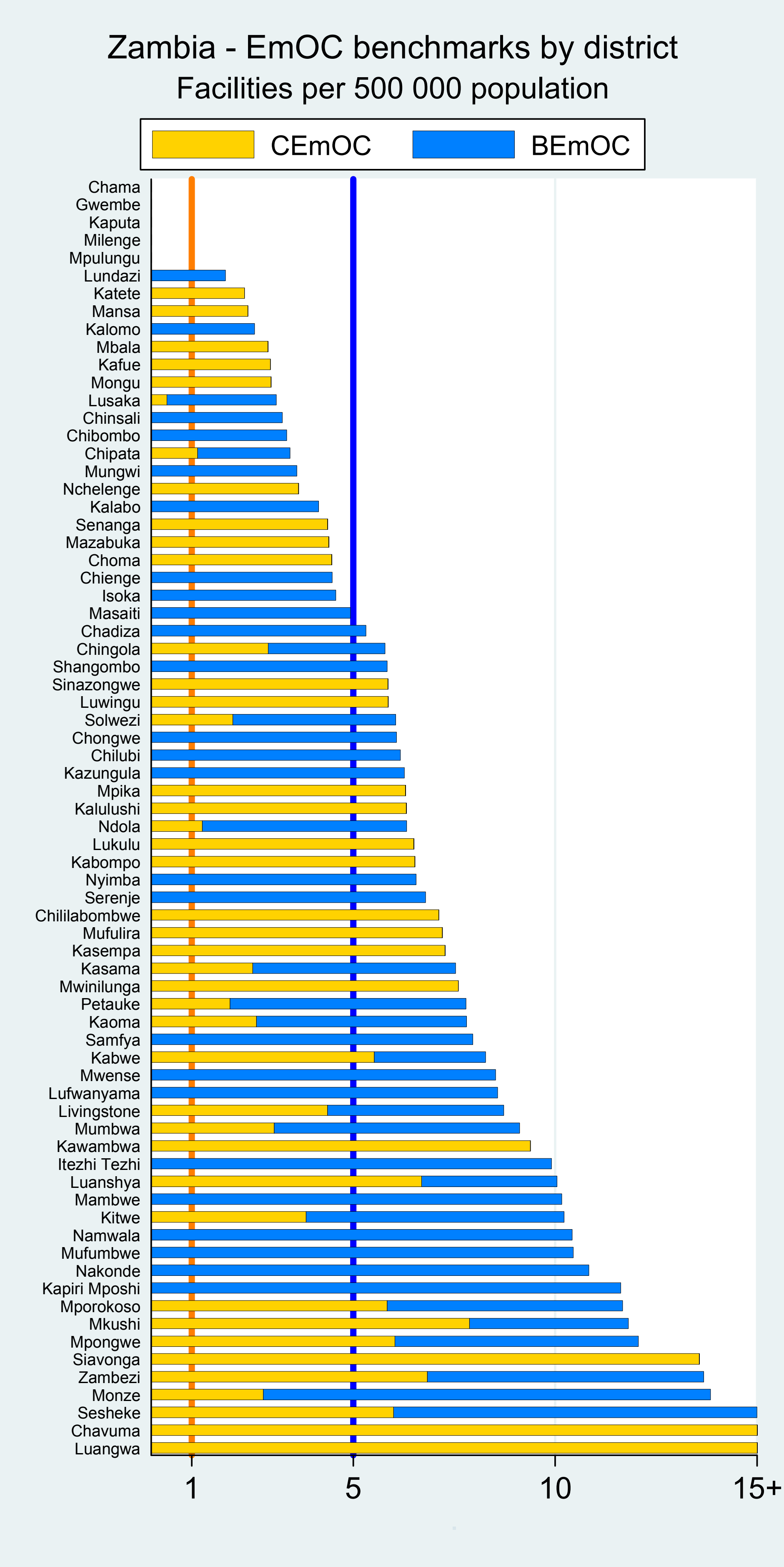
The graphs with the districts sorted by province (Fig. 27a and b) show that in Eastern Province, Luapula and Northern Province more than half of the districts fall short of a benchmark. For better visibility in the range that matters, very high numbers were cut off; for example any bars reaching to the “15+” end of the following graph represent 15 or more facilities.

Figure 25



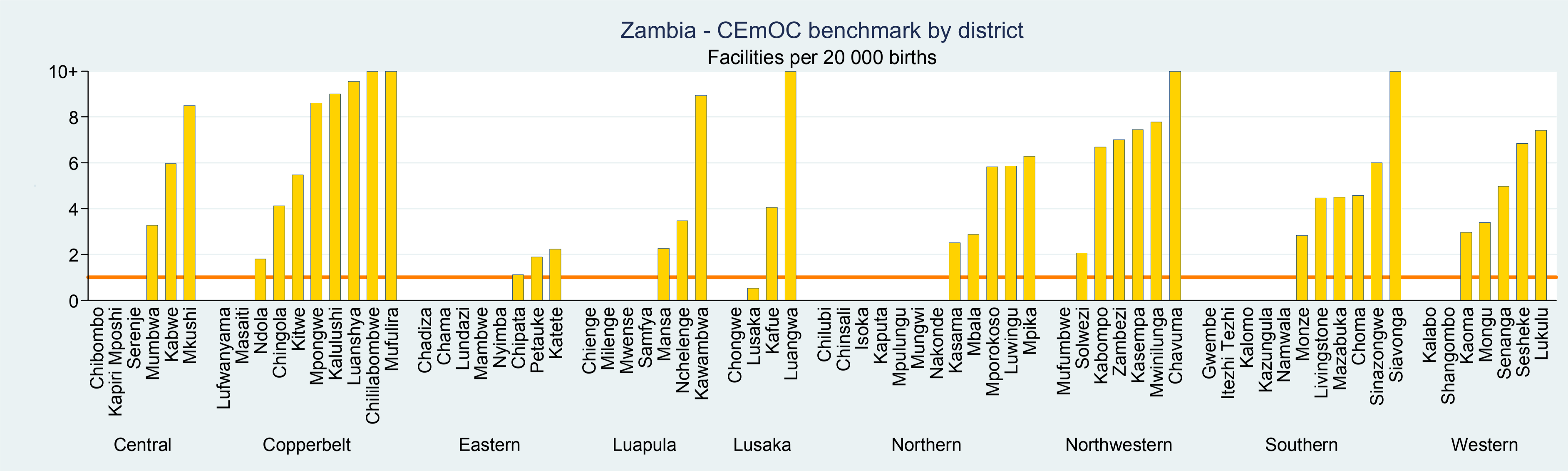
Zambia - EmOC benchmarks by district
Facilities per 500 000 population
CEmOC
BEmOC
Chadiza
Chama
Chibombo
Chienge
Chilubi
Chinsali
Chongwe
Gwembe
Isoka
Itezhi Tezhi
Kalabo
Kalomo
Kapiri Mposhi
Kaputa
Kazungula
Lufwanyama
Lundazi
Mambwe
Masaiti
Milenge
Mpulungu
Mufumbwe
Mungwi
Mwense
Nakonde
Namwala
Nyimba
Samfya
Serenje
Shangombo
Lusaka
Chipata
Ndola
Petauke
Solwezi
Katete
Mansa
Kasama
Kaoma
Monze
Mbala
Chingola
Kafue
Mongu
Mumbwa
Nchelenge
Kitwe
Senanga
Livingstone
Mazabuka
Choma
Kabwe
Mporokoso
Sinazongwe
Luwingu
Sesheke
Mpongwe
Mpika
Kalulushi
Lukulu
Kabompo
Luanshya
Zambezi
Chililabombwe
Mufulira
Kasempa
Mwinilunga
Mkushi
Kawambwa
Siavonga
Chavuma
Luangwa
1
5
10
15+

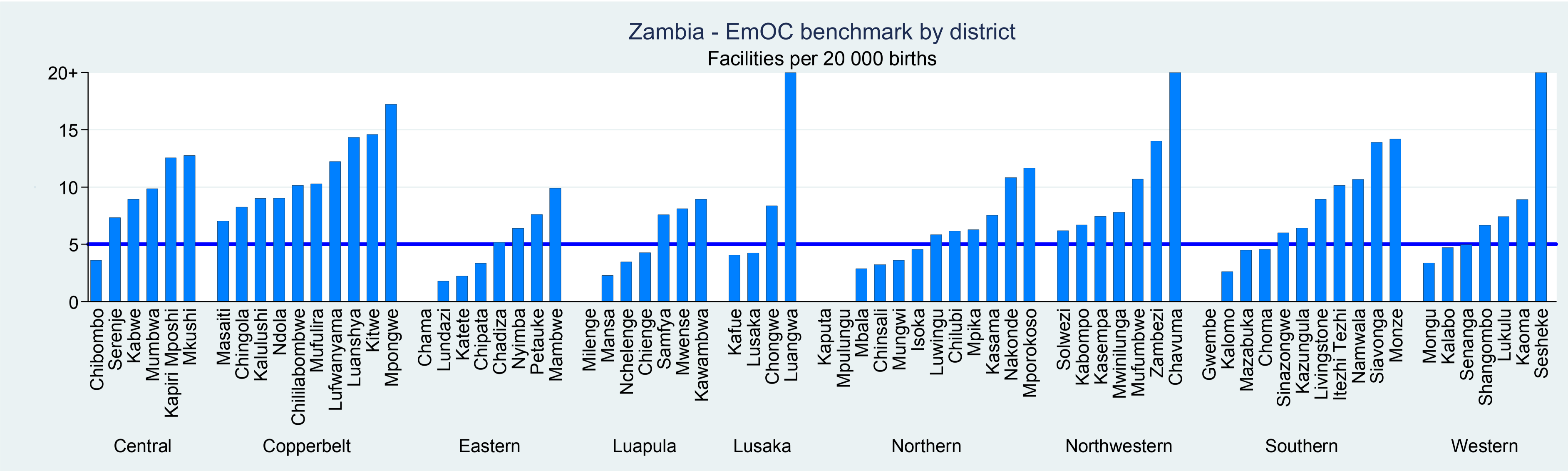
Figure 26



Zambia - EmOC benchmarks by district
Facilities per 500 000 population
CEmOC
BEmOC
Chama
Gwembe
Kaputa
Milenge
Mpulungu
Lundazi
Katete
Mansa
Kalomo
Mbala
Kafue
Mongu
Lusaka
Chinsali
Chibombo
Chipata
Mungwi
Nchelenge
Kalabo
Senanga
Mazabuka
Choma
Chienge
Isoka
Masaiti
Chadiza
Chingola
Shangombo
Sinazongwe
Luwingu
Solwezi
Chongwe
Chilubi
Kazungula
Mpika
Kalulushi
Ndola
Lukulu
Kabompo
Nyimba
Serenje
Chililabombwe
Mufulira
Kasempa
Kasama
Mwinilunga
Petauke
Kaoma
Samfya
Kabwe
Mwense
Lufwanyama
Livingstone
Mumbwa
Kawambwa
Itezhi Tezhi
Luanshya
Mambwe
Kitwe
Namwala
Mufumbwe
Nakonde
Kapiri Mposhi
Mporokoso
Mkushi
Mpongwe
Siavonga
Zambezi
Monze
Sesheke
Chavuma
Luangwa
1
5
10
15+

Figure 27 a and b





3.2.2 Health professionals

Overall, there were around 940 doctors, 8500 nurses/midwives and 1200 clinical officers registered at the 1389 health facilities with human resource information visited during the Health Facility Census 2005, which included nearly all public facilities but excluded some private for-profit facilities. This compares to 1264 physicians and a surprising 22,000 nursing or midwifery personnel in 2004 in the WHO Statistical Information System [163]. Approximately half of the staff registered was found present on the day of visit in the HFC.

The population census counted 9.9 million inhabitants in Zambia in 2000 and the projected population for 2005 is 11.4 million [157]. This means according to the HFC, the health professional density in 2005 was 0.8 doctors and 8.5 nurses/ midwives/ clinical officers per 10,000 population, or slightly higher taking into account that not all facilities were captured.

For comparison, Sweden, a country with similar population size (around 9 million inhabitants) and roughly half the land area of Zambia, employs approximately 29,000 doctors and 97,000 nurses and midwives. [163] This is about 30 times more doctors and 10 times more other health professionals than in Zambia. Health worker densities in Sweden are 32 doctors per 10,000 population and 108 nurses and midwives [163]. The Crude Birth Rate in Sweden is around 10 per 1000 population, a quarter of that in Zambia [7].

When trying to establish staffing levels for delivery care, it would be useful to know how many health professionals are engaged in delivery care and what proportion of their time they dedicate to this purpose. Unfortunately, there is no such information available in Zambia. Excluding health facilities that do not offer any delivery care leaves around 880 registered doctors and 8300 nurses and clinical officers who are potentially involved in delivery care. It is likely, however, that most work in other areas of health care. The following graphs refer to the total of health professionals employed in facilities offering delivery care and not to the number involved in delivery care.

3.2.2.1 By province

Figure 28

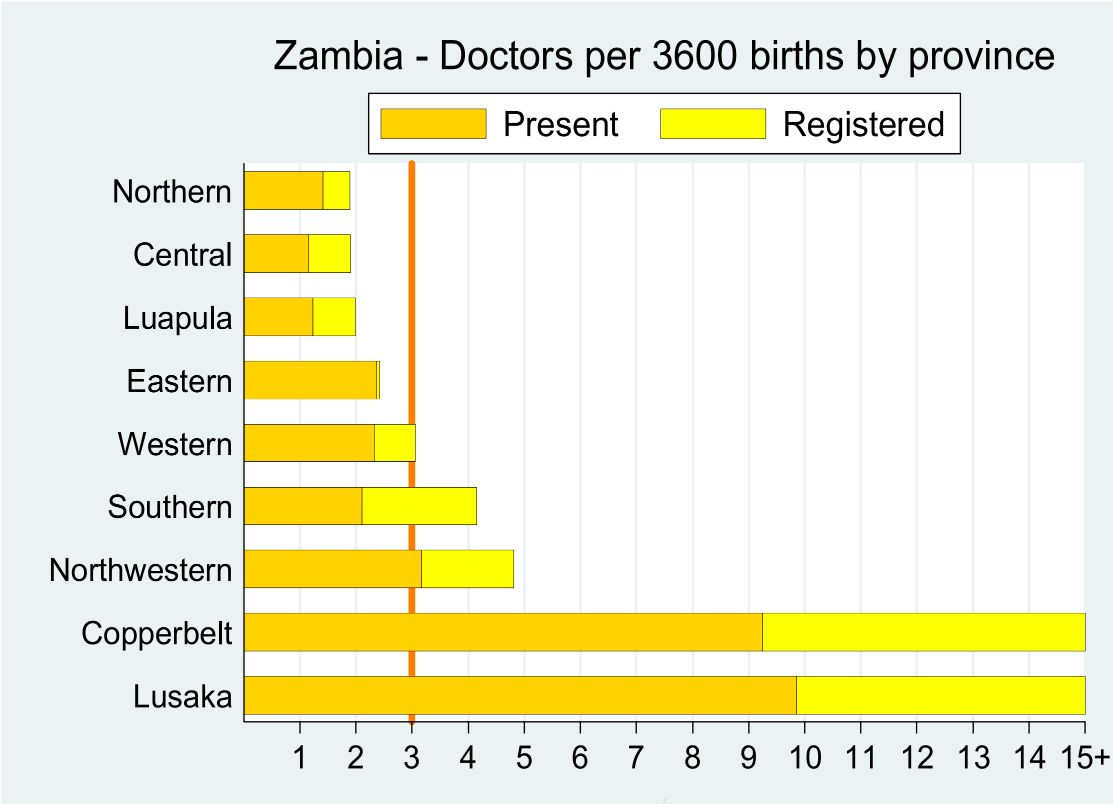


Figure 29

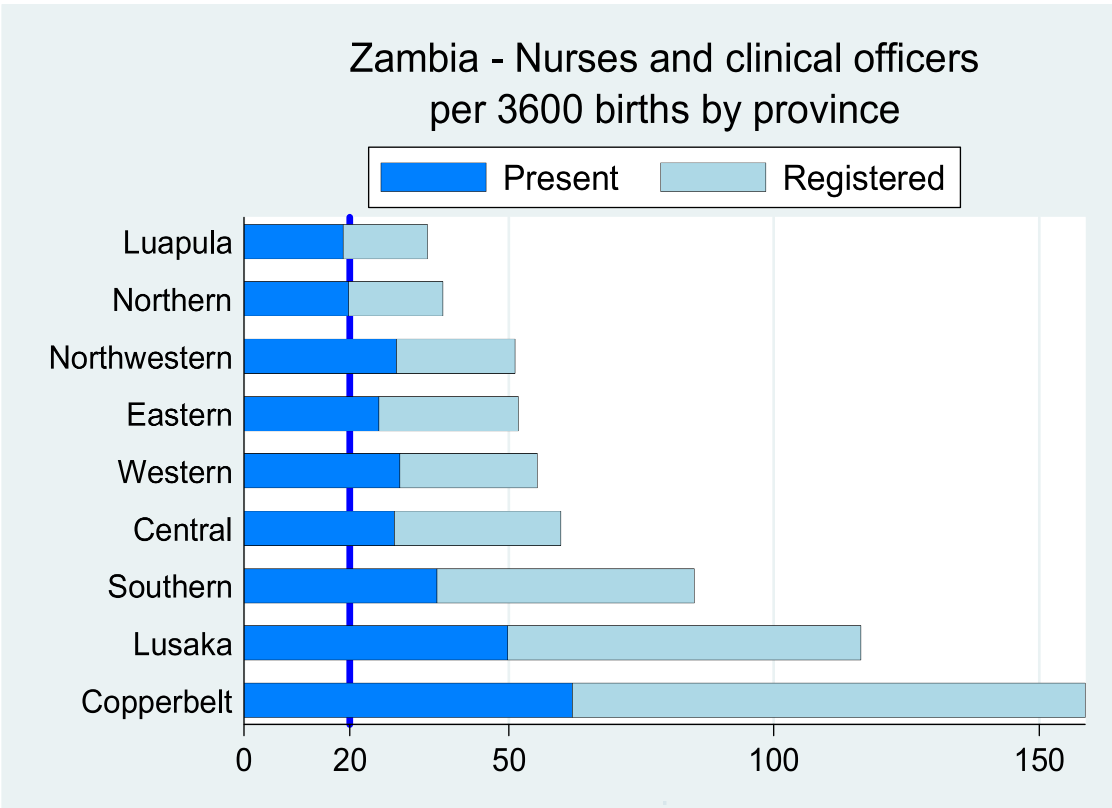
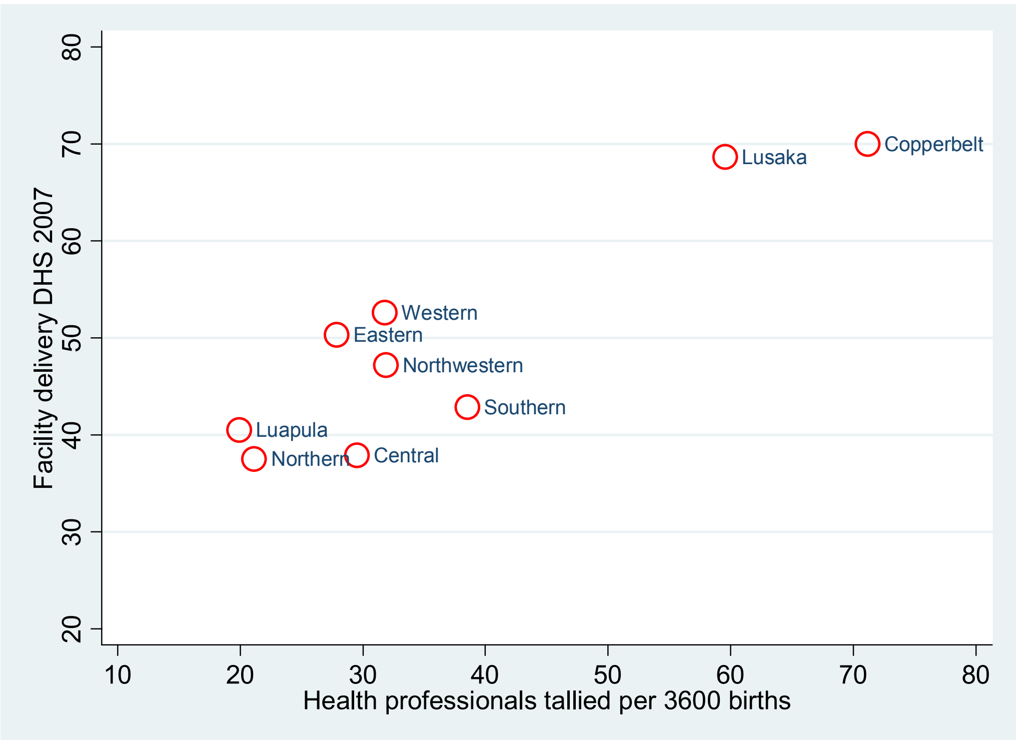


Figure 28 shows that while very large numbers of doctors are registered in the urbanised provinces of Lusaka and the Copperbelt, four others (Northern, Central, Luapula and Eastern Province) do not meet the minimum recommended level of 3 doctors per 3600 births.

The situation seems better in terms of other health professionals (Fig. 29). All provinces employ more than 20 nurses, midwives and clinical officers per 3600 births, although this does not take into account that these are not just midwives and most probably do not work in delivery care. Assuming that only a quarter are actually providing delivery care, would make the picture look much different, with Luapula and Northern Province in particular falling far short of staffing levels required for providing delivery care for all births.

In Zambia, nationwide only approximately half of all women deliver in a health facility of any kind (about 80% in urban areas and 30% in rural areas). Figure 30 relates levels of facility delivery by province to how many health professionals were found present during the Health Facility Census per 3600 births in that province. It shows that while Lusaka and Copperbelt provinces have comparatively high levels of both, the other seven provinces employ fewer health professionals and have lower levels of facility delivery.

Figure 30: Facility delivery and health worker density by province



3.2.2.2 By district

Figure 31

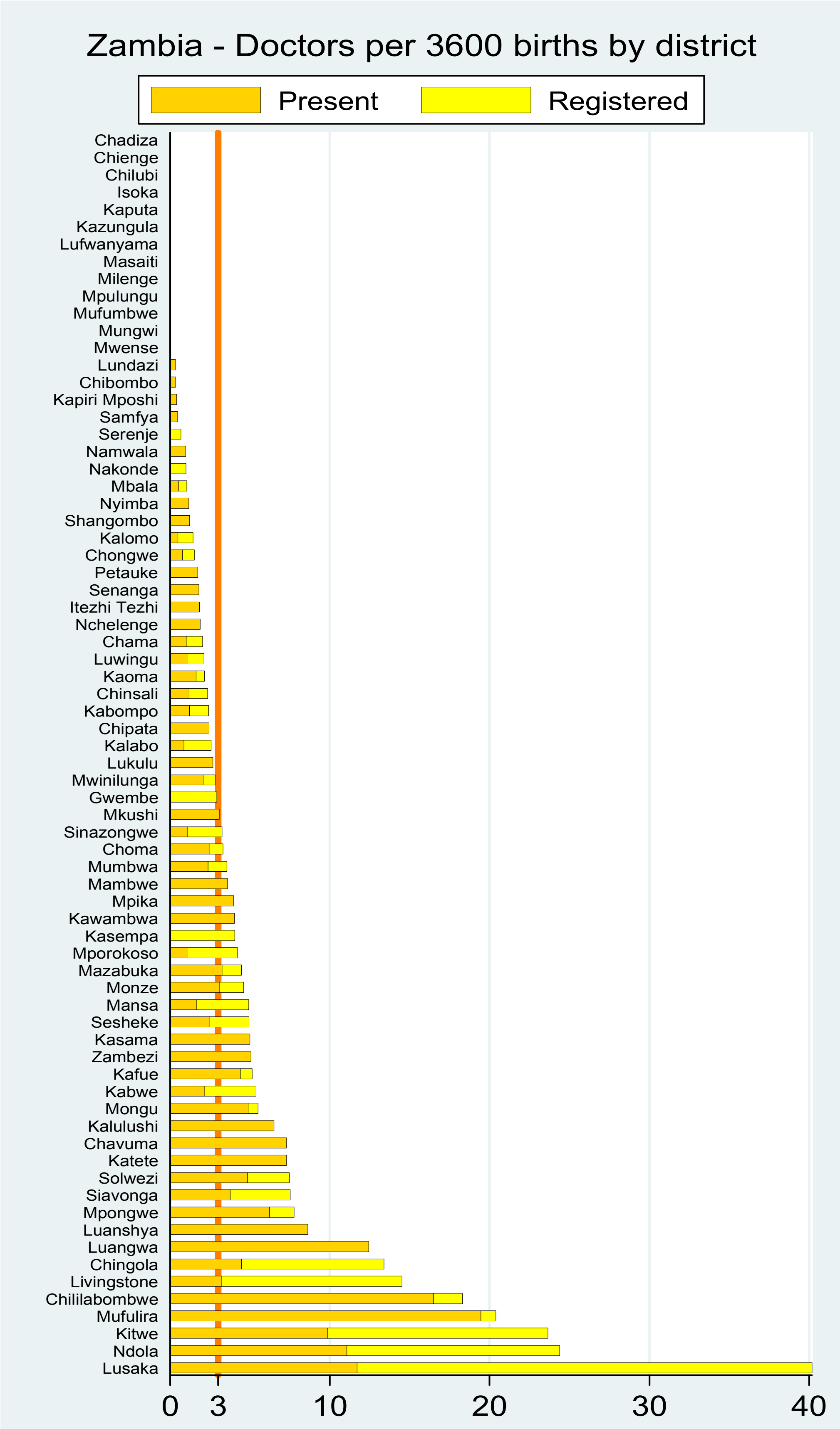


Figure 32

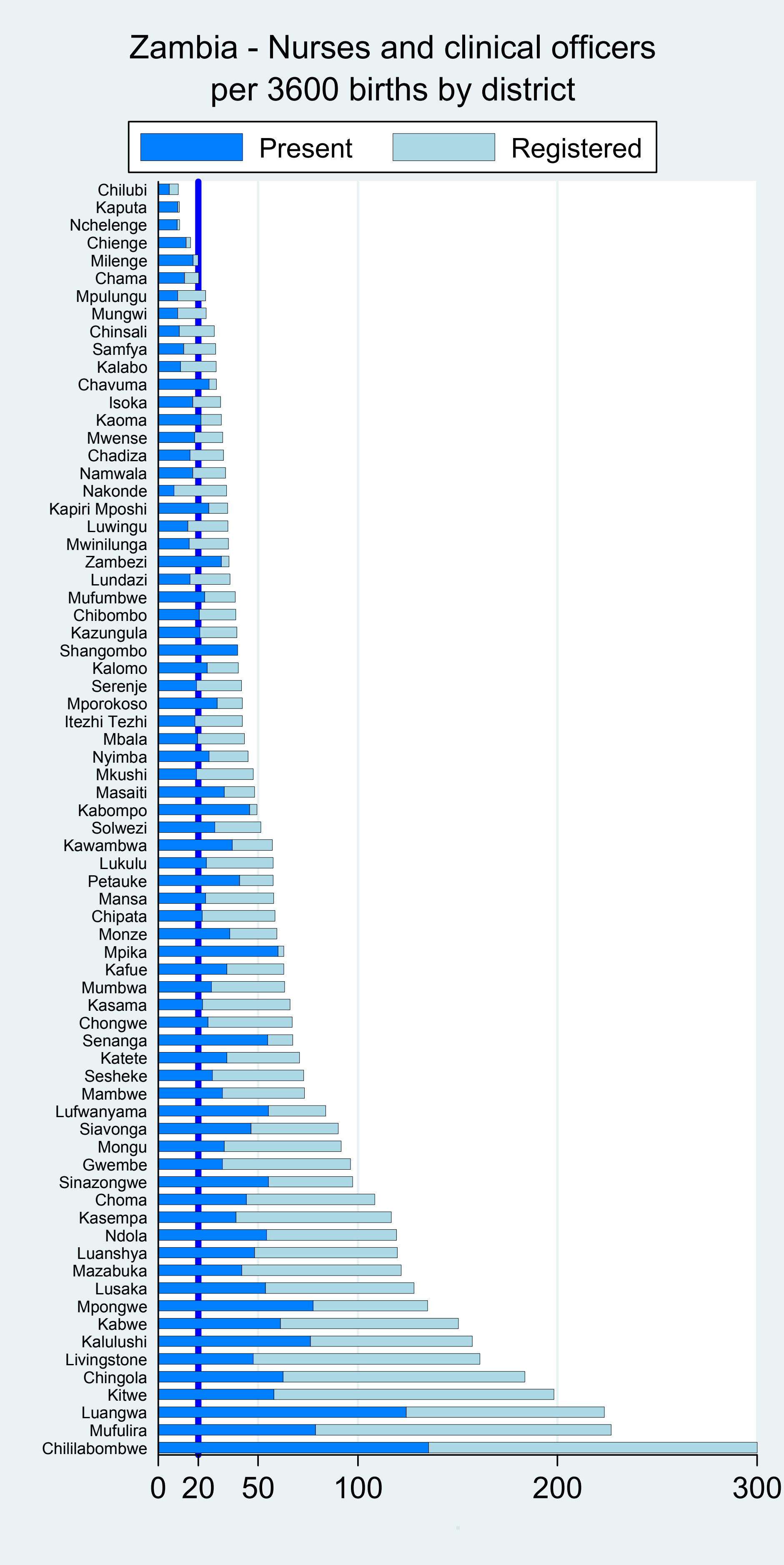
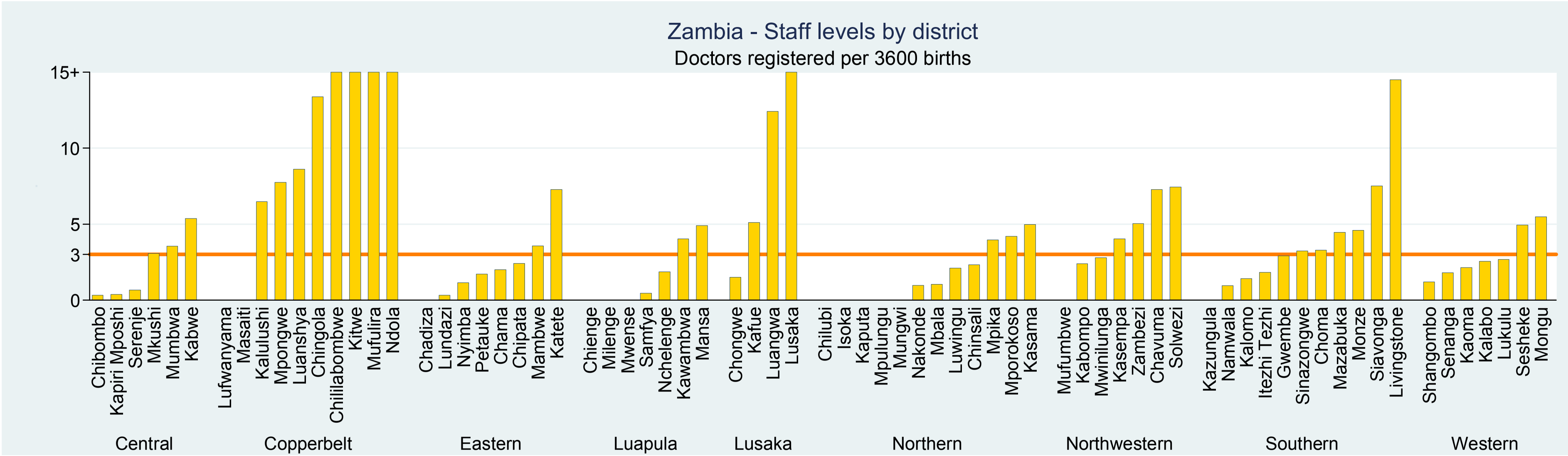

Zambia - Nurses and clinical officers
per 3600 births by district
Present
Registered
Chilubi
Kaputa
Nchelenge
Chienge
Milenge
Chama
Mpulungu
Mungwi
Chinsali
Samfya
Kalabo
Chavuma
Isoka
Kaoma
Mwense
Chadiza
Namwala
Nakonde
Kapiri Mposhi
Luwingu
Mwinilunga
Zambezi
Lundazi
Mufumbwe
Chibombo
Kazungula
Shangombo
Kalomo
Serenje
Mporokoso
Itezhi Tezhi
Mbala
Nyimba
Mkushi
Masaiti
Kabompo
Solwezi
Kawambwa
Lukulu
Petauke
Mansa
Chipata
Monze
Mpika
Kafue
Mumbwa
Kasama
Chongwe
Senanga
Katete
Sesheke
Mambwe
Lufwanyama
Siavonga
Mongu
Gwembe
Sinazongwe
Choma
Kasempa
Ndola
Luanshya
Mazabuka
Lusaka
Mpongwe
Kabwe
Kalulushi
Livingstone
Chingola
Kitwe
Luangwa
Mufulira
Chililabombwe
0
20
50
100
200
300

Figure 33 a and b



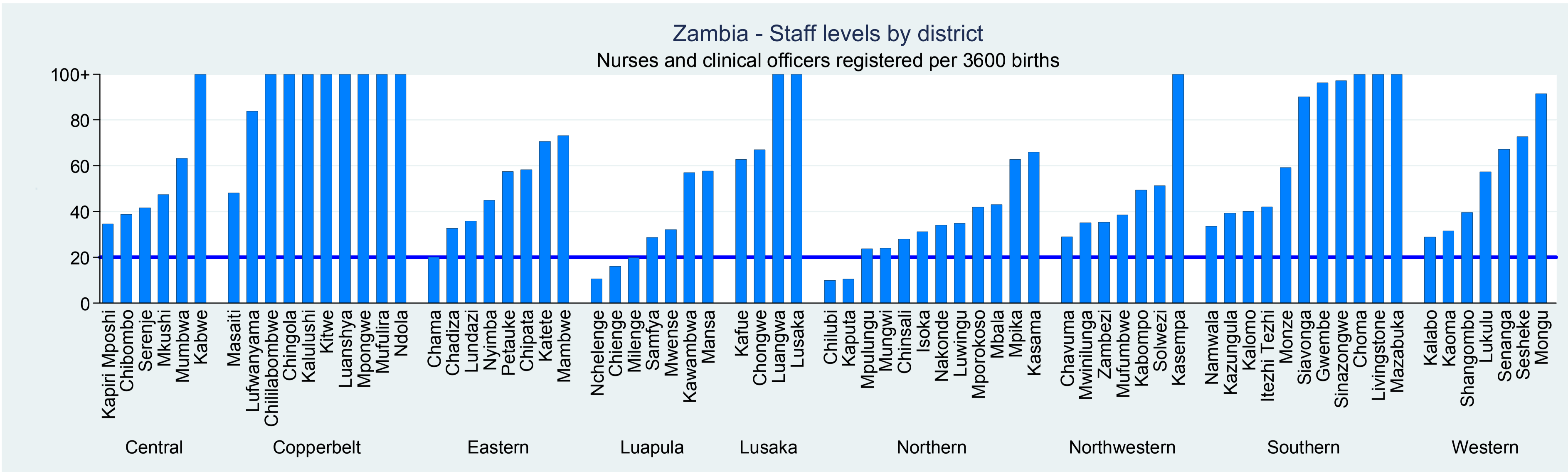


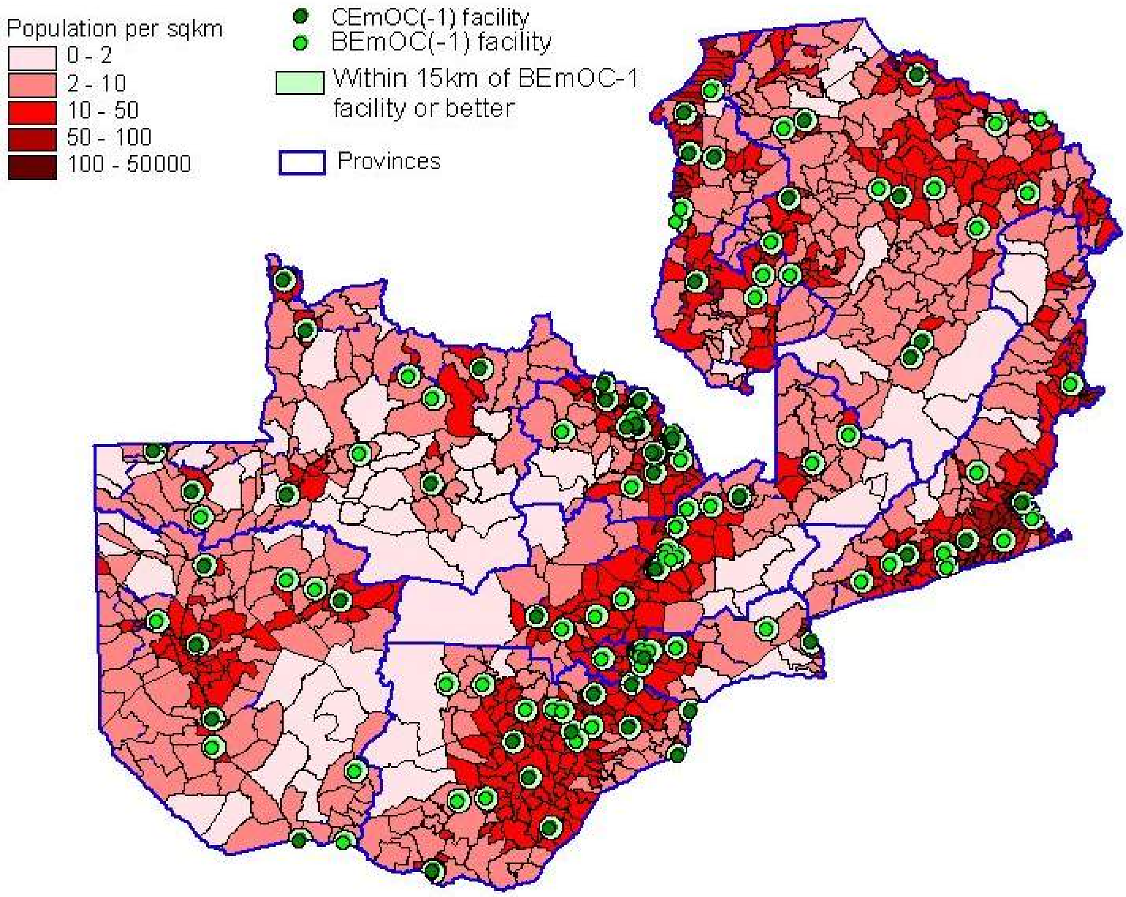
Figure 31 and 33a show that about half of all districts employ less than 3 doctors per 3600 births, and 13 districts employ none at all. It can also be seen that doctors are unevenly distributed inside provinces, often there are a few districts with an acceptable number of doctors and others with very few or none at all.

Concerning other health workers, with the exception of four districts, all employ 20 or more per 3600 births, but again there are strong imbalances within provinces (Fig. 32 and 33b). If one employed a stricter benchmark taking into account that far from all (maybe one in four) of these health workers provide delivery care, the picture again looks different. Three quarters of districts employ less than 80 nurses, midwives and clinical officers per 3600 births.

3.2.3 Geographical access

As described in the methods, facilities were mapped in a GIS and those ward land surface areas lying within 15 km distance of a facility offering delivery care and within 15 km of a facility offering at least BEmOC-1, respectively, were computed. Subsequently, the respective proportions of the population within 15 km reach of delivery care and of EmOC were calculated, making the assumption that the population is evenly distributed inside wards. Figure 34 shows a map depicting all EmOC facilities and population density by ward.

Fig 34: EmOC facility coverage areas and ward population density



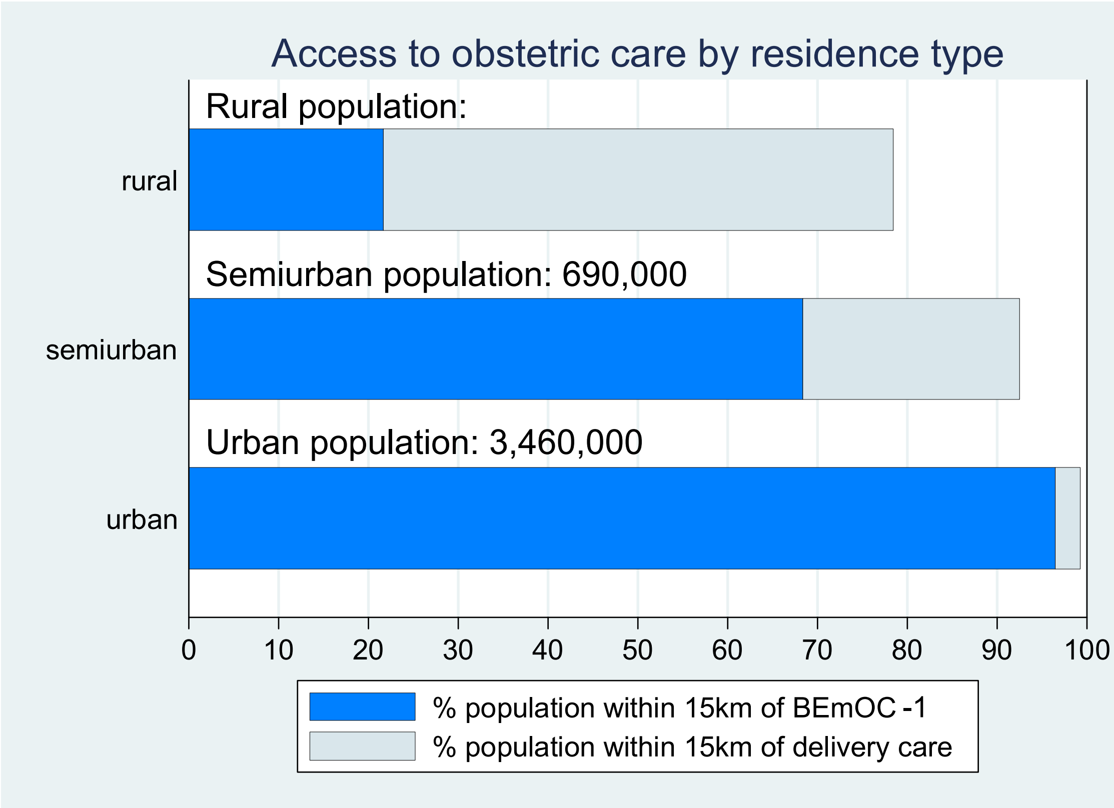
<u>3.2.3.1 National</u>

Overall, 86% of the Zambian population are within 15 km of a facility offering any type of delivery care and 48% live within 15km of an EmOC facility.

It makes sense to disaggregate these figures by type of residence. Using the modified ward classification (see section 2.3.1), 62% of the population live in rural wards and 31% in urban wards, leaving 6% in the semiurban category.

In urban wards, 99% are within 15 km of delivery care and 96% within 15km of EmOC. In semiurban wards, these figures are 92% and 68%. In rural wards, 78% of the population are within 15km of a facility offering delivery area and only 22% are within 15 km of an EmOC facility (Fig. 35).

Figure 35



<u>3.2.3.2 By province</u>

In the mostly urban provinces Copperbelt and Lusaka around 90% of the population live within 15 km of an EmOC facility, while this figure lies between 23% and 39% in all other provinces (Fig. 36). Facility delivery is also much more common in Copperbelt and Lusaka (Fig. 37).

Figure 36

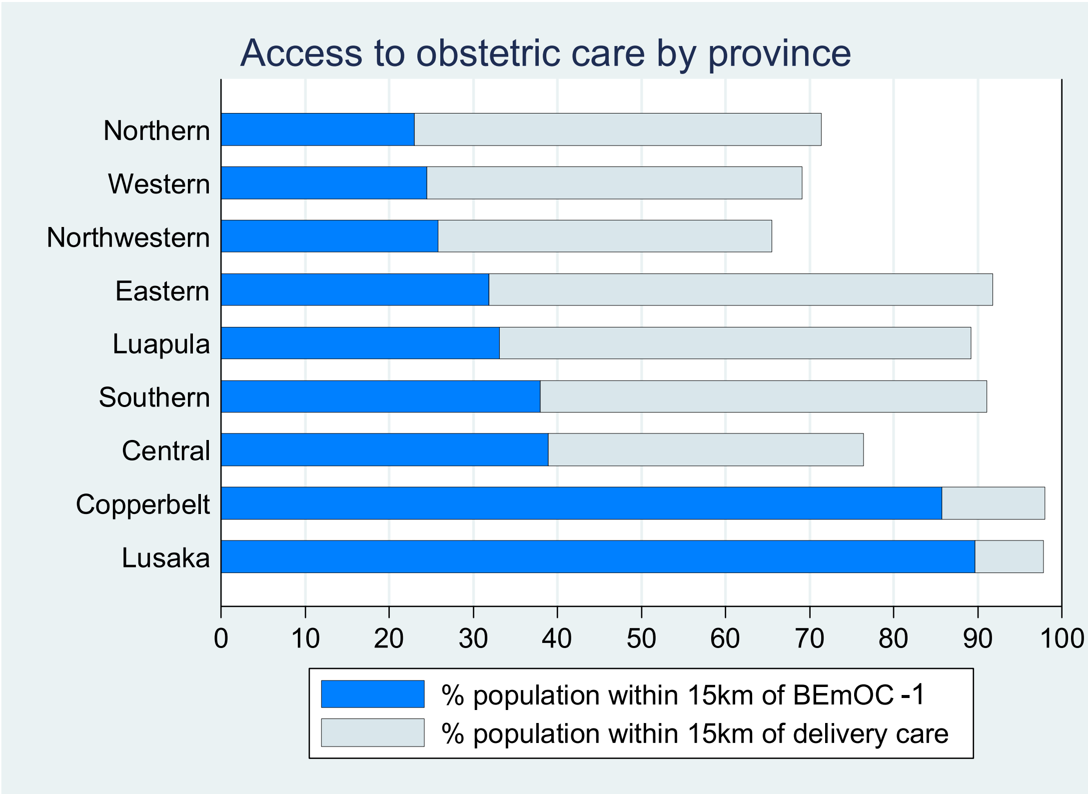
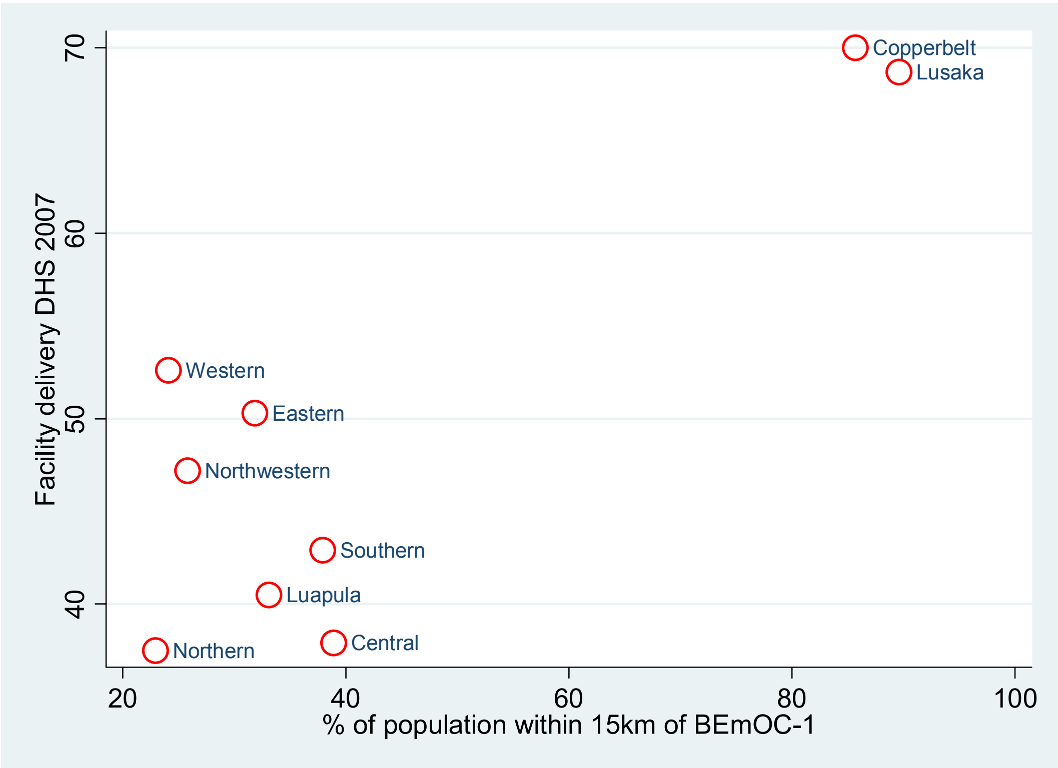
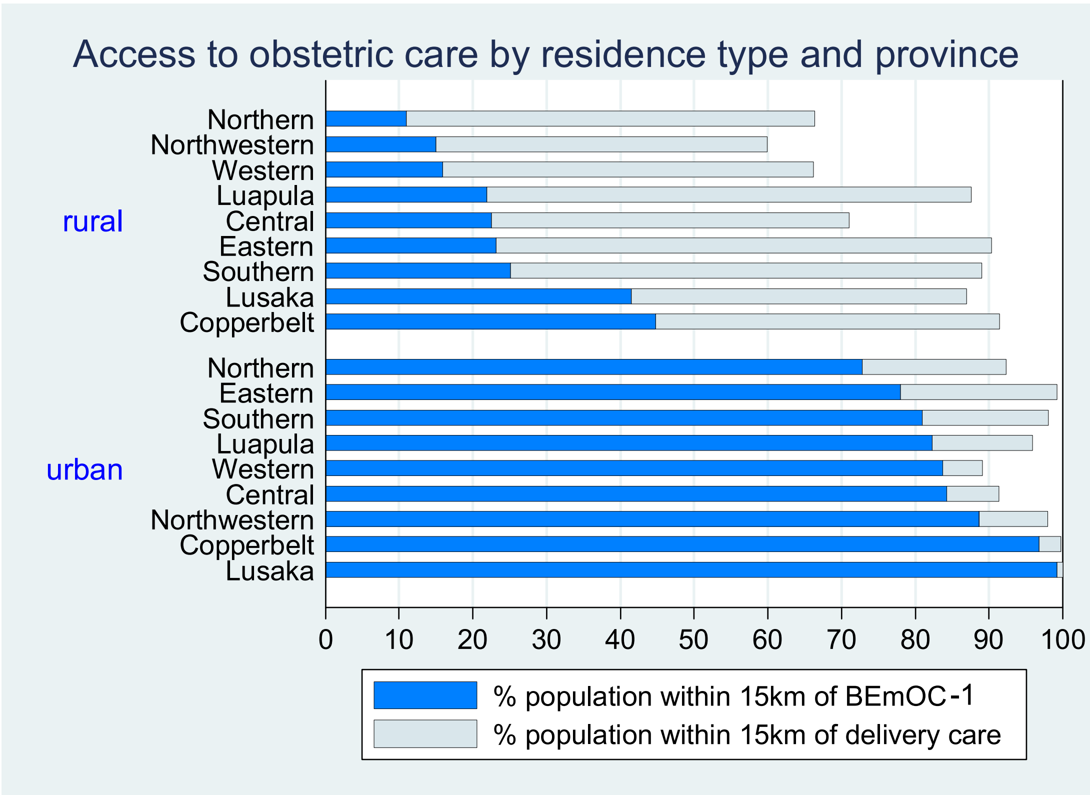


Figure 37: Population within 15km of BEmOC-1 and percentage of facility deliveries by province



Looking separately at the urban (including semiurban) and rural wards inside each province (Fig. 38), shows that more than 70% of the urban population in all provinces live within 15 km of EmOC services while coverage in rural wards is much lower. Only 11% of the population in the rural wards of Northern Province are within 15 km of an EmOC facility.

Figure 38



3.2.3.3 By district

Figure 39

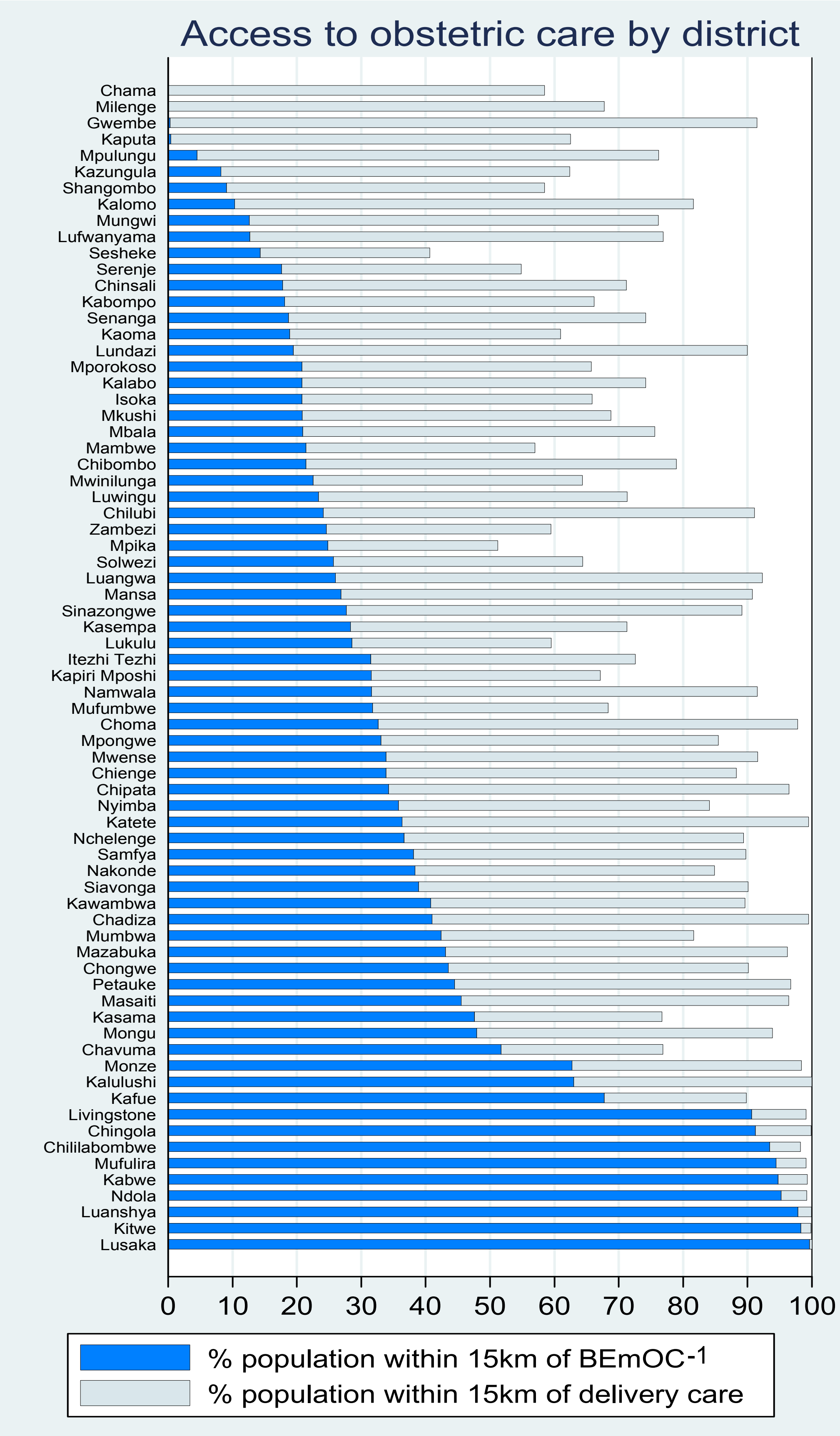
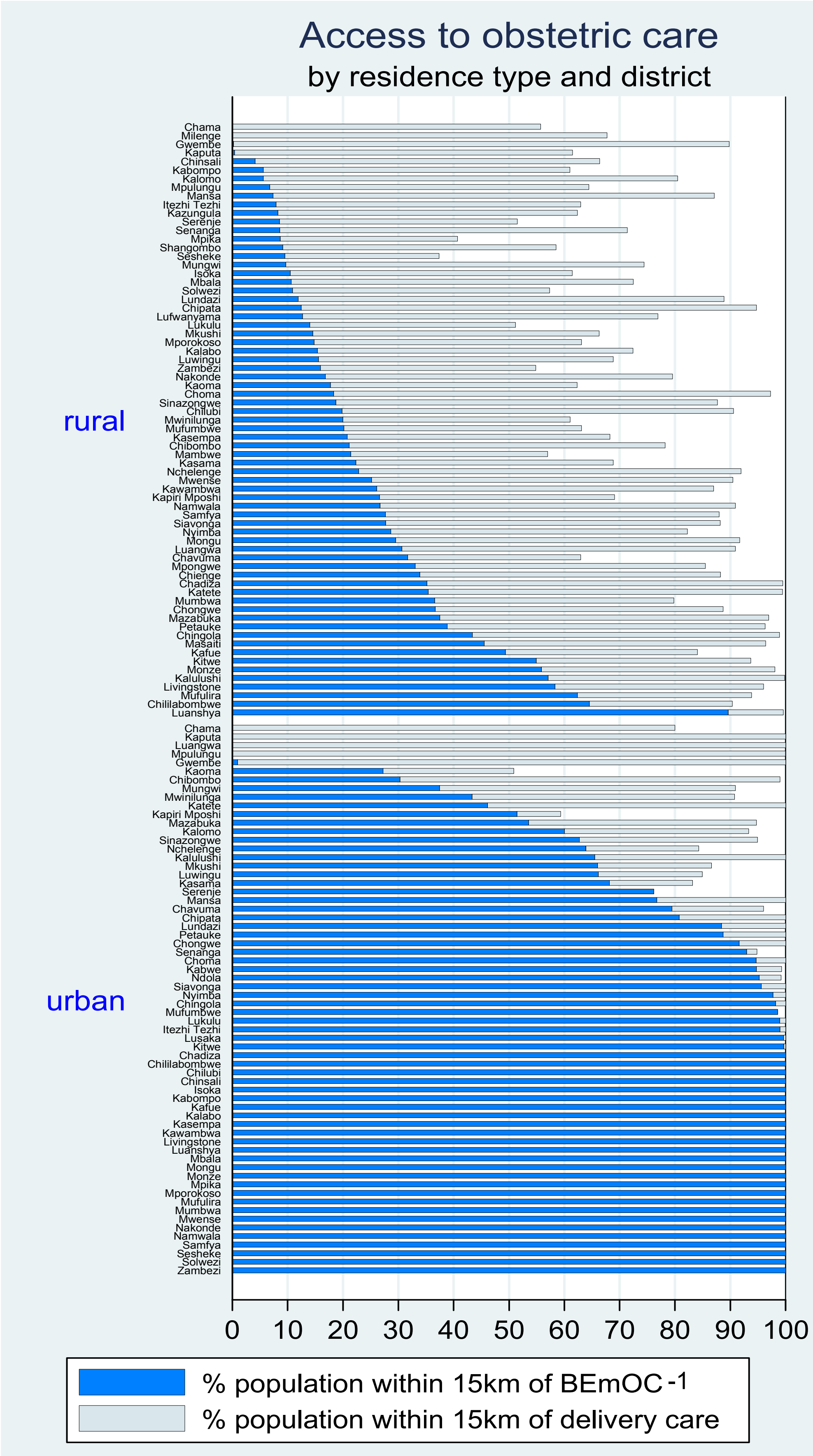


Figure 40



Access to obstetric care
by residence type and district
rural
Chama
Milenge
Gwembe
Kaputa
Chinsali
Kabompo
Kalomo
Mpulungu
Mansa
Itezhi Tezhi
Kazungula
Serenje
Senanga
Mpika
Shangombo
Sesheke
Mungwi
Isoka
Mbala
Solwezi
Lundazi
Chipata
Lufwanyama
Lukulu
Mkushi
Mporokoso
Kalabo
Luwingu
Zambezi
Nakonde
Kaoma
Choma
Sinazongwe
Chilubi
Mwinilunga
Mufumbwe
Kasempa
Chibombo
Mambwe
Kasama
Nchelenge
Mwense
Kawambwa
Kapiri Mposhi
Namwala
Samfya
Siavonga
Nyimba
Mongu
Luangwa
Chavuma
Mpongwe
Chienge
Chadiza
Katete
Mumbwa
Chongwe
Mazabuka
Petauke
Chingola
Masaiti
Kafue
Kitwe
Monze
Kalulushi
Livingstone
Mufulira
Chililabombwe
Luanshya
urban
Chama
Kaputa
Luangwa
Mpulungu
Gwembe
Kaoma
Chibombo
Mungwi
Mwinilunga
Katete
Kapiri Mposhi
Mazabuka
Kalomo
Sinazongwe
Nchelenge
Kalulushi
Mkushi
Luwingu
Kasama
Serenje
Mansa
Chavuma
Chipata
Lundazi
Petauke
Chongwe
Senanga
Choma
Kabwe
Ndola
Siavonga
Nyimba
Chingola
Mufumbwe
Lukulu
Itezhi Tezhi
Lusaka
Kitwe
Chadiza
Chililabombwe
Chilubi
Chinsali
Isoka
Kabompo
Kafue
Kalabo
Kasempa
Kawambwa
Livingstone
Luanshya
Mbala
Mongu
Monze
Mpika
Mporokoso
Mufulira
Mumbwa
Mwense
Nakonde
Namwala
Samfya
Sesheke
Solwezi
Zambezi
0 10 20 30 40 50 60 70 80 90 100
% population within 15km of BEmOC -1
% population within 15km of delivery care

Disaggregating by district (Fig. 39), and by rural and urban wards inside districts (Fig. 40), shows huge differences in EmOC coverage, ranging from 0% of the population covered to 100%. With some exceptions, most urban areas are well covered, while in most rural areas only a small proportion of the population lives within reach of an EmOC facility.

Access to any delivery care can only be equal to or better than access to EmOC. In Zambia, it is consistently much better than access to EmOC. This reflects the fact that only 12% of delivery facilities in Zambia were classified as offering at least BEmOC-1. The majority of facilities are offering substandard services. So while most people have access to a facility offering delivery care, these are unable to deal with complications, which defeats the purpose of having a health professional attend since key signal skills are lacking and the environment is substandard.

The bubble graph below (Figure 41) classifies population groups (bubbles) according to physical access (15 km distance to any delivery care) and functionality of the access (15 km distance to EmOC). If all facilities were EmOC, the population groups would be located along the diagonal, further up if the proportion of the population covered is high. Where facilities are available, but not of EmOC standard, the bubbles fall below the diagonal, further down if the proportion of facilities fulfilling EmOC criteria is low. Bubble size is in proportion to population size, i.e. big bubbles represent big populations.

This categorisation creates three broad groupings (Fig. 41): Those in the top right corner have good access to quality care. Those in the bottom left corner do not have sufficient access even to substandard care. And those in the bottom right corner do have access to facilities offering delivery care, but these are substandard. Interventions would accordingly be upgrading of existing facilities and/or improving access e.g. by building new facilities (Fig. 41).

Figure 41: Access to delivery care and EmOC: categories and interventions

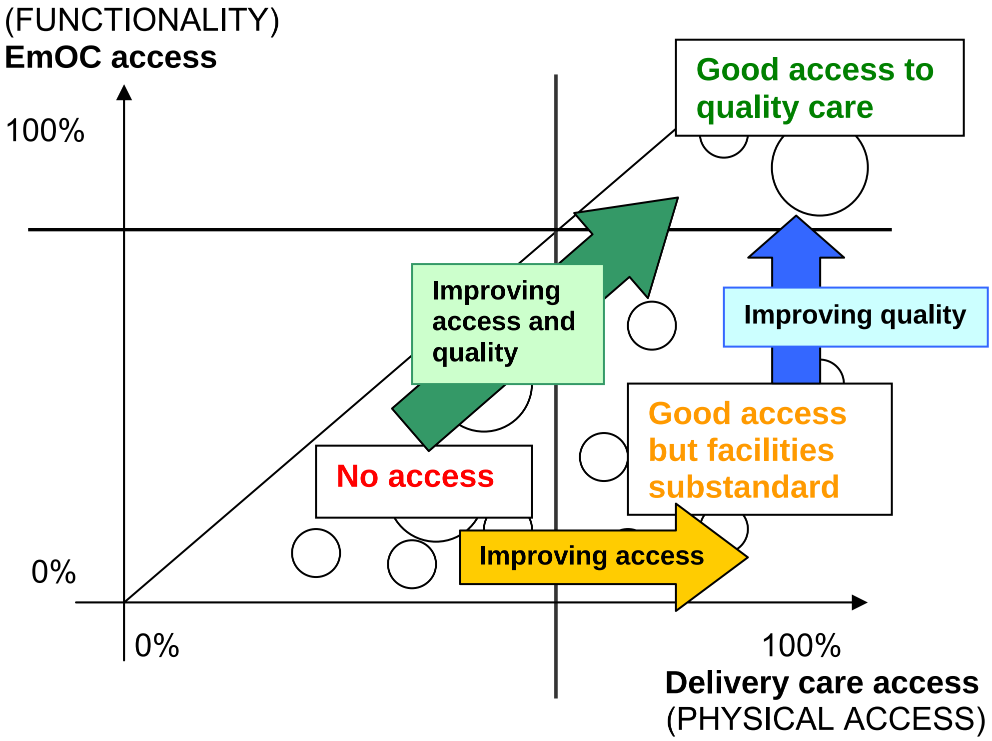
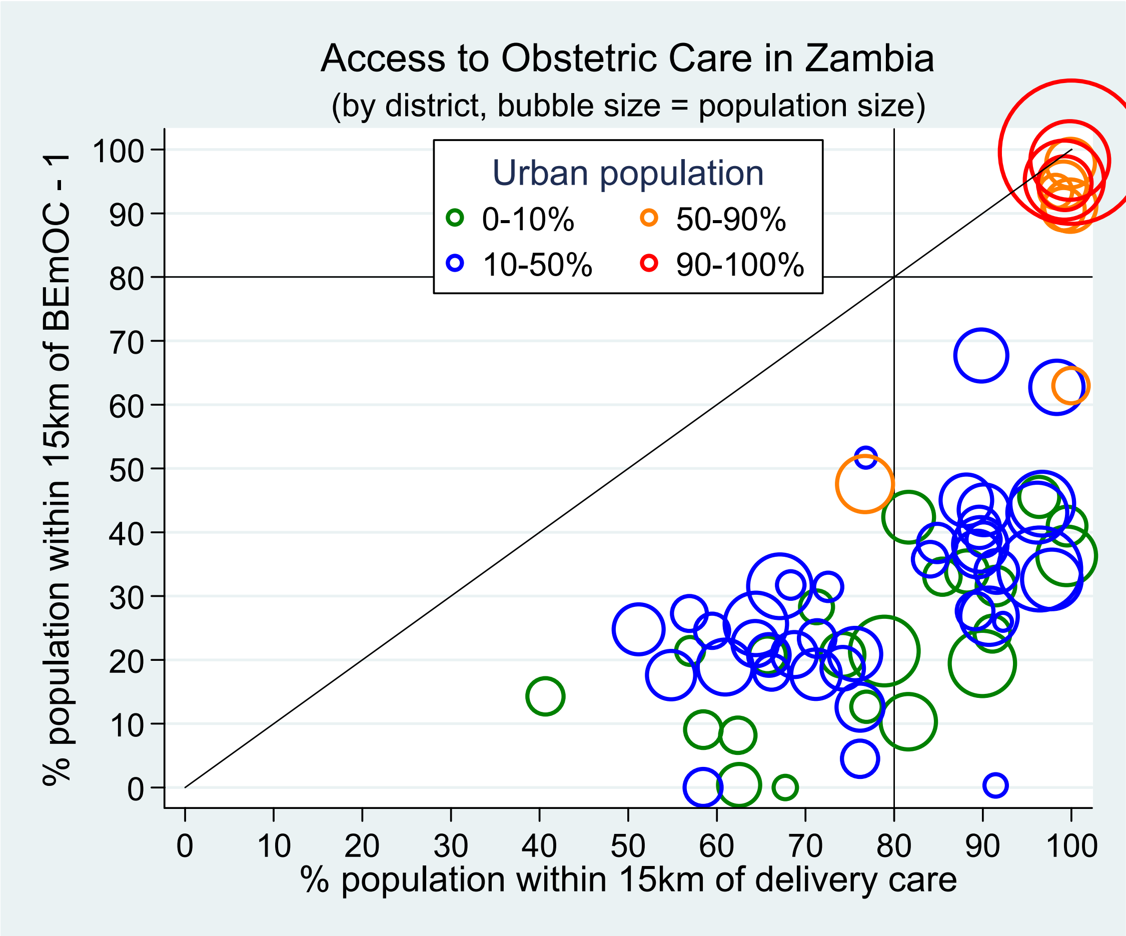


Figure 42 shows such a categorisation of all Zambian districts. The colours indicate how urbanised a district is. The size of the bubbles corresponds to the population of the district, thus giving due weight to the larger populations of Lusaka and other urbanised districts, but also showing that all rural districts taken together make up the bulk of the Zambian population.

Figure 42

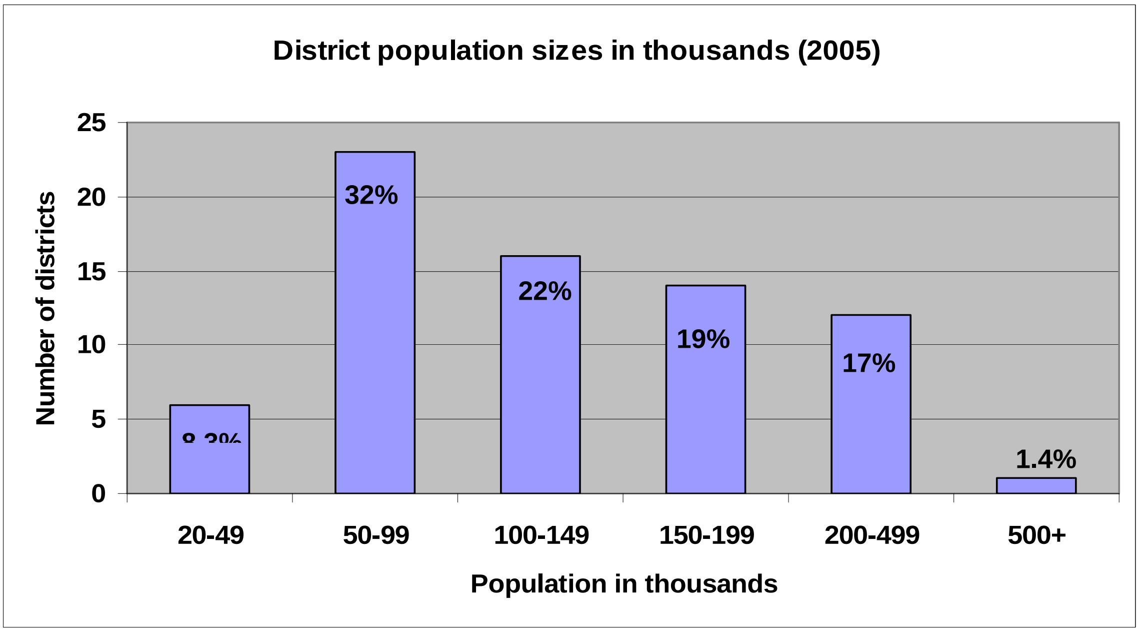


All highly urbanised districts have very good access to quality care as do most districts with 50-90% urban population. All districts with less than 50% urban population fall either in the bottom right corner (having access but to substandard care) or the bottom left corner of general lack of access.

No district has less than 40% of its population within 15 km of delivery care, with most covering between 60% and 100%. In contrast, only three rural districts have more than 50% of their population within 15 km of EmOC services.

In order to assess whether the denominator of the EmOC benchmarks is appropriate for district planning in Zambia, the following graph (Fig. 43) shows the distribution of district sizes using the projected population figures for 2005. The vast majority of districts have populations between 50,000 and 200,000, much less than the 500,000 population used as reference in the UN benchmarks.

Figure 43: Distribution of district population sizes in Zambia



Population density in the mainly rural districts lies between 3 and 75 inhabitants per km^2 with a mean of 20, while in Lusaka there are nearly 3000 people per km^2. Instead of plotting population per km^2, I plotted births per 700 km^2; 700 km^2 is approximately the size of a circular area with 15 km radius around a health facility. 20 people per km^2 correspond to 14,000 people per 700 km^2. Given a CBR of 40, these generate 560 births. Fig. 44 presents birth densities by districts in a map and Fig. 45 shows the strong correlation between birth density (x-axis in log-units) and EmOC coverage.

Figure 44: Birth density (projected for 2005) by district

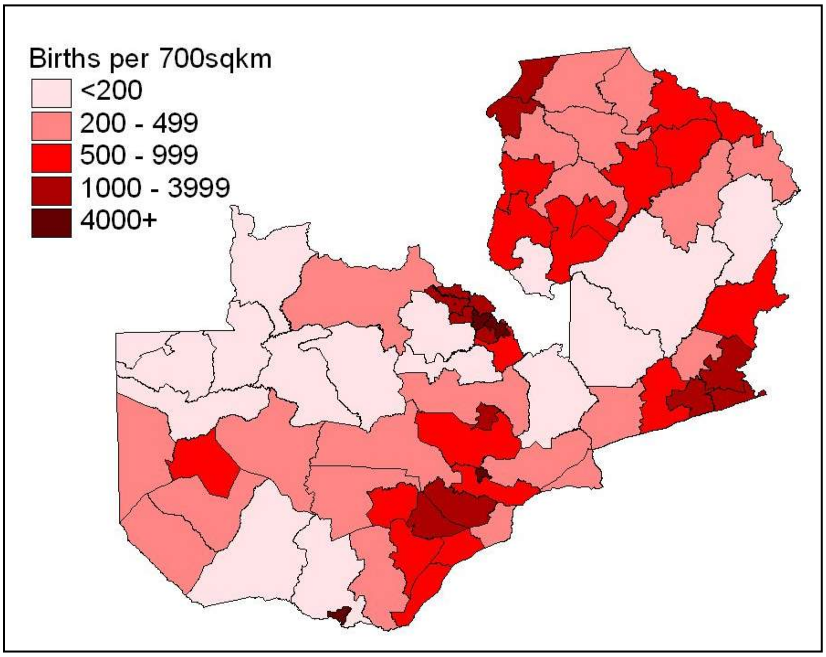
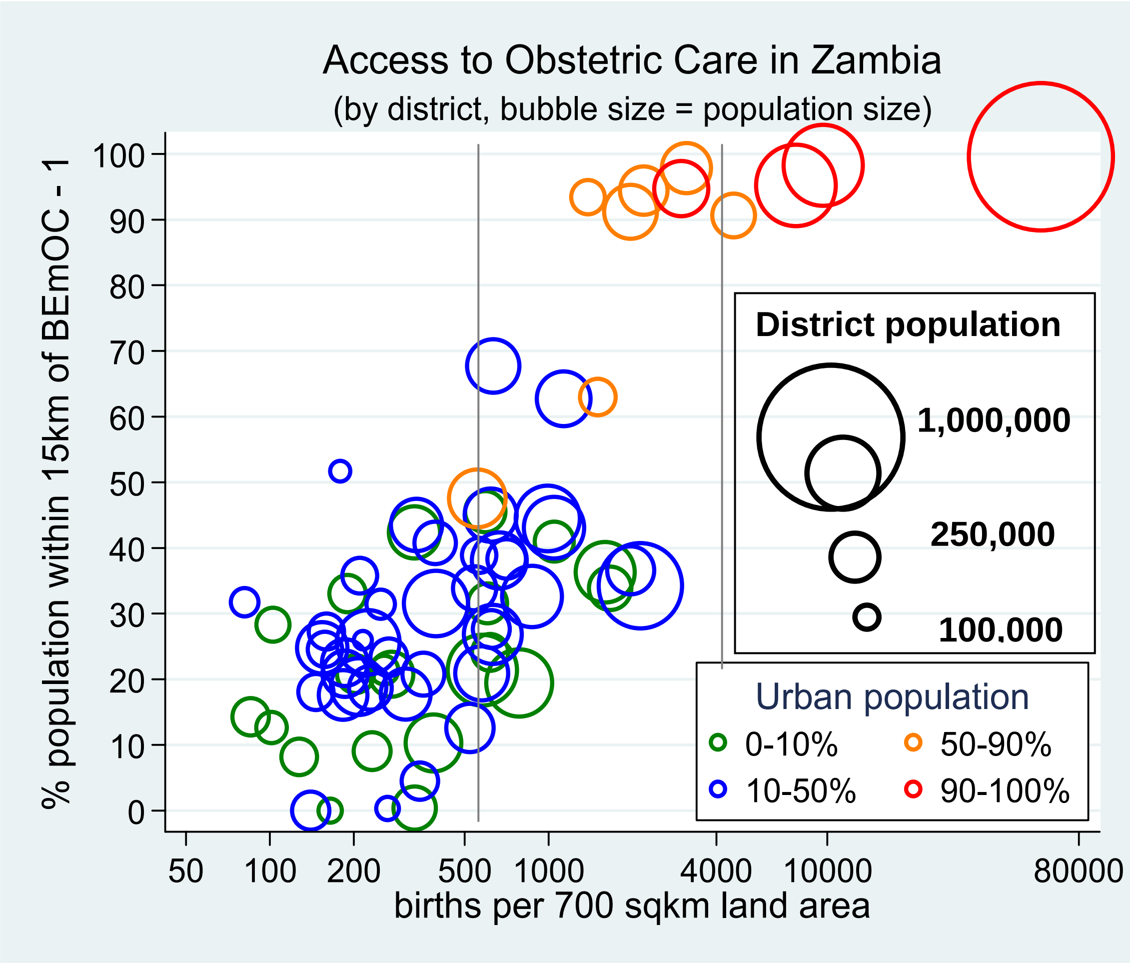


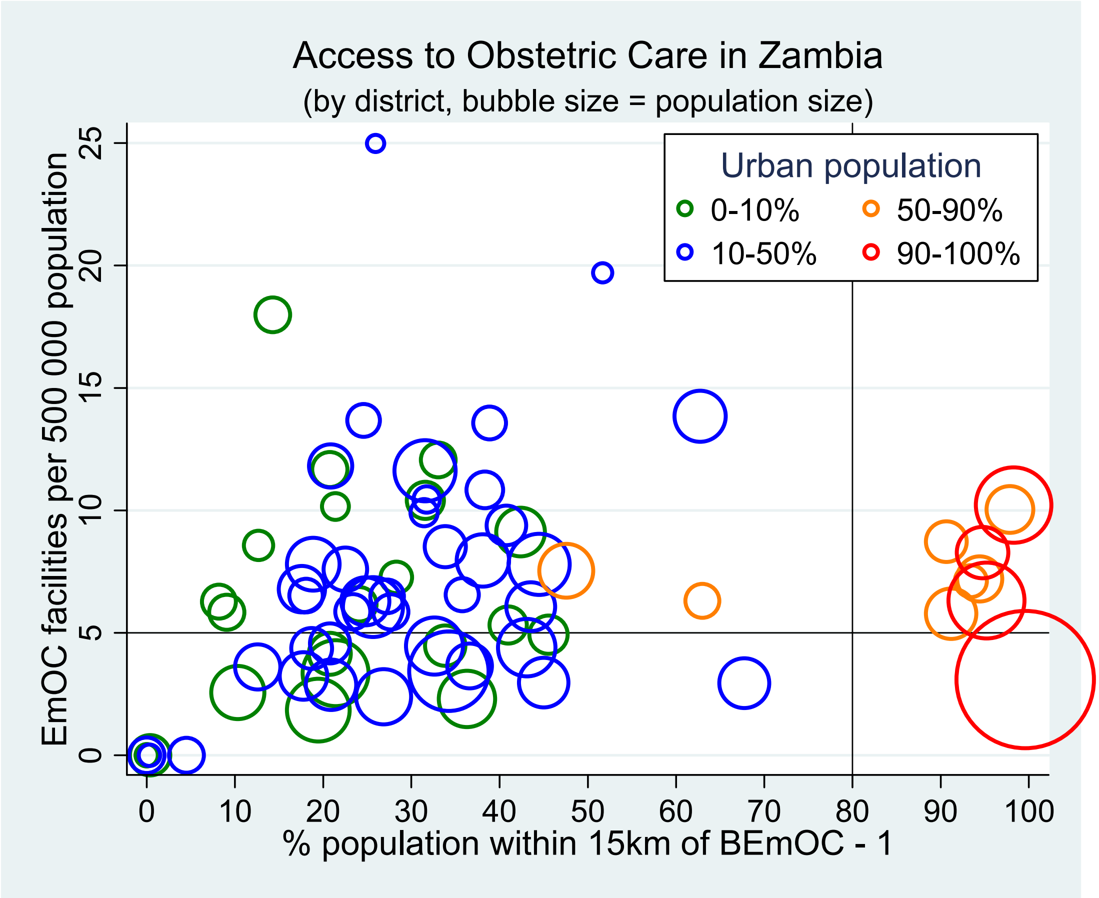
Figure 45



The presentation of births per 700 km^2 allows to relate density to case loads implied by the various benchmarks: for instance, 5 EmOC facilities per 20,000 births implies 4000 births per facility, or a group of 3 midwives in a health centre each handling 175 births implies 525 births per health centre.

Figure 46 compares the percentage of population within 15 km of an EmOC facility (with a line at 80% coverage) with the UN indicator of EmOC facilities per 500,000 population, highlighting its 5/500,000 benchmark.

Figure 46



All highly urbanised districts meet both criteria, except for Lusaka which has high coverage but fewer than 5 facilities per 500,000 population. All intermediately urbanised districts (50-90% population in urban wards) meet the UN indicator benchmark, but two have less than 70% of their population living within 15 km of the EmOC facilities.

While more than half of the primarily rural districts (less than 50% urban population) meet the UN indicator benchmark of at least 5 EmOC facilities per 500,000 population, none achieve a high population coverage, mostly ranging between 10% and 50% of the population living within 15 km of an EmOC facility.

3.2.3.4 By ward

Disaggregating even further and examining service availability by ward shows that while coverage with delivery care of any level is generally not problematic (Figure 47a), in the vast majority of wards most of the population is not within 15 km of an EmOC facility (Figure 47b). Since there are 1286 wards, this cannot be easily depicted in graphs, and therefore a map is shown.

Figure 47a: Percentage of the ward population living within 15km of a facility offering delivery care for all Zambian wards

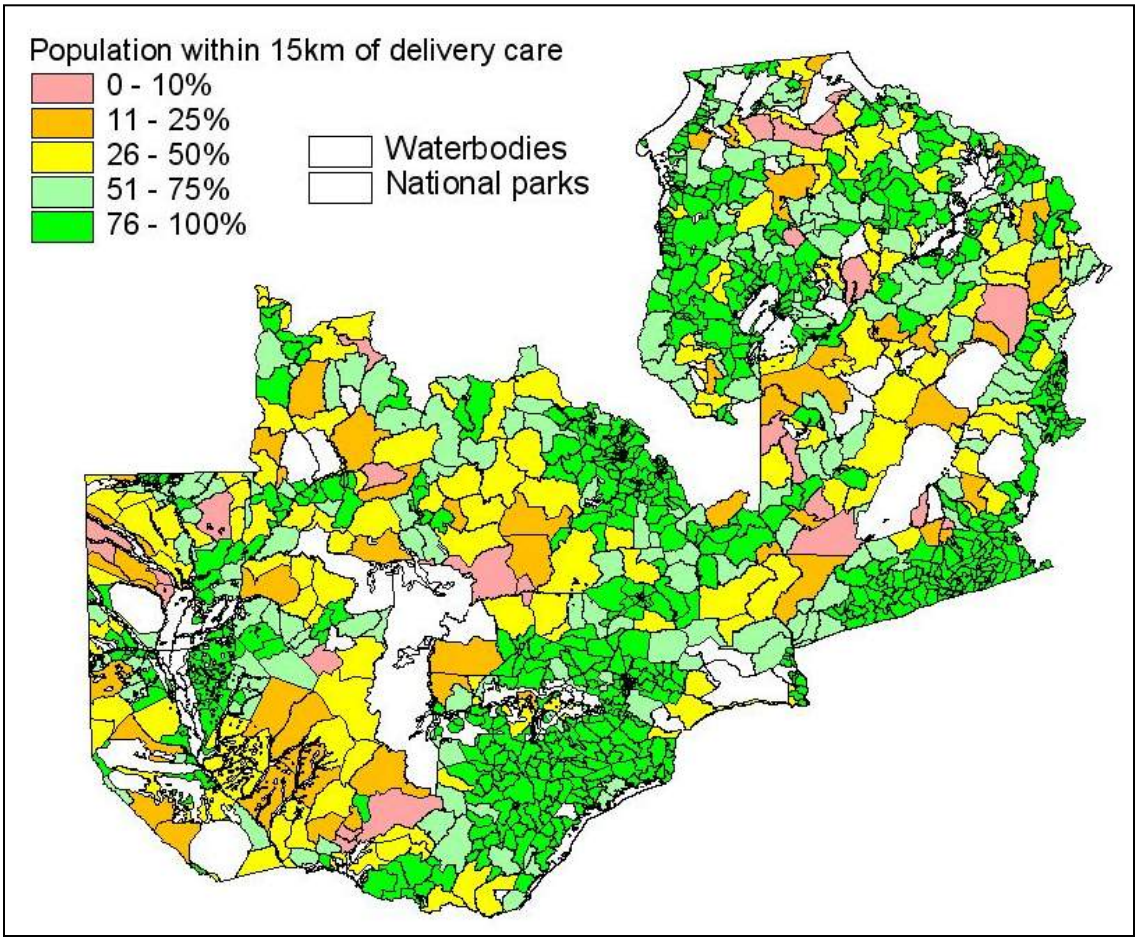
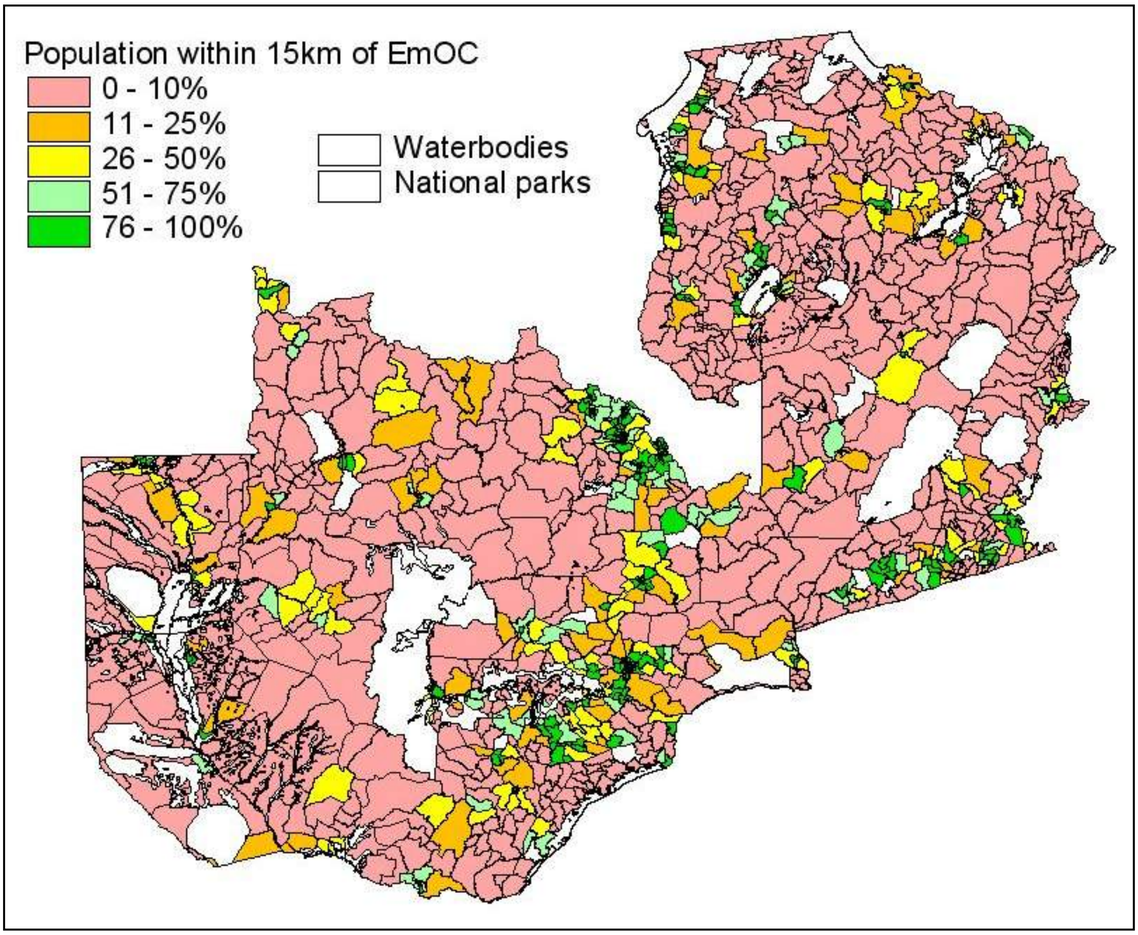


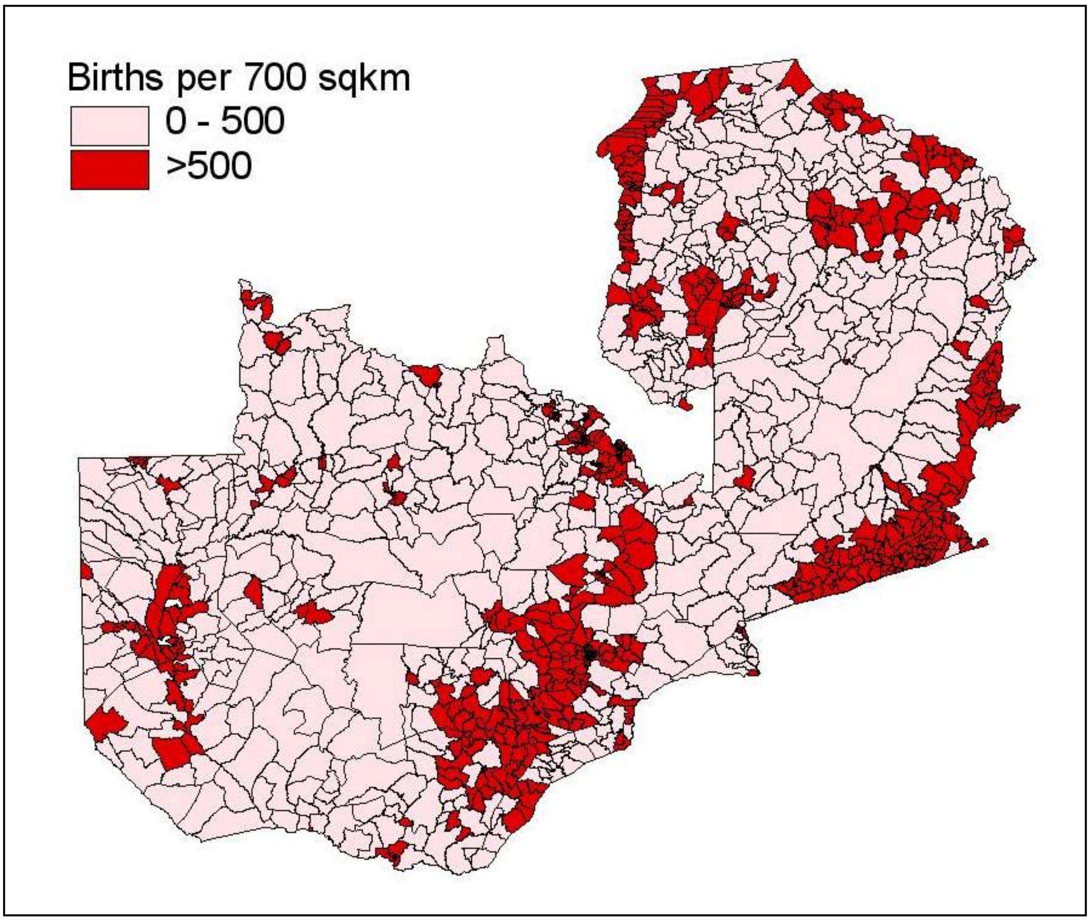
Figure 47b: Percentage of the ward population living within 15km of an EmOC facility for all Zambian wards



Note: Maps attract attention on larger areas and as absolute population numbers cannot be shown simultaneously, this makes the situation look worse than it is.

The following graph (Figure 48) shows birth density by ward. Most Zambian wards have a density of less than 500 births in the 15 km radius area around a health facility which makes it difficult to provide 24 hour delivery care in an efficient way.

Figure 48: Wards with birth densities above and below the level that allows efficient care provision

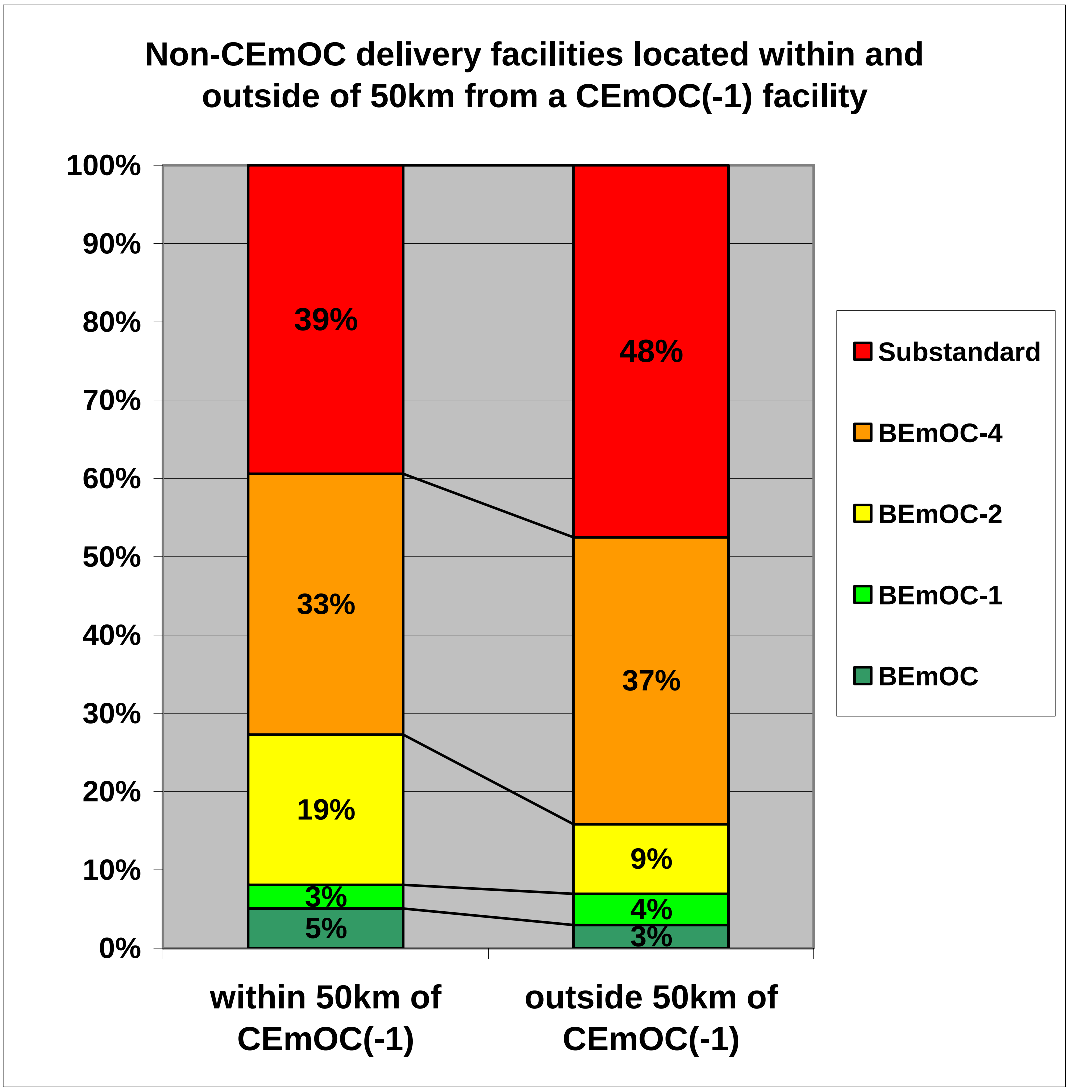


3.2.3.5 EmOC in relation to CEmOC access

In the areas far away from a CEmOC facility, there should ideally be a sufficient number of BEmOC facilities that can handle as many complications as possible.

Comparing the level of EmOC offered at facilities within 50 km reach of a CEmOC / CEmOC-1 facility to those further away, reveals that fewer of the facilities further away from a CEmOC(-1) fulfill BEmOC(-1) or BemOC-2 criteria and more are substandard (Fig. 49).

Figure 49: Facility functionality close and far from CEmOC(-1) facilities



The absolute number of EmOC facilities per population in areas further than 50 km from a CEmOC(-1) is also lower (Table 6). The mismatch would be even larger when looking at births instead of population as the CBR is higher in rural areas.

Table 6: Comparison of areas close and far from CEmOC(-1) facilities

Location	**< 50km of CEmOC(-1)**	**> 50km from CEmOC(-1)**
Land area	228,000 km^2	413,000 km^2
Population (2000)	6.8 million	3.0 million
EmOC facilities	101	32
EmOC per 500,000 population	7.4	5.3

3.3 Effect of distance on health facility use

3.3.1 Sample description

The analysis of the effect of distance on health facility use was restricted to births in rural areas (see 2.5.1). Figures 50 and 51 compare distance to delivery care and percentage of facility delivery among urban and rural births (excluding movers) to justify this restriction.

Nearly all urban births are within 5km of a health facility offering delivery care (Fig. 50) and the proportion of births delivered in a facility is much higher in urban than rural areas (Fig. 51). Urban areas are thus not of major interest to this analysis.

Figure 50: Birth distribution by distance to closest delivery care for urban and rural births 2002 and 2007

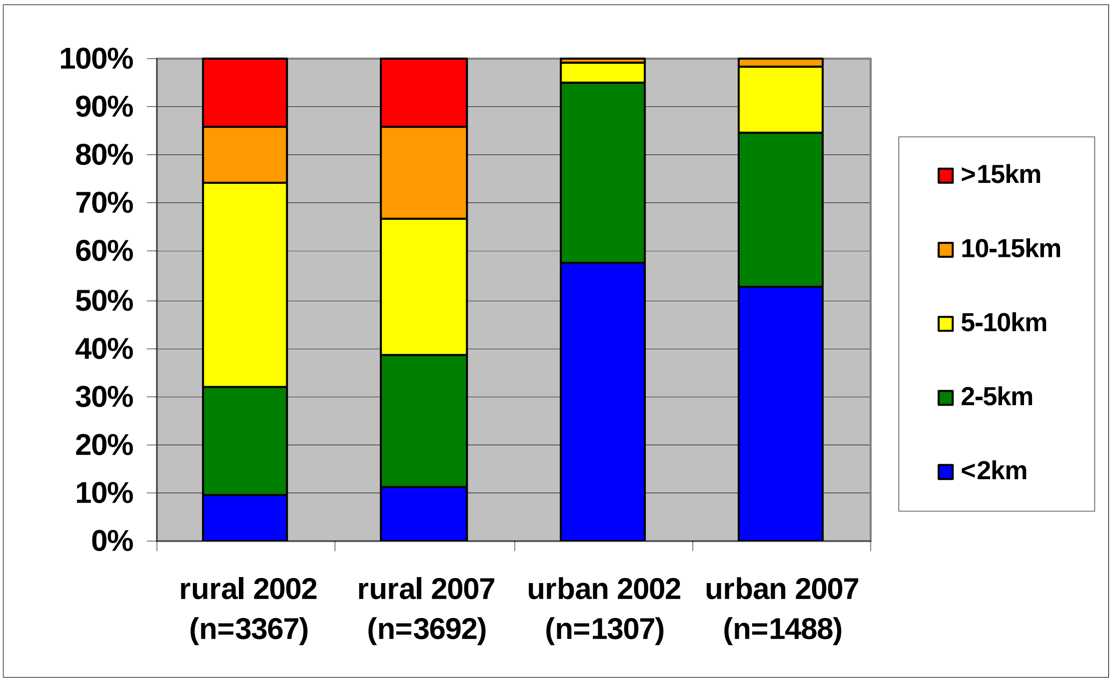
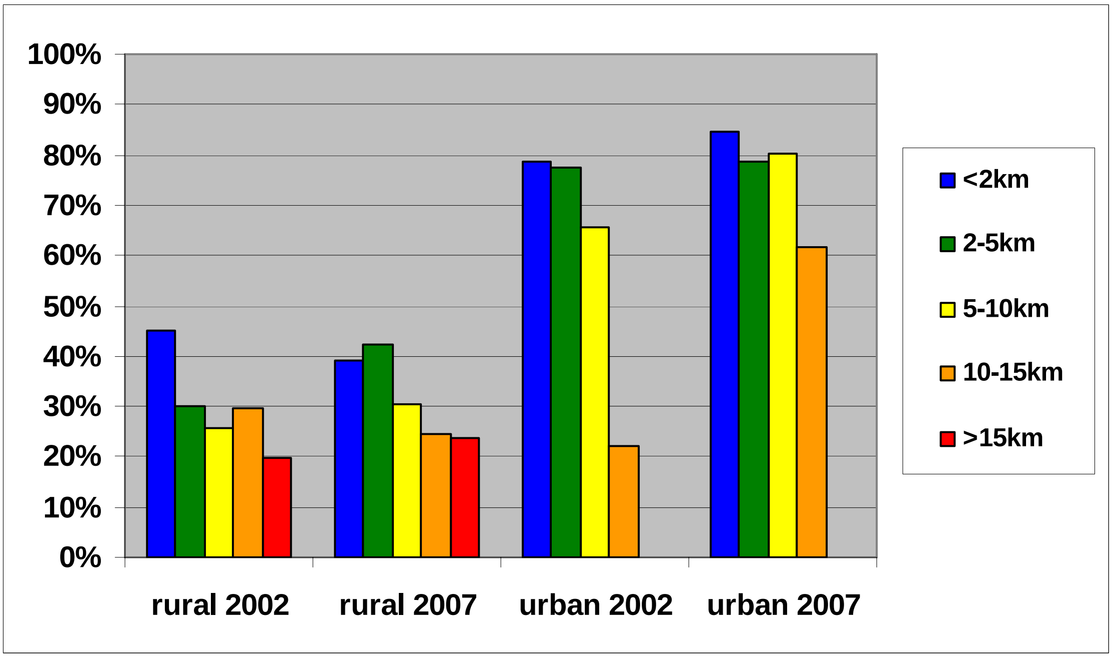


Figure 51: Percentage of facility delivery by distance to closest delivery care for urban and rural births 2002 and 2007



The following description of the distribution of outcome (facility birth) and exposure variables (physical access and confounders) is restricted to the subsets of births where distance information is available and where the mother lived in a rural area at the time of birth. These represent 69% of all births in the DHS 2002 sample and 83% of births in the DHS 2007 sample, counting twins as one birth. Information for the complete DHS sample is available in the DHS reports [6, 164].

There are two reasons for lacking distance information. The first reason is that the mother moved since the birth or is just visiting at the place of interview (so her interview cluster's distance is not the one relevant at time of birth). The second reason is that for some DHS clusters in the 2002 survey, GIS coordinates were lacking (all of Luapula province and some others) or were found to be incorrect and excluded (see 2.4.3).

The births to women who moved their cluster afterwards differ from those who did not: more of them were urban, first-order births and in facilities. Births from areas with missing GIS (nearly half of which are in Luapula) are also different from the rest, having much lower facility delivery and lower female education.

In the DHS 2002, 616 of 4679 rural births (13%) occurred before a move and of the remaining 4063 births 696 (17%) lack GIS data (Table 7).

Table 7: Births with available and missing distance in the DHS 2002

Rural residence at birth sample 2002	Total rural DHS sample	Sample with relevant distance information	Move of cluster after birth	Lacking GIS
Births	**4679**	**3367**	**616**	**696**
Facility births (%)	1247 (26.7%)	946 (28.2%)	193 (31.4%)	108 (15.5%)
First births (%)	926 (19.8%)	632 (18.8%)	182 (29.6%)	112 (16.1%)
Mother literate (%)	1600 (34.4%)	1176 (35.1%)	206 (33.9%)	218 (31.6%)

In the DHS 2007 there are no missing GIS data, so the only reason to exclude births is moving of cluster. Amongst the rural subset of interest, 454 of 4146 births (11%) occurred before a move.

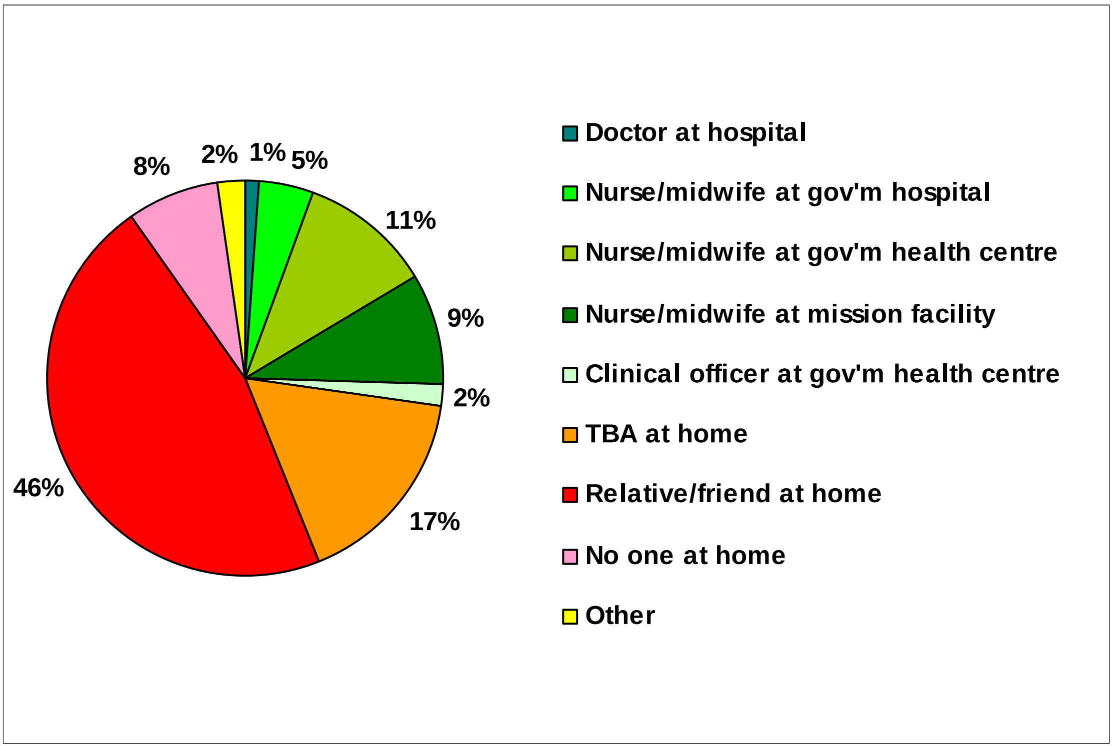
Table 8: Births with available and missing distance in the DHS 2007

Rural residence at birth sample 2007	Total rural DHS sample	Sample with relevant distance information	Move of cluster after birth
Births	**4146**	**3692**	**454**
Facility births (%)	1376 (33.3%)	1198 (32.5%)	178 (39.4%)
First births (%)	675 (16.3%)	556 (15.1%)	119 (26.2%)
Mother literate (%)	1346 (33.2%)	1186 (32.8%)	160 (36.5%)

3.3.2 Description of delivery service use and of distance

The following figures (Fig. 52 and 53) and tables (Table 9 and 10) show where rural Zambian women deliver and with whom, using data from the DHS 2002 and 2007. This is not representative for rural Zambia as a whole as it just includes the samples used for the subsequent distance analysis (i.e. excluding movers etc) and it is not weighted for the sampling design.

Figure 52: Delivery place and attendant for the 2002 sample (3357 rural births)



Note: Where numbers do not add up exactly, this is due to rounding.

Table 9: Delivery place and attendant for the 2002 sample (3357 rural births)

	Doctor	Nurse/ midwife	Clinical officer	TBA	Relative/ friend	No one	Other	Total
Gov'm hospital	0.5%	4.6%	0%	0%	0%	0%	0%	5.1%
Gov'm health centre	0.1%	10.7%	1.6%	0.4%	0%	0%	0%	12.8%
Mission	0.5%	9.4%	0%	0%	0%	0%	0%	10.0%
Private	0%	0.3%	0%	0%	0%	0%	0%	0.3%
Home	0%	0.4%	0.1%	16.6%	46.4%	7.6%	0.1%	71.2%
Other	0%	0%	0%	0.2%	0.3%	0.3%	0%	0.6%
Total	1.0%	25.4%	1.7%	17.0%	46.8%	7.9%	0.2%	100%

Figure 53: Delivery place and attendant for the 2007 sample (3680 rural births)

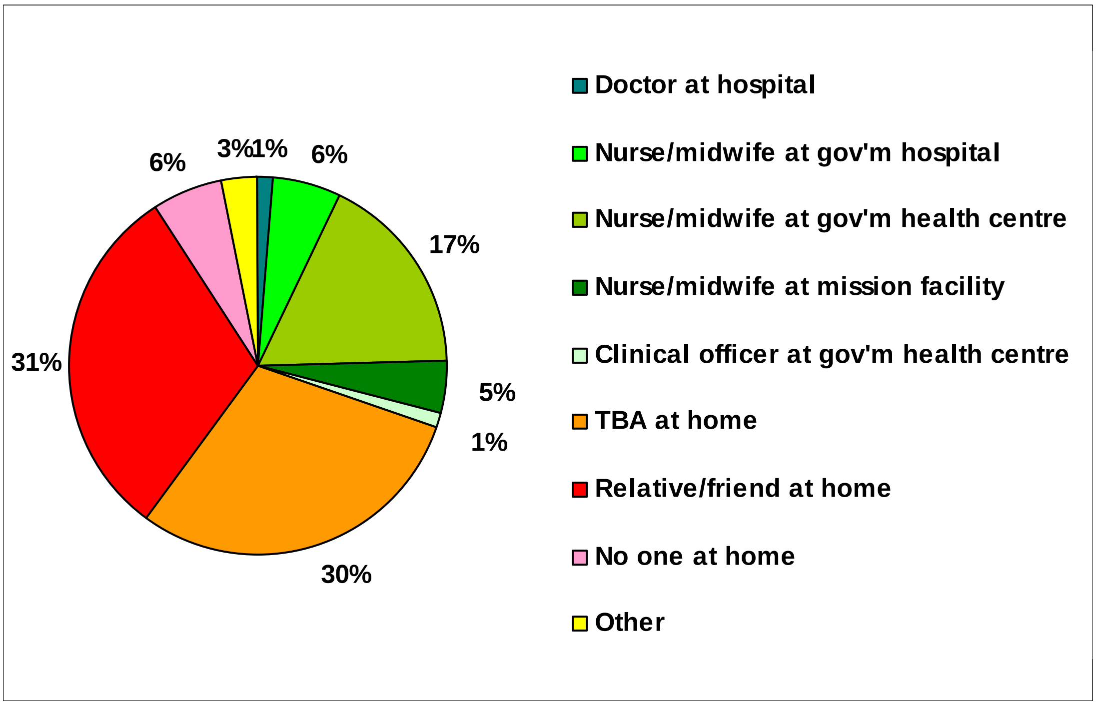


Table 10: Delivery place and attendant for the 2007 sample (3680 rural births)

	Doctor	Nurse/ midwife	Clinical officer	TBA	Relative/ friend	No one	Other	Total
Gov'm hospital	0.9%	5.8%	0.2%	0%	0%	0%	0%	6.9%
Gov'm health centre	0.1%	17.4%	1.0%	1.3%	0.1%	0.1%	0.4%	20.3%
Mission	0.4%	4.7%	0.1%	0%	0%	0%	0%	5.2%
Private	0%	0.1%	0%	0%	0%	0%	0%	0.1%
Home	0%	0.4%	0%	29.8%	30.7%	6.1%	0.1%	67.1%
Other	0%	0%	0%	0.1%	0.2%	0.1%	0%	0.4%
Total	1.4%	28.3%	1.3%	31.2%	31.1%	6.2%	0.5%	100%

Facility deliveries by health professionals comprised 28% of the 2002 sample and 30% of the 2007 sample. There was some shift from mission facilities to government health centres between the surveys and more women used TBAs for home births instead of relying on friends and relatives. In 2007, there were a small number of TBA births in health centres, so the overlap between facility delivery and skilled attendance is only 98% in 2007 as compared to 99% in 2002.

The following graphs (Fig. 54-57) show how far the births are from different types of health facilities, among the sample used for the main analysis (rural non-movers). While most people are close to a facility offering delivery care, few are close to one that fulfills BEmOC criteria, and even fewer are close to one that fulfills CEmOC criteria.

Figure 54: Distance distributions for the 2002 sample (3367 rural births)

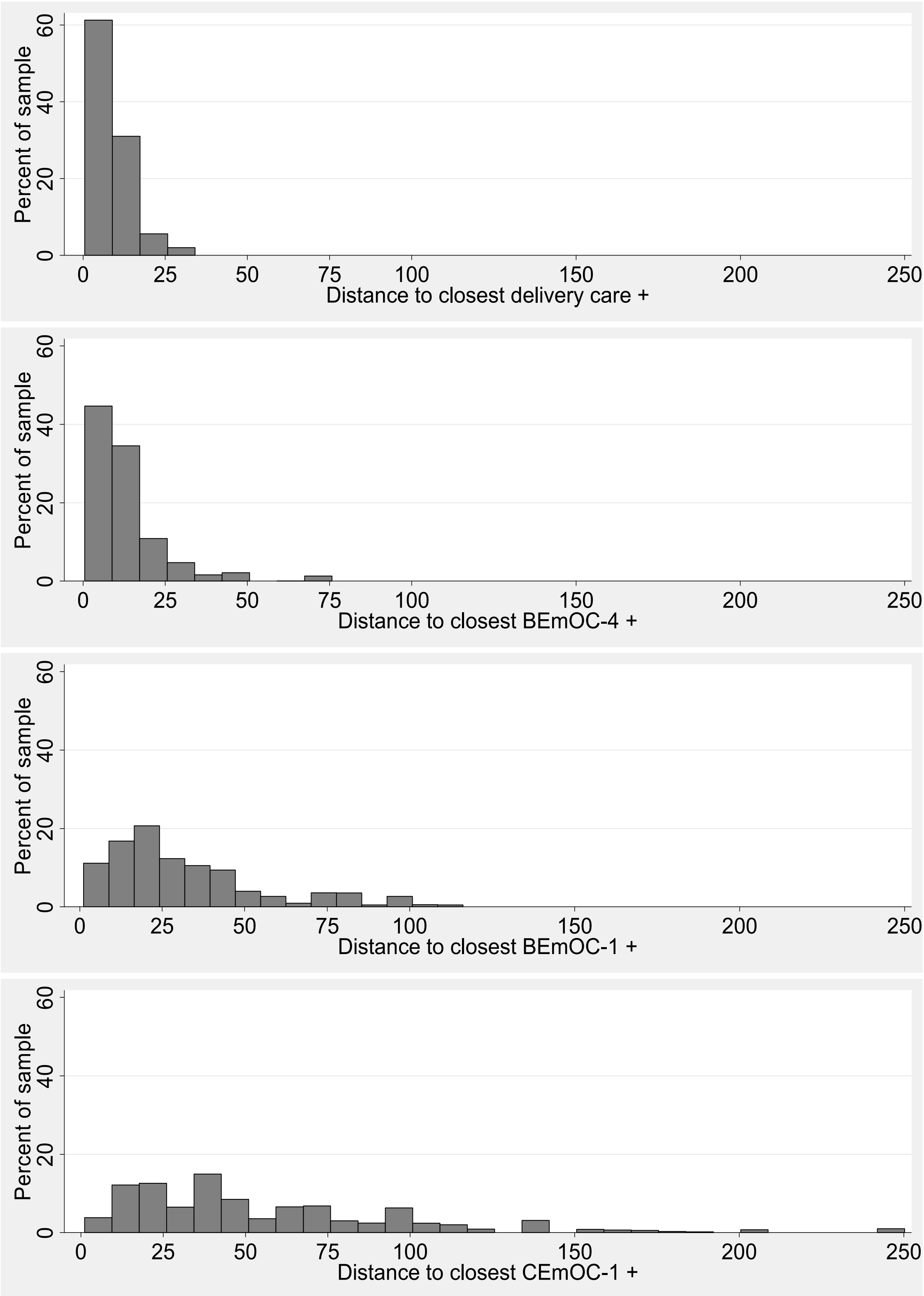


Figure 55: Distance distributions for the 2007 sample (3692 rural births)

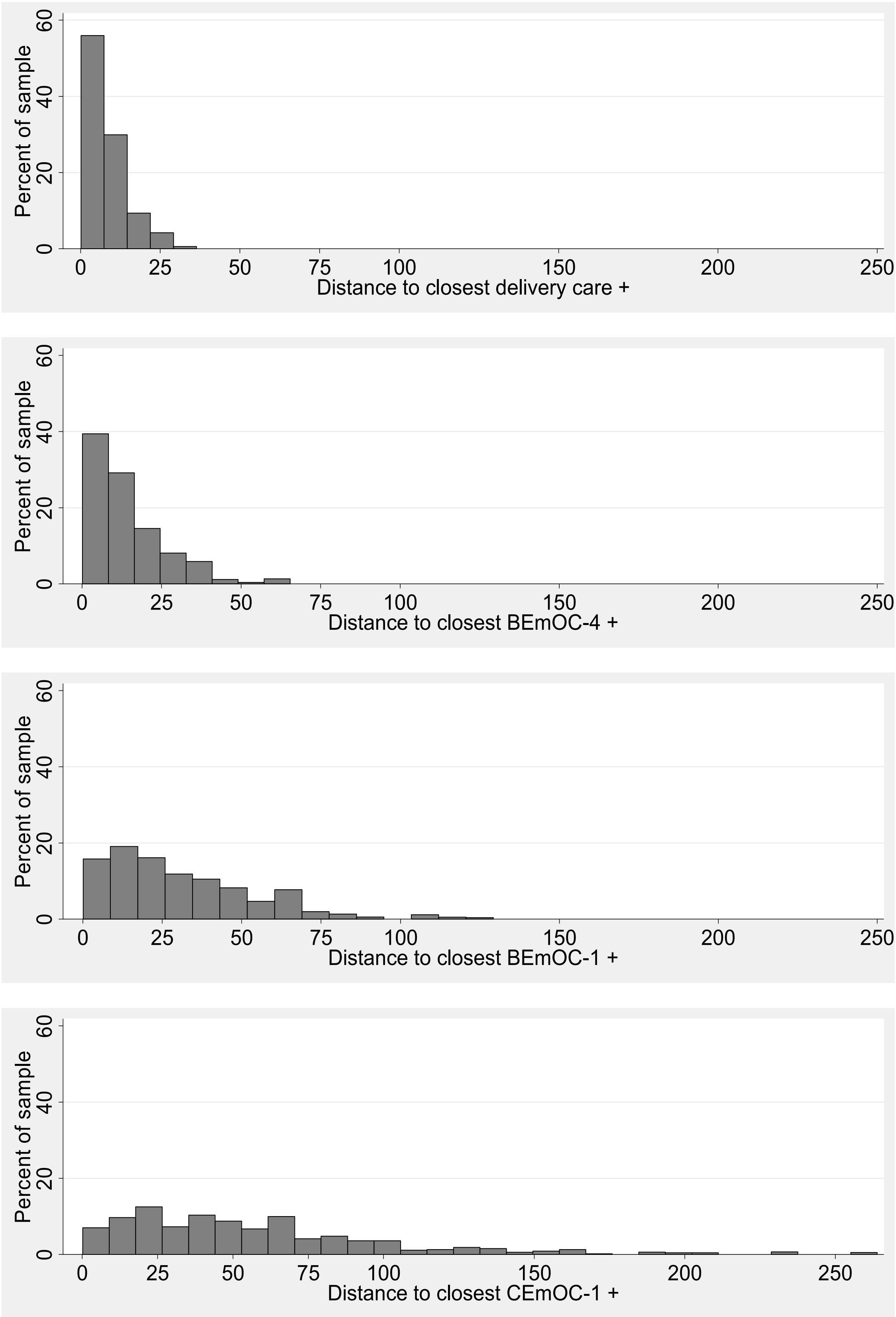
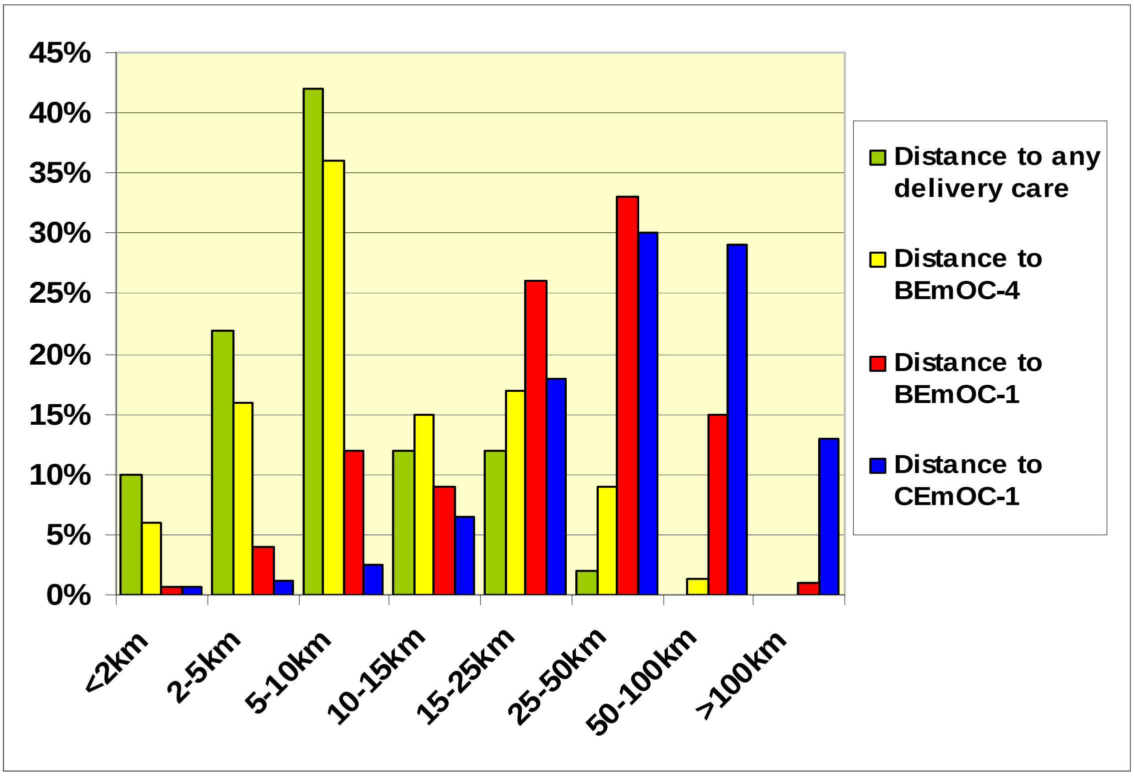


Figure 56: Distance distributions for the 2002 sample (3367 rural births)
(top panel for four distances, bottom for all eight with smoothed lines)



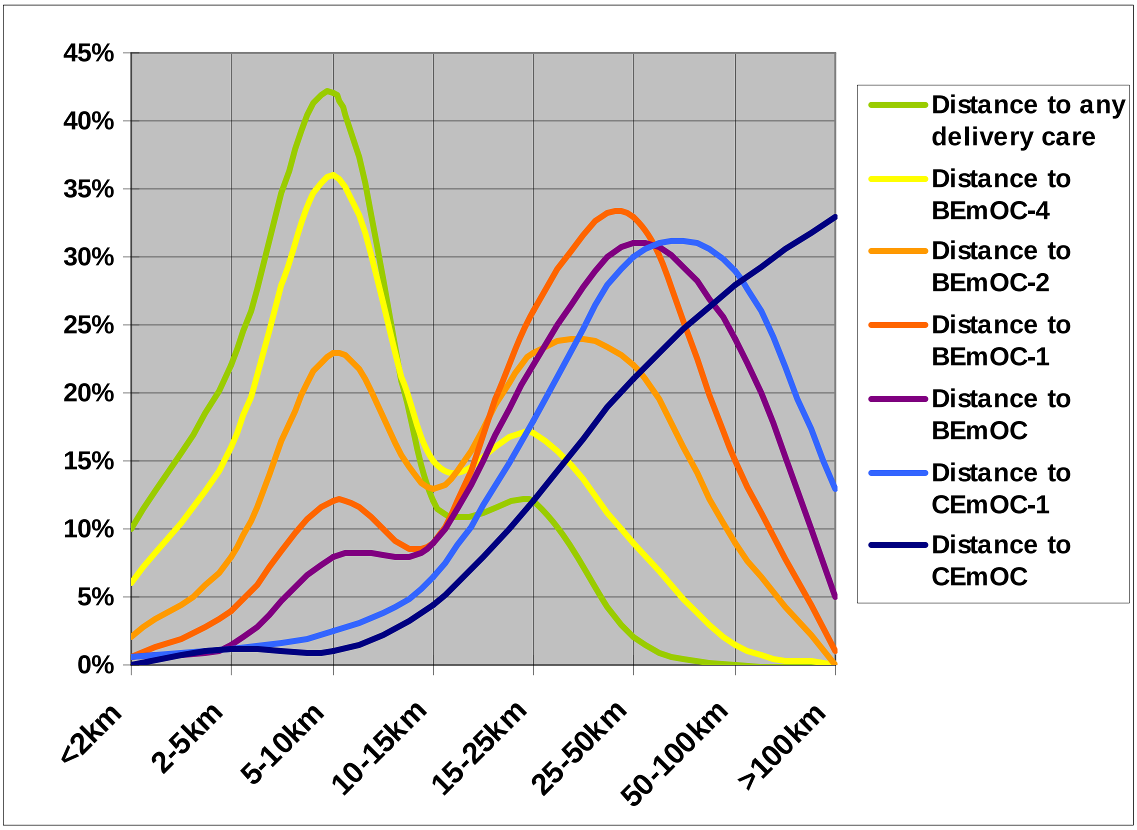
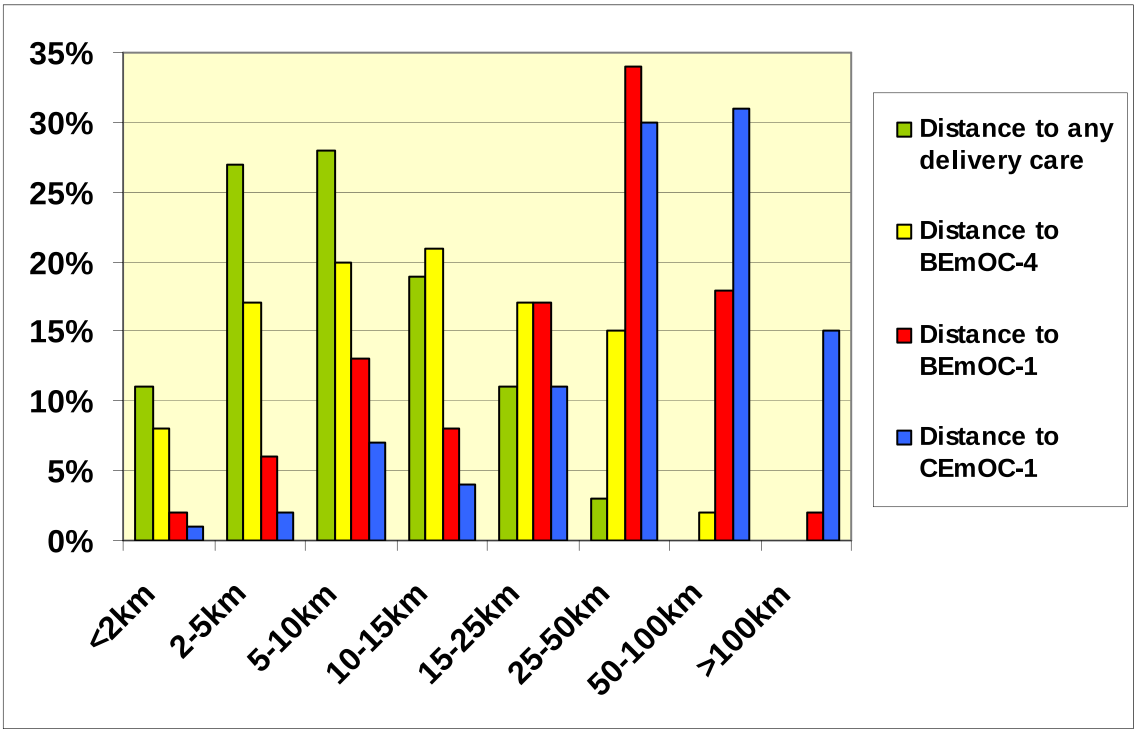
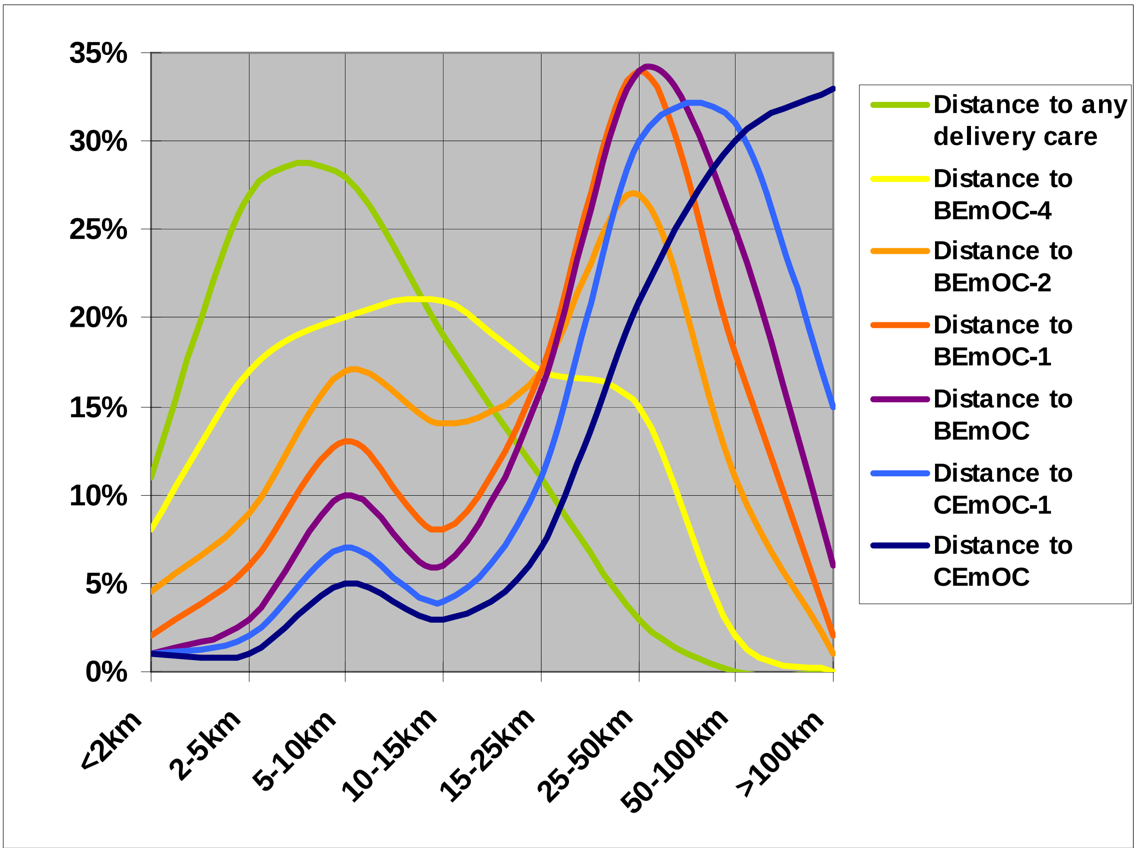


Figure 57: Distance distributions for the 2007 sample (3692 rural births)
(top panel for four distances, bottom for all eight with smoothed lines)





3.3.3 Univariable analysis of distance

Table 11 describes the distribution of the various physical accessibility variables in the samples, as well as the univariable association with facility delivery.

Table 11 : Distribution of distance and other measures of physical accessibility (or possible effect modifiers) and univariate association with facility birth in rural Zambia

	Zambia 2002 (n=3367)			Zambia 2007 (n=3692)		
Physical accessibility	**% per category**	**Facility births (%)**	**Crude OR[#]**	**% per category**	**Facility births (%)**	**Crude OR[#]**
Distance to health facility considered big problem	n=3364	n=3355	p<0.001	n=3689	n=3679	p<0.001
Big problem	60.7	20.6	1	58.8	26.3	1
No problem	39.3	39.9	2.77	41.2	41.5	2.21
Transport availability considered big problem	n=3364	n=3355	p<0.001	n=3688	n=3678	p<0.001
Big problem	62.4	21.5	1	59.4	26.9	1
No problem	37.6	39.3	2.30	40.6	40.9	2.15
Season of birth	n=3367	n=3358	p=0.01	n=3692	n=3682	p=0.15
Rainy, pre-harvest	33.0	26.1	1	32.3	31.3	1
Rainy, harvest	23.9	26.5	0.86	24.6	31.7	1.00
Dry, post-harvest	43.1	30.7	1.40	43.2	34.0	1.25
Household transport means	n=3362	n=3353	p=0.11	n=3692	n=3682	p=0.02
None	57.2	26.4	1	41.7	32.3	1
Bike	41.9	30.0	1.35	57.4	32.3	1.24
Motorised	0.9	53.3	3.04	0.8	61.3	5.94
Distance to health facility big problem for % women in cluster*	n=3367	n=3358	p<0.001	n=3692	n=3682	p<0.001
> 75%	39.1	19.6	1	32.9	24.0	1
50-75%	29.0	22.9	1.36	29.4	30.0	1.60
25-49%	17.5	37.0	5.43	19.7	37.6	3.11
< 25%	14.4	51.1	24.88	18.0	46.8	6.82
Transport to health facility big problem for % women in cluster*	n=3367	n=3358	p<0.001	n=3692	n=3682	p<0.001
> 75%	39.2	18.5	1	33.1	21.9	1
50-75%	32.1	24.2	2.21	29.0	31.2	2.19
25-49%	17.8	43.5	10.62	24.0	41.0	5.06
< 25%	11.0	49.6	27.84	13.9	45.8	8.33

	Zambia 2002 (n=3367)			Zambia 2007 (n=3692)		
Physical accessibility	**% per category**	**Facility births (%)**	**Crude OR#**	**% per category**	**Facility births (%)**	**Crude OR#**
Distance to closest delivery care*	n=3367	n=3358	p=0.03	n=3692	n=3682	p<0.001
> 15km	14.1	19.6	1	14.1	23.6	1
10-15km	11.8	29.8	2.42	19.0	24.6	1.35
5-10km	42.1	25.6	2.36	28.4	30.4	2.04
2-5km	22.3	30.2	3.85	27.1	42.1	5.76
< 2km	9.7	45.1	12.04	11.4	39.2	4.43
Distance to closest BEmOC-4*	n=3367	n=3358	p<0.001	n=3692	n=3682	p<0.001
> 15km	26.9	18.9	1	34.3	26.9	1
10-15km	15.3	24.3	1.62	21.2	27.4	1.19
5-10km	35.9	29.9	3.76	19.6	34.6	2.07
2-5km	15.5	33.4	5.44	16.7	43.4	4.19
< 2km	6.4	54.2	28.02	8.2	42.2	3.72
Distance to closest BEmOC-1*	n=3367	n=3358	p=0.06	n=3692	n=3682	p<0.001
> 25km	49.0	26.0	1	53.9	26.4	1
15-25km	25.5	24.9	0.91	17.4	36.8	2.58
10-15km	9.1	36.4	3.08	8.3	34.1	2.05
5-10km	11.9	33.5	4.22	12.8	42.7	3.84
2-5km	3.9	35.1	4.20	5.7	46.0	5.77
< 2km	0.6	66.7	27.79	1.9	52.2	6.12
Distance to closest CEmOC-1*	n=3367	n=3358	p=0.02	n=3692	n=3682	p<0.001
> 50km	41.5	23.6	1	46.1	26.6	1
25-50km	30.3	28.7	1.64	30.3	31.5	1.65
15-25km	17.6	30.0	1.94	10.7	42.1	3.72
5-15km	8.9	37.0	4.73	10.4	49.0	5.43
< 5km	1.8	63.3	59.65	2.6	45.3	4.23
Best level of delivery care within 15km	n=3367	n=3358	p=0.008	n=3692	n=3682	p<0.001
None	14.1	19.6	1	14.1	23.6	1
Substandard	12.8	18.1	0.93	20.2	29.2	1.85
BEmOC-4	27.3	28.9	2.27	20.8	26.4	1.68
BEmOC-2	20.3	30.2	3.27	16.1	36.5	3.66
BEmOC	14.9	31.4	5.09	15.9	36.0	3.51
CEmOC	10.6	41.5	11.86	12.9	48.2	7.63

* Variable presented in categories for ease of presentation only, continuous variable used in analysis
# from model adjusting for clustering by cluster and by mother; p-values from Wald tests

Distance and transport availability are considered a big problem in 60% of the sample and those considering it a big problem are only half as likely to have delivered in a facility. There is also such an effect on cluster level, i.e. when averaging over women's answers. In 40% of clusters in 2002 and 33% in 2007, more than 75% of births were to mothers for whom distance and transport are a big problem. Only around 20% of births to women from such clusters were delivered in a facility setting, compared to approximately 50% from clusters where only few consider distance and transport a big problem. (Table 11)

When cross-tabulating the two questions, the overlap is large: In 2002, 56% consider both distance and transport a big problem and 33% do not consider either a problem, around 5% only have a problem with either distance or transport. The numbers are very similar in 2007 with 54% having a problem with both and 36% with neither. (not shown)

Motorised transport is virtually absent in rural Zambia with less than 1% of births being to mothers whose household owns a car or motorbike (in absolute numbers around 30 births total). These births are much more likely to have been in a facility. Bike ownership is common (increased from 42% in 2002 to 57% in 2007) and associated with slightly higher levels of facility delivery. (Table 11)

Births in the dry season were more likely to be delivered in a facility compared to those in the rainy season in 2002 and 2007, although not statistically significant in the latter. Post- or pre-harvest time did not seem to influence care-seeking for deliveries. (Table 11)

Longer distance from health facilities is strongly associated with a decrease in facility deliveries showing a clear trend over categories for all levels of care and in both datasets. While ORs are more extreme in the 2002 data, significance is higher in the 2007 dataset. Level of care also clearly matters, with a clear increase in facility deliveries over the categories of delivery care available within 15km. (Table 11)

Comparing actual distance from health facility with women's perception on whether distance to health facilities is in general a big problem shows a correlation (Figure 58), but not as strong as might be expected. Comparing distance from delivery care with problem perception gives nearly identical figures (not shown). There is virtually no difference in problem perception by distance to a facility offering at least BEmOC-1 (Figure 59).

In further analysis, distances were used as continuous variables. The effect of distance on facility use is not linear, but levels off with larger distances, as would be expected. After a logarithmic transformation, the effect is approximately linear for most distance measures. This is shown below for distance to a facility offering at least BEmOC-4 in 2002 and for BEmOC-1 in 2007 (Fig. 60 and 61).

Figure 58: Distance seen as a big problem for accessing care, by distance to any facility

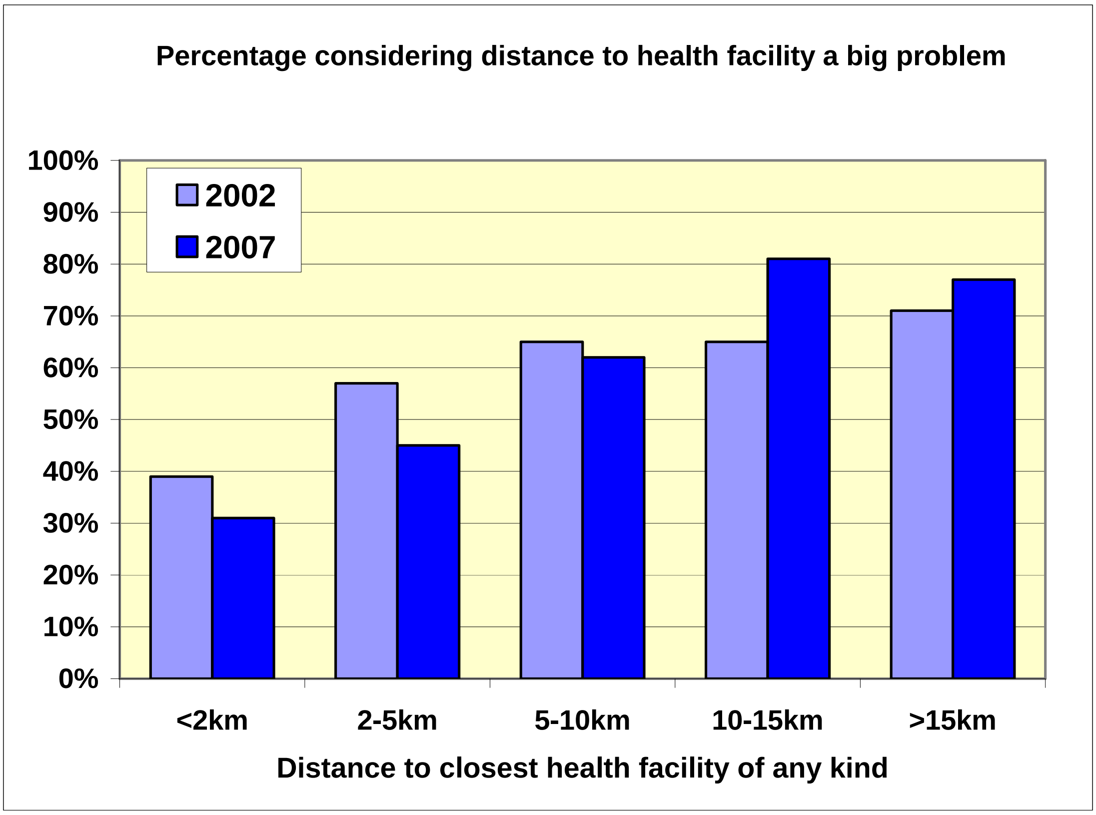


Figure 59: Distance seen as a big problem for accessing care by distance to a facility offering at least BEmOC-1

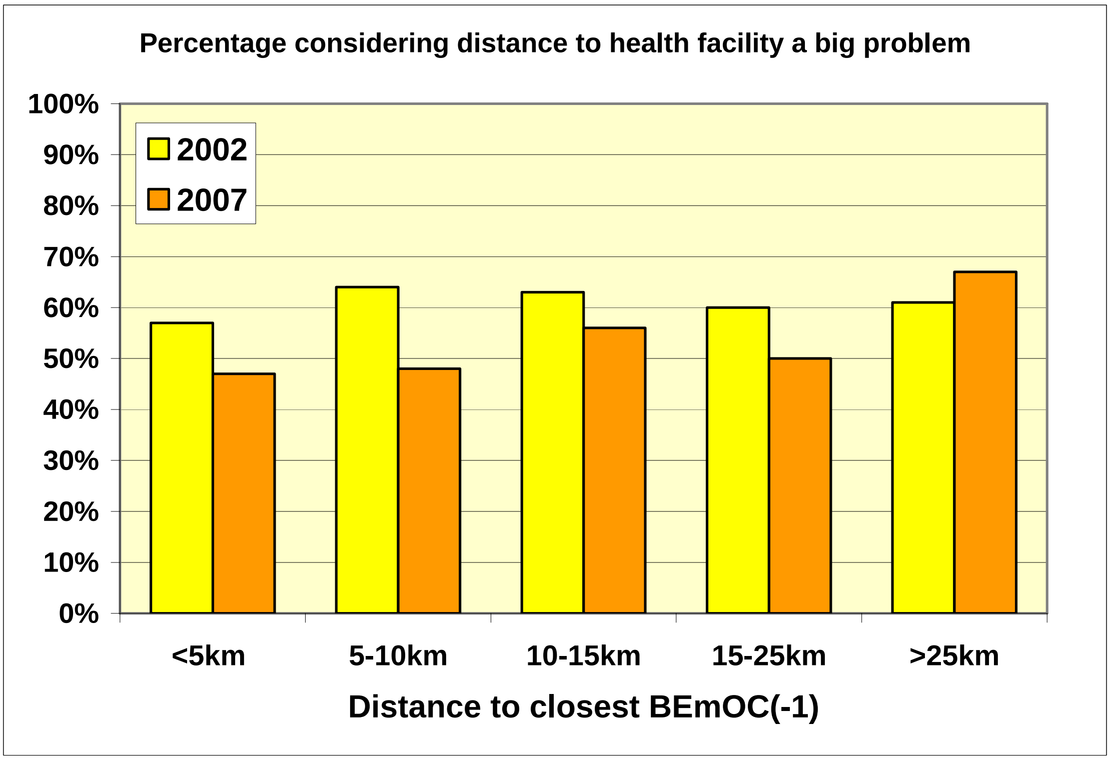


Figure 60: Mean facility delivery by distance to closest BEmOC-4 (DHS 2002) (top panel for untransformed distance, bottom for log-transformed distance)

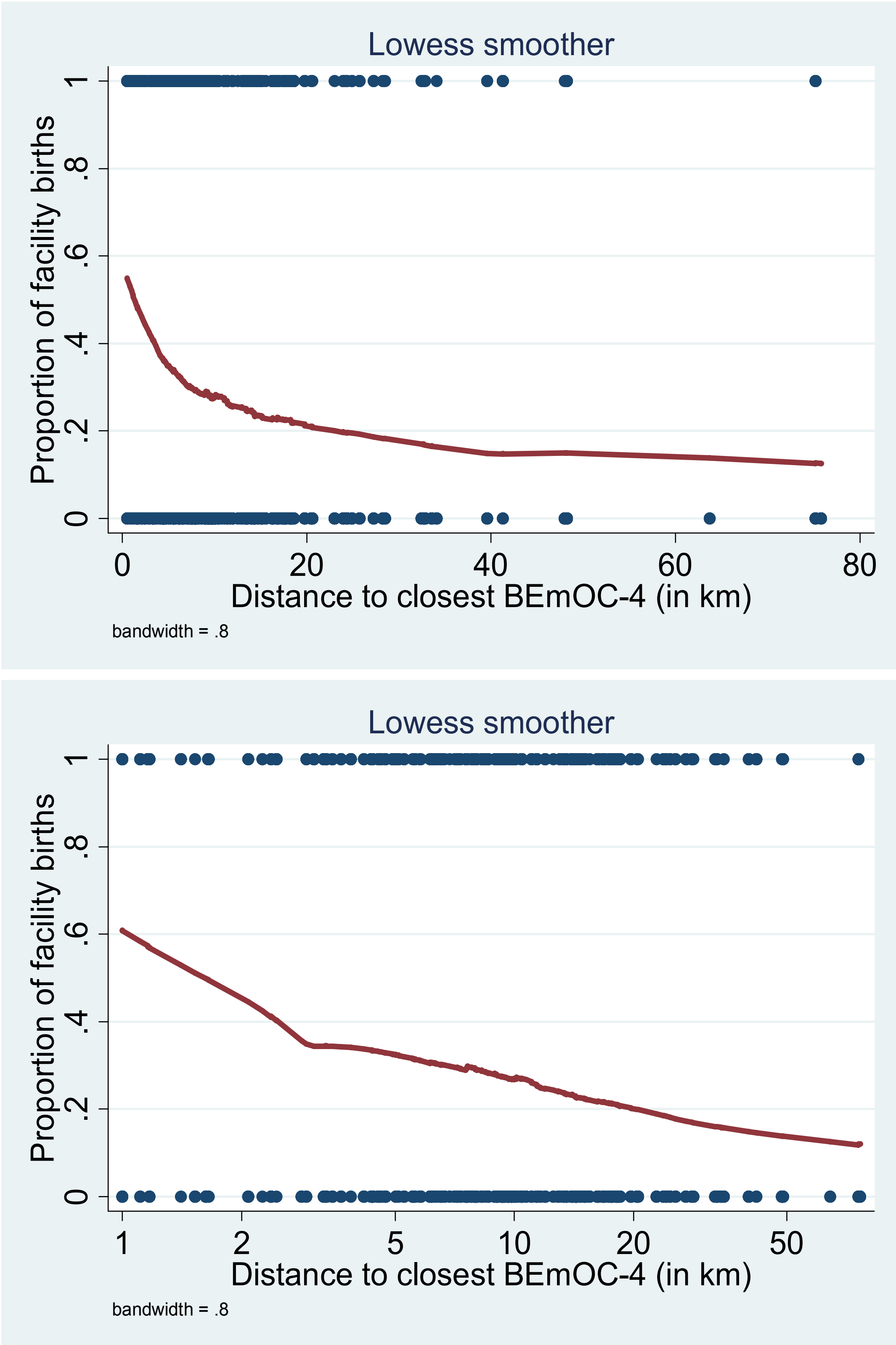
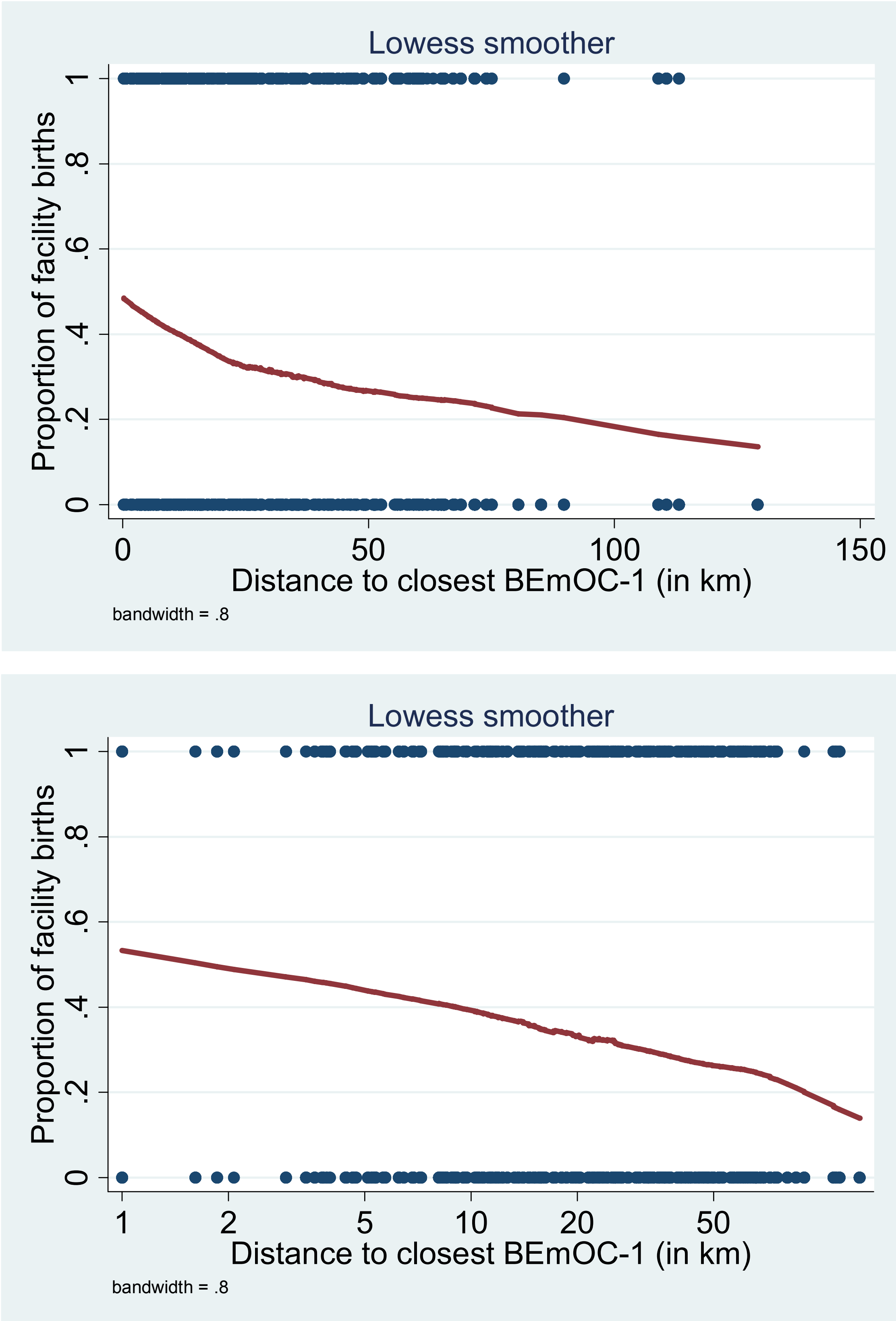


Figure 61: Mean facility delivery by distance to closest BEmOC-1 (DHS 2007) (top panel for untransformed distance, bottom for log-transformed distance)



The crude linear effects of all log-transformed distance variables on health facility delivery in rural Zambia are shown in Table 12 for 2002 and Table 13 for 2007.

Table 12: Linear effect of distance (log-transformed) on health facility delivery in rural Zambia (DHS 2002)
(models adjusting for clustering by cluster and by mother; p-values from Wald tests; n=3358)

Log-distance to	OR	95% CI	p-value
Any facility	0.39	0.24 – 0.64	<0.001
Any delivery care	0.41	0.25 – 0.67	<0.001
BEmOC-4 or better	0.33	0.21 – 0.52	<0.001
BEmOC-2 or better	0.38	0.25 – 0.59	<0.001
BEmOC-1 or better	0.42	0.26 – 0.67	<0.001
Full BEmOC or better	0.42	0.26 – 0.66	<0.001
CEmOC-1 or better	0.49	0.31 – 0.78	0.002
Full CEmOC	0.69	0.45 – 1.06	0.088

Table 13: Linear effect of distance (log-transformed) on health facility delivery in rural Zambia (DHS 2007)
(models adjusting for clustering by cluster and by mother; p-values from Wald tests; n=3682)

Log-distance to	OR	95% CI	p-value
Any facility	0.53	0.38 – 0.72	<0.001
Any delivery care	0.52	0.38 – 0.71	<0.001
BEmOC-4 or better	0.57	0.44 – 0.74	<0.001
BEmOC-2 or better	0.56	0.44 – 0.72	<0.001
BEmOC-1 or better	0.52	0.40 – 0.68	<0.001
Full BEmOC or better	0.52	0.39 – 0.68	<0.001
CEmOC-1 or better	0.55	0.42 – 0.72	<0.001
Full CEmOC	0.62	0.48 – 0.79	<0.001

The results for the DHS 2002 show that a one unit increase in the log-distance to the nearest delivery care is associated with a decrease in the odds of facility delivery by nearly 60%. The effect of distance on facility use is stronger when restricting to those 60% of facilities that offer at least two signal functions, provide 24 hour service, provide a vehicle for referral or have a communication tool and where at least one health professional was found on duty at the day of visit (BEmOC-4). The effect of distance to a BEmOC facility is somewhat weaker than that to facilities not required to fulfill all these criteria and the effect of distance to a comprehensive EmOC facility is even weaker.

The distance effects in the DHS 2007 are somewhat weaker than in 2002, except for distance to full CEmOC facilities which is stronger in 2007, and more homogenous over the various facility types. Standard errors are smaller due to a lower intra-cluster correlation for health facility use.

I decided to take four distance variables forward for further analysis: Distance to any delivery care, distance to BEmOC-4 or better, distance to BEmOC-1 or better and distance to CEmOC-1 or better. These should represent all important levels of care.

3.3.4 Univariable analysis of other risk factors

Potential confounders of the effect of distance on health facility delivery were examined for their distribution in the sample and their association with the outcome (Tables 14a-d), grouped into sociocultural factors, perceived need / benefit, economic accessibility and cluster-level factors, in line with the conceptual framework (Fig. 8a).

Of the sociocultural factors (Table 14a), higher education shows the strongest association with facility use. Modern fertility attitudes, both of the mother and her husband, are also strongly associated with use of delivery care. Relationship autonomy shows the strongest association among the autonomy variables, with women enjoying greater autonomy being much more likely to deliver in a facility setting. Never married women form their own category for several variables, and are more likely to use facilities for giving birth than other women.

Table 14a : Distribution of sociocultural factors and their association with facility birth

	Zambia 2002 (n=3367)			Zambia 2007 (n=3692)		
Sociocultural factors	**% per category**	**Facility births (%)**	**Crude OR#**	**% per category**	**Facility births (%)**	**Crude OR#**
Mother's age	n=3367	n=3358	p=0.45	n=3692	n=3682	p<0.001
13-17 years	8.4	28.6	0.94	5.5	43.8	2.04
18-19 years	11.6	29.1	1.12	9.8	37.6	1.33
20-24 years	28.6	28.7	1 (baseline)	28.2	32.9	1 (baseline)
25-29 years	21.8	28.7	0.87	24.5	31.1	0.77
30-34 years	15.2	24.6	0.72	17.0	33.8	0.87
35-49 years	14.4	29.1	1.20	15.0	25.4	0.46
Marital status	n=3367	n=3358	p=0.004	n=3692	n=3682	p=0.002
Married, together	80.4	26.4	1	78.3	31.0	1
Married, apart	3.9	29.0	1.29	8.0	30.0	0.84
With partner	1.0	41.2	4.07	0.3	50.0	3.80
Widowed	2.1	40.3	2.15	1.6	25.0	0.52
Divorced	5.3	25.8	0.79	4.2	43.0	1.73
Separated	1.8	19.4	0.45	1.9	40.9	1.62
Never union	5.4	51.4	3.23	5.6	48.3	2.89
Ethnic group	n=3367	n=3358	p=0.09	n=3692	n=3682	p=0.05
Others	29.1	26.1	1	31.5	30.8	1
Bemba	14.7	25.2	1.24	17.2	33.0	1.02
Tonga	12.6	20.4	0.56	11.9	21.4	0.48
Luvale	3.7	46.3	1.77	2.7	38.4	1.65
Lunda	7.3	25.2	0.57	5.6	30.9	1.58
Kaonde	5.5	41.4	2.01	4.2	38.1	1.64
Lozi	5.4	26.7	0.95	6.2	37.9	1.51
Chewa	9.0	25.5	1.43	6.1	46.4	2.08
Nsenga	3.8	34.1	0.84	5.1	36.2	1.04
Mbunda	4.1	42.7	3.02	3.5	47.7	2.41
Mambwe	1.0	31.3	0.91	1.7	12.7	0.33
Tumbuka	4.0	35.6	2.69	4.4	32.1	1.05
Religion	n=3363	n=3354	p=0.31	n=3685	n=3675	p=0.02
protestant	74.9	28.5	1	79.8	33.0	1
catholic	22.8	28.3	0.98	17.7	33.1	0.93
others	2.3	14.5	0.39	2.5	13.2	0.22
Fertility attitudes	n=3364	n=3355	p<0.001	n=3688	n=3678	p<0.001
Traditional	27.7	17.6	1	27.2	24.8	1
Intermediate	61.6	31.2	2.60	62.8	34.1	1.66
Modern	10.7	38.7	3.59	10.0	43.9	3.52

	Zambia 2002 (n=3367)			Zambia 2007 (n=3692)		
Sociocultural factors	**% per category**	**Facility births (%)**	**Crude OR[#]**	**% per category**	**Facility births (%)**	**Crude OR[#]**
Family composition	n=3367	n=3358	p<0.001	n=3692	n=3682	p<0.001
Mother,husband + sibling < 7 yrs	37.3	22.6	1	44.4	28.7	1
Mother alone + sibling <7 years	3.6	36.7	1.87	6.0	27.4	0.84
Mother, 1 other adult + sib.<7y	2.5	27.4	1.78	2.4	36.0	1.72
Mother, 2 adults + sibling < 7y	14.5	24.7	1.40	14.3	29.7	1.02
Mother, 3+ adults + sib<7y	14.1	34.7	2.43	9.9	34.3	1.35
No siblings under 7 years	28.1	33.2	2.33	23.0	42.0	2.52
Literacy	n=3350	n=3341	p<0.001	n=3611	n=3601	p<0.001
Illiterate	55.0	19.3	1	55.6	26.5	1
Partly literate	9.9	31.3	2.90	11.6	41.5	2.87
Literate	35.1	40.8	4.74	32.8	38.9	2.72
Education*	n=3367	n=3358	p<0.001	n=3692	n=3682	p<0.001
No schooling	19.7	15.0	1	18.2	21.6	1
Incomplete primary school	52.0	24.5	2.48	49.9	31.4	2.23
Complete primary school	16.6	34.7	5.63	19.0	36.6	3.51
Incomplete secondary	10.8	54.4	13.7	11.9	43.7	5.59
Complete sec. or higher	1.0	90.9	488.7	1.1	72.5	35.40
Husband's education	n=3364	n=3355	p<0.001	n=3680	n=3670	p<0.001
No schooling	9.0	23.9	1.13	10.0	28.3	1.13
Incomplete primary school	31.3	20.2	1 (baseline)	31.0	24.1	1 (baseline)
Complete primary school	26.5	21.5	1.18	25.0	31.7	2.00
Incomplete secondary	21.1	36.6	2.72	20.8	38.7	3.29
Complete sec. or higher	5.7	57.1	7.19	6.1	47.1	7.65
Don't know	1.1	23.7	1.87	1.6	39.7	2.93
No husband	5.4	51.4	4.83	5.6	48.3	7.86
Husband's fertility attitudes[c]	n=3367	n=3358	p<0.001	n=3671	n=3661	p<0.001
Traditional	26.8	18.8	1	65.9	28.4	1
Intermediate	43.7	27.9	2.12	14.0	39.0	1.91
Modern	14.9	37.8	3.69	6.7	35.8	2.02
No husband	14.6	36.5	2.69	13.4	42.7	2.28

	Zambia 2002 (n=3367)			Zambia 2007 (n=3692)		
Sociocultural factors	**% per category**	**Facility births (%)**	**Crude OR#**	**% per category**	**Facility births (%)**	**Crude OR#**
Financial autonomy[c]	n=3346	n=3337	p=0.09	n=3683	n=3673	p=0.004
None	53.1	25.3	1	36.4	29.1	1
Low	18.3	30.6	1.42	26.8	32.5	1.26
Medium	22.2	30.8	1.18	17.6	33.1	1.42
High	6.5	35.9	2.06	5.8	28.8	0.83
Not married	–	–	–	13.4	42.7	2.18
Care-seeking autonomy[c]	n=3367	n=3358	p=0.79	n=3688	n=3678	p=0.004
Low	55.4	26.9	1	32.1	28.3	1
Medium	12.3	25.2	1.08	30.3	31.0	1.20
High	32.3	31.5	1.14	24.3	34.5	1.32
Not married	–	–	–	13.3	42.7	2.19
Mobility autonomy[c]	n=3353	n=3344	p=0.40	n=3688	n=3678	p=0.01
Low	53.6	26.9	1	31.3	31.0	1
Medium	24.5	29.1	1.00	36.9	31.1	0.96
High	22.0	30.2	1.30	18.5	30.7	0.89
Not married	–	–	–	13.3	42.7	1.80
Relationship autonomy*[c]	n=3367	n=3358	p<0.001	n=3692	n=3682	p<0.001
Very low	11.9	13.8	1	13.6	23.1	1
Low	31.7	21.2	1.43	32.1	29.2	1.51
Medium	36.1	29.9	2.32	26.3	32.4	1.75
High	15.0	41.8	5.58	14.6	39.8	2.70
Never/ not married	5.4	51.4	6.54	13.3	42.7	3.20
Violence experience*[c]	n=2553	n=2546	p<0.001	n=3275	n=3265	p=0.001
High	5.3	28.4	1	27.1	30.7	1
Medium	39.7	24.5	0.45	27.4	31.8	1.10
None/low	47.9	27.1	0.58	39.2	30.7	1.10
Never married	7.1	51.4	1.99	6.3	48.3	3.18

* Variable presented in categories for ease of presentation only, continuous variable used in analysis
# from model adjusting for clustering by cluster and by mother; p-values from Wald tests
[c] questions / variable coding changed between surveys

Few of the variables relating to perceived need / benefit of facility delivery show a strong univariate association (Table 14b). Women having their first child are more likely to deliver in a health facility than those of higher parities. Women's media use – which increased substantially from 16% to 36% daily use from 2002 to 2007 – is also highly predictive of facility use for delivery.

Table 14b: Distribution of perceived benefit/need factors and their association with facility birth

	Zambia 2002 (n=3367)			Zambia 2007 (n=3692)		
Perceived benefit / need	**% per category**	**Facility births (%)**	**Crude OR#**	**% per category**	**Facility births (%)**	**Crude OR#**
Media use	n=3367	n=3358	p<0.001	n=3692	n=3682	p=0.009
Not at all	54.7	21.9	1	33.8	28.2	1
Less than once a week	17.4	30.3	1.79	14.7	31.2	1.43
At least once a week	12.0	33.3	2.25	15.8	32.7	1.35
Almost daily	15.9	43.4	3.77	35.7	37.1	1.80
Exposure to media health programmes	n=3367	n=3358	p<0.001	n=3692	n=3682	p<0.001
None	64.4	22.6	1	64.1	29.5	1
Some	21.2	36.4	3.02	23.5	35.5	1.50
Many	14.5	41.0	3.70	12.4	42.5	2.51
Wantedness	n=3361	n=3358	p=0.31	n=3679	n=3679	p=0.75
Then	65.6	27.2	1	62.2	32.1	1
Later	19.8	27.7	0.83	22.8	32.1	1.02
No more	14.6	33.3	1.21	15.0	35.3	1.14
Birth order	n=3367	n=3358	p=0.02	n=3692	n=3682	p<0.001
1	18.8	34.6	1	15.1	45.4	1
2-3	32.6	28.5	0.64	34.1	32.9	0.40
4-5	22.3	26.3	0.57	24.8	28.6	0.30
6+	26.3	24.8	0.54	26.1	28.4	0.32
Twin/triplet	n=3367	n=3358	p=0.53	n=3690	n=3680	p=0.27
No	98.5	28.2	1	97.9	32.4	1
Yes	1.5	24.5	0.70	2.1	41.0	1.53
C-section	n=3365	n=3358	–	n=3690	n=3680	–
No	99.0	27.4	1	98.5	31.5	1
Yes	1.0	100	∞	1.5	100	∞
Previous C-section	n=3367	n=3358	p=0.04	n=3692	n=3682	p<0.001
No	29.4	31.1	1	23.5	40.4	1
Yes	0.3	72.7	3.84	0.4	85.7	8.11
No information§	70.3	26.8	0.71	76.1	29.9	0.41
Previous stillbirth[c]	n=3367	n=3358	p<0.001	n=3692	n=3682	p=0.56
No	93.9	27.8	1	98.5	32.5	1
Yes	6.2	34.3	2.89	1.5	32.1	1.36
Previous newborn death	n=3367	n=3358	p=0.37	n=3692	n=3682	p=0.29
None	90.0	28.4	1	90.0	33.0	1
One	7.9	26.2	1.46	8.3	28.6	0.69
Two or more	2.2	23.9	1.29	1.7	29.0	0.92

*#c: see previous table

§ mother had births more than five years before the survey and mode of delivery was not asked

Table 14c: Distribution of economic accessibility factors and their association with facility birth

	Zambia 2002 (n=3367)			Zambia 2007 (n=3692)		
Economic accessibility	**% per category**	**Facility births (%)**	**Crude OR#**	**% per category**	**Facility births (%)**	**Crude OR#**
Occupation[c]	n=3367	n=3358	p<0.001	n=3685	n=3675	p<0.001
Agricultural self-employed	46.1	22.2	1	39.2	29.2	1
Professional, technical, managerial, clerical	0.7	85.7	99.4	0.7	66.7	22.67
No occupation	35.1	30.0	1.36	36.0	32.9	1.32
Agricultural employee	9.4	27.0	0.89	10.9	30.0	1.14
Domestic	1.9	47.7	2.45	–	–	–
Services	5.1	40.8	2.77	9.9	42.0	2.02
Manual	1.8	49.2	6.49	3.5	43.8	2.83
Husband's occupation[c]	n=3354	n=3345	p<0.001	n=3617	n=3607	p<0.001
Agricultural self-employed	65.0	21.5	1	53.0	28.8	1
Professional, technical, managerial, clerical	3.2	66.0	9.61	3.0	47.7	3.17
No occupation	1.9	38.7	3.41	–	–	–
No husband	5.4	51.4	4.13	5.7	48.3	3.44
Agricultural employee	7.8	30.4	1.27	13.8	27.6	0.78
Domestic	4.4	28.1	1.26	–	–	–
Services	5.3	37.7	2.10	9.8	41.6	1.94
Manual	7.1	43.9	2.75	14.8	34.3	1.38
Household asset score*[c]	n=3367	n=3358	p<0.001	n=3692	n=3682	p<0.001
0-9	22.8	19.0	1	22.1	26.8	1
10-19	38.4	23.6	1.59	38.0	29.6	1.44
20-29	23.9	30.4	2.68	24.7	34.0	1.97
30-39	9.7	41.5	4.91	9.1	41.3	3.25
40+	5.3	66.3	19.28	6.0	52.7	6.81
Getting money for treatment or transport	n=3363	n=3354	p=0.007	n=3684	n=3674	p<0.001
Big problem	74.2	26.8	1	38.7	26.9	1
No problem	25.8	32.3	1.61	61.3	36.1	1.78
Mother has health insurance		–		n=3687	n=3677	p=0.04
No				97.1	32.4	1
Yes				2.9	38.3	2.35

* Variable presented in categories for ease of presentation only, continuous variable used in analysis
# from model adjusting for clustering by cluster and by mother; p-values from Wald tests
[c] questions / variable coding changed between surveys

Table 14d: Distribution of cluster-level factors and their association with facility birth

	Zambia 2002 (n=3367)			Zambia 2007 (n=3692)		
Cluster-level factors	**% per category**	**Facility births (%)**	**Crude OR#**	**% per category**	**Facility births (%)**	**Crude OR#**
Province	n=3367	n=3358	p=0.07	n=3692	n=3682	p=0.001
Central	12.4	21.7	1	9.6	22.4	1
Copperbelt	2.4	35.8	4.17	5.2	39.7	4.95
Eastern	19.3	29.4	2.33	17.7	41.0	4.54
Luapula$	3.2	32.1	3.39	12.7	30.8	1.75
Lusaka	2.2	41.3	6.58	5.5	40.6	4.47
Northern	20.5	19.1	0.46	13.7	23.8	0.87
Northwestern	17.9	38.5	3.98	12.3	35.5	4.00
Southern	11.2	27.2	1.45	11.2	23.4	1.35
Western	10.9	29.0	1.35	12.1	38.7	3.33
Women's media use*	n=3367	n=3358	p<0.001	n=3692	n=3682	p<0.001
Very low	18.0	16.2	1	4.7	11.6	1
Low	41.1	26.9	2.79	18.5	30.8	10.44
Medium	34.0	29.9	6.14	25.7	31.0	10.60
High	7.0	58.1	78.36	51.1	35.9	17.12
Women's exposure to media health programmes*	n=3367	n=3358	p<0.001	n=3692	n=3682	p=0.003
Low	55.6	22.9	1	60.4	29.6	1
Medium	35.6	30.7	2.99	30.0	34.5	1.76
High	8.7	51.5	22.36	9.6	44.9	3.92
Women's financial autonomy*	n=3367	n=3358	p=0.04	n=3692	n=3682	p=0.11
Very low	13.0	18.8	1	4.7	20.9	1
Low	31.9	23.1	1.61	25.6	34.0	2.87
Medium	26.9	33.9	4.43	32.2	30.1	2.06
High	28.3	32.9	4.27	37.5	35.1	3.65
Women's care-seeking autonomy*	n=3367	n=3358	p=0.99	n=3692	n=3682	p=0.02
Low	26.0	26.0	1	7.3	24.4	1
Medium	37.4	27.9	1.01	35.4	27.4	1.62
High	36.7	30.1	1.04	57.3	36.8	3.01
Women's mobility autonomy*	n=3367	n=3358	p=0.50	n=3692	n=3682	p=0.25
Low	21.2	24.6	1	8.8	35.0	1
Medium	56.2	29.4	1.75	42.9	30.1	0.61
High	22.6	28.5	1.20	48.3	34.3	0.95

	Zambia 2002 (n=3367)			Zambia 2007 (n=3692)		
Cluster-level factors	**% per category**	**Facility births (%)**	**Crude OR#**	**% per category**	**Facility births (%)**	**Crude OR#**
Women's relationship autonomy* c	n=3367	n=3358	p<0.001	n=3692	n=3682	p<0.001
Very low	10.7	11.4	1	13.4	20.5	1
Low	34.6	18.6	2.52	34.5	27.0	1.66
Medium	37.5	30.7	11.27	39.7	36.1	3.64
High	17.1	52.3	74.27	12.4	49.8	9.75
Women's violence experience*c	n=3367	n=3358	p=0.09	n=3692	n=3682	p=0.63
High	40.0	26.1	1	29.3	33.7	1
Medium	35.9	24.9	0.80	44.2	32.8	0.85
None/low	24.1	36.5	2.46	26.5	30.8	0.71
Women's fertility attitudes*	n=3367	n=3358	p<0.001	n=3692	n=3682	p=0.003
Traditional	22.6	19.7	1	23.7	24.4	1
Rather traditional	35.6	24.7	1.69	29.9	32.6	1.76
Rather modern	17.0	33.0	4.91	27.7	32.4	1.85
Modern	24.9	37.6	7.85	18.8	43.0	4.18
Husbands' approval of birth control*	n=3367	n=3358	p<0.001		–	
0-40%	13.7	18.3	1			
41-60%	30.7	24.3	1.86			
61-70%	26.4	32.4	5.60			
71-80%	19.8	23.0	2.66			
81-100%	9.4	54.6	35.79			
Men's media use*	n=3346	n=3337	p<0.001	n=3692	n=3682	p=0.02
Low	50.9	27.2	1	6.9	25.5	1
Medium	43.6	25.2	0.93	82.5	31.4	1.47
High	5.5	60.9	31.28	10.6	46.0	4.34
Men's media health programme exposure*	n=3346	n=3337	p=0.10		–	
Low	36.5	30.6	1			
Medium	40.8	24.5	0.53			
High	22.7	30.8	1.58			

	Zambia 2002 (n=3367)			Zambia 2007 (n=3692)		
Cluster-level factors	**% per category**	**Facility births (%)**	**Crude OR#**	**% per category**	**Facility births (%)**	**Crude OR#**
Men's opinion on female autonomy*	n=3346	n=3337	p<0.001	n=3692	n=3682	p=0.06
Unfavourable	21.4	17.3	1	4.4	27.3	1
Intermediate	61.4	29.3	4.91	77.4	30.8	1.62
Favourable	17.2	37.7	13.37	18.2	41.0	3.27
Men's fertility attitudes*[c]	n=3346	n=3337	p=0.003	n=3692	n=3682	p<0.001
Traditional	16.0	23.0	1	30.2	24.0	1
Medium	69.1	26.3	1.92	55.6	33.9	2.41
Modern	14.9	42.6	9.37	14.2	45.3	5.01
Men's skilled attendance support		–		n=3692	n=3682	p=0.25
<75%				15.5	25.8	1
75-95%				36.9	35.1	1.95
>95%				47.7	32.8	1.50

* Variable presented in categories for ease of presentation only, continuous variable used in analysis
# from model adjusting for clustering by cluster and by mother; p-values from Wald tests
[c] questions / variable coding changed between surveys
$ Luapula province: many missing and unidentifiable cluster coordinates in DHS 2001/02

In terms of economic accessibility (Table 14c), there is a strong and clear trend of more facility deliveries among those with higher household wealth. Certain occupation groups of the mother and her husband also make facility delivery more likely, with farmers having the lowest levels of delivery care use.

There are differences in facility use between provinces, Northern Province being both in 2002 and 2007 the province with the lowest level of facility deliveries among its rural population (Table 14d). Many of the variables that were associated with facility use on the individual level, show an even stronger association on the cluster level. Clusters with higher average women's media use, women's relationship autonomy and modern fertility attitudes among men and women have higher levels of health facility deliveries. Men's support of skilled attendance, a specific variable added in 2007, did not show much of an association, but levels of reported support were very high overall. (Table 14d)

3.3.5 Multivariable analysis of distance and level of care

Nearly all variables considered as potential confounders show some association with facility delivery, judging from Tables 14a-d and from looking at associations using the continuous form of the variable where one exists. Notable exceptions are wantedness of the pregnancy, previous neonatal death and, surprisingly, twin/triplet pregnancy. Virtually all variables except twin pregnancy and season show some association with distance. Therefore, all variables were checked for whether they confound the association of distance and health facility delivery.

Tables 15 and 16 (for 2002 and 2007 respectively) present the variables that change the logOR of the crude distance effects by more than 10% for at least one of the four distances, when examining one confounder at a time. (For example, a 10% change from a logOR of -0.650 means that the adjusted logOR is either < -0.715 or > -0.585.) The adjusted logORs where the change was less than 10% are shown in grey italics. Variables that did not change any logOR of any of the variables by at least 10% in one of the datasets are not shown.

Table 15: Controlling the distance effects for confounding (DHS 2002)

Log-distance effect adjusted for	Delivery care logOR	BEmOC-4 logOR	BEmOC-1 logOR	CEmOC-1 logOR
– (crude)	-0.886	-1.110	-0.873	-0.704
Education (linear over years of schooling)	-0.751	-0.982	-0.724	-0.571
Household wealth (linear)	-0.768	*-1.024*	-0.740	*-0.652*
Husband's education (categorical)	-0.759	-0.979	-0.754	-0.605
Literacy	-0.785	*-1.008*	-0.756	-0.608
Media use	*-0.812*	*-1.060*	-0.785	-0.630
Exposure to media health programmes	*-0.815*	*-1.063*	-0.781	*-0.650*
Violence autonomy	*-0.885*	*-1.118*	*-0.857*	-0.594
Ethnic group	*-0.969*	*-1.162*	*-0.951*	-0.792
Women's media use	-0.493	-0.857	-0.446	-0.344
Women's exposure to media health programmes	-0.527	-0.866	-0.517	-0.441
Women's fertility attitudes	-0.619	-0.812	-0.554	-0.556
Women's relationship autonomy	-0.634	-0.925	-0.692	-0.524
Cluster husbands' approval of birth control	-0.679	-0.914	-0.648	-0.564
Men's fertility attitudes	-0.757	*-1.037*	-0.662	-0.588
Men's opinion on female autonomy	-0.796	-0.966	-0.745	*-0.648*
Men's media use	-0.780	*-1.047*	-0.763	*-0.648*
Province	*-0.808*	-1.223	*-0.793*	-0.527

Table 16: Controlling the distance effects for confounding (DHS 2007)

Log-distance effect adjusted for	Delivery care logOR	BEmOC-4 logOR	BEmOC-1 logOR	CEmOC-1 logOR
– (crude)	-0.657	-0.567	-0.650	-0.596
Education (linear over years of schooling)	*-0.626*	-0.510	-0.581	-0.536
Household wealth (linear)	-0.570	-0.476	-0.546	-0.516
Ethnic group	*-0.700*	-0.642	*-0.687*	-0.661
Men's fertility attitudes	-0.490	-0.384	-0.457	-0.446
Women's exposure to media health programmes	-0.515	-0.416	-0.488	-0.430
Women's media use	-0.546	-0.408	-0.504	-0.451
Women's fertility attitudes	-0.547	-0.442	-0.529	-0.486
Women's relationship autonomy	*-0.598*	-0.433	-0.550	-0.472

Household wealth strongly confounds the effect on facility delivery of all four distance variables in 2007 and somewhat less consistently so in 2002. Mother's education is also a confounder for most distance effects as is literacy in the 2002 data. Ethnic group seems to be a negative confounder of some of the distance effects, in particular in the 2007 dataset. (Tables 15 and 16)

In terms of cluster-level confounders, women's average media use and exposure to media health programmes, women's fertility attitudes and relationship autonomy are important confounders for all distance effects. Men's fertility attitudes are also a strong confounder as is average approval of birth control by husbands (a variable only present in the 2002 dataset). (Tables 15 and 16)

Tables 17 and 18 present the final models for distance effects adjusted for several confounders at a time, presenting models with and without cluster-level confounders. Most variables that showed a confounding effect when added individually to the model, did not exhibit any appreciable confounding effect once other important confounders were already in the model. The final models include household wealth, mother's education, ethnic group, women's media use, women's relationship autonomy and men's fertility attitudes.

Table 17: Crude and adjusted effects of distance on health facility delivery (DHS 2002)

Log-distance effect adjusted for	Delivery care OR (95%CI), p-value	BEmOC-4 OR (95%CI), p-value	BEmOC-1 OR (95%CI), p-value	CEmOC-1 OR (95%CI), p-value
– (crude)	0.41 (0.25-0.67) p<0.001	0.33 (0.21-0.52) p<0.001	0.42 (0.26-0.67) p<0.001	0.49 (0.31-0.78) p=0.002
Individual and household factors:				
Mother's education + household wealth + ethnic group	0.46 (0.31-0.70) p<0.001	0.36 (0.25-0.53) p<0.001	0.49 (0.33-0.74) p=0.001	0.53 (0.36-0.79) p=0.002
Adding cluster-level confounders:				
+ men's fertility attitudes + women's media use + women's relationship autonomy	0.61 (0.41-0.91) p=0.02	0.43 (0.30-0.61) p<0.001	0.64 (0.43-0.94) p=0.02	0.66 (0.46-0.96) p=0.03

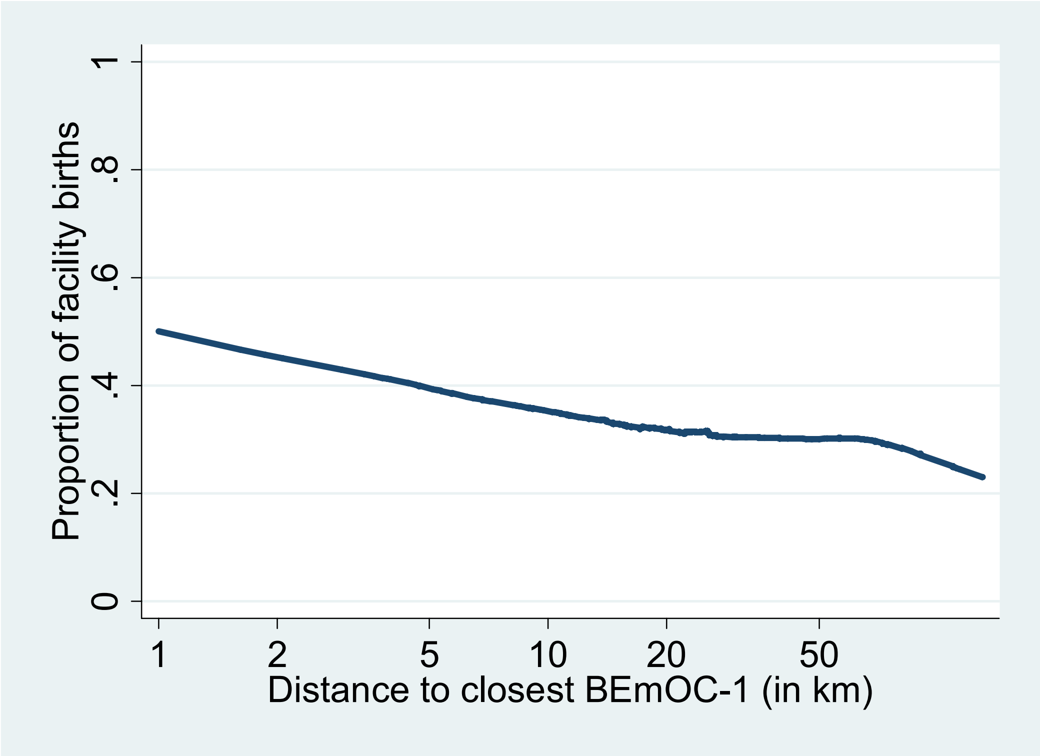
Table 18: Crude and adjusted effects of distance on health facility delivery (DHS 2007)

Log-distance effect adjusted for	Delivery care OR (95%CI), p-value	BEmOC-4 OR (95%CI), p-value	BEmOC-1 OR (95%CI), p-value	CEmOC-1 OR (95%CI), p-value
– (crude)	0.52 (0.38-0.71), p<0.001	0.57 (0.44-0.74), p<0.001	0.52 (0.40-0.68), p<0.001	0.55 (0.42-0.72), p<0.001
Individual and household factors:				
Mother's education + household wealth + ethnic group	0.54 (0.41-0.72), p<0.001	0.59 (0.46-0.76), p<0.001	0.58 (0.45-0.74), p<0.001	0.57 (0.45-0.73), p<0.001
Adding cluster-level confounders:				
+ men's fertility attitudes + women's media use + women's relationship autonomy	0.62 (0.48-0.81), p=0.001	0.73 (0.57-0.93), p=0.012	0.70 (0.54-0.89), p=0.004	0.68 (0.54-0.88), p=0.002

The results show strong effects of distance on health facility use for delivery for all four levels of care examined. For each additional unit increase in log-distance, the odds of delivering in a facility setting decrease by around 30-40% in most models, adjusting for all confounders. The magnitude of effects is similar in the two datasets, except for distance to BEmOC-4 which has a stronger effect in the 2002 dataset than in the 2007 dataset. Confidence intervals are wider in the 2002 dataset and significance levels lower for the same effect size.

I have shown before that the effect of distance on health facility use is approximately linear when log-transforming the distance. Since we are really interested in the effect of distance once adjusted for all confounders, the Lowess plots were repeated adjusting for these (mlowess command). As an example, Figure 62 shows the effect of the log-transformed distance to BEmOC-1, adjusted for all confounders in the 2007 dataset. While the graph is flatter than that in Figure 61, it is still approximately linear.

Figure 62: Facility delivery by distance to closest BEmOC-1 facility, adjusted for confounders (DHS 2007)



The analyses of distance variables so far do not take into account what other facilities are in the surroundings as they just focus on one level of care. Two villages may be at the same distance from delivery care, but for one this is a substandard facility, while for the other this is a BEmOC facility – or a BEmOC facility is just a few kilometers further away.

Therefore, an indicator variable was introduced to be used together in the model with distance to any delivery care (Tables 19 and 20), in order to take account of both distance to the closest delivery care facility and what level of care is available at that distance.
The indicator has four levels: whether the facility at that distance - or a facility within 10km of that distance - offers:

1) only substandard delivery care,
2) BEmOC-4 or BEmOC-2,
3) BEmOC-1 or BEmOC or
4) CEmOC-1 or CEmOC.

Table 19: Distance and level of care effects on health facility use for delivery (DHS 2002), adjusted for confounders (n=3324)

Models and variables of interest	OR	95%CI	p-value
Model 1a			
Log-distance to closest delivery care (linear effect)	0.58	0.39-0.84	0.005
Closest facility is substandard level of care	1 (baseline)	-	-
Closest facility (or within 10km) is BEmOC-4/-2	4.16	1.59-10.92	0.004
Closest facility (or within 10km) is BEmOC(-1)	4.24	1.45-12.42	0.008
Closest facility (or within 10km) is CEmOC(-1)	7.79	2.47-24.58	<0.001
Model 1b			
Log-distance to closest delivery care (linear effect)	0.57	0.39-0.84	0.005
Level of care of closest facility (linear effect over categories)	1.68	1.19-2.37	0.003
Evidence against linear effect over categories: LRT (Model 1b vs Model 1a) p-value 0.12			
Model 1c			
Log-distance to closest delivery care (linear effect)	0.58	0.40-0.86	0.006
Closest facility is substandard level of care	1 (baseline)	-	-
Closest facility (or within 10km) is BEmOC-4 or better	4.75	1.88-12.01	0.001
Evidence against binary effect: LRT (Model 1c vs Model 1a) p-value 0.35			

Table 20: Distance and level of care effects on health facility use for delivery (DHS 2007), adjusted for confounders (n=3682)

Models and variables of interest	OR	95%CI	p-value
Model 2a			
Log-distance to closest delivery care (linear effect)	0.63	0.49-0.82	0.001
Closest facility is substandard level of care	1 (baseline)	-	-
Closest facility (or within 10km) is BEmOC-4/-2	1.09	0.61-1.94	0.78
Closest facility (or within 10km) is BEmOC(-1)	1.45	0.72-2.92	0.30
Closest facility (or within 10km) is CEmOC(-1)	2.44	1.21-4.91	0.01
Model 2b			
Log-distance to closest delivery care (linear effect)	0.62	0.48-0.81	<0.001
Level of care of closest facility (linear effect over categories)	1.36	1.09-1.70	0.007
Evidence against linear effect over categories: LRT p-value 0.62			
Model 2c			
Log-distance to closest delivery care (linear effect)	0.62	0.47-0.80	<0.001
Closest facility is substandard level of care	1 (baseline)	-	-
Closest facility (or within 10km) is BEmOC-4 or better	1.37	0.79-2.40	0.26
Evidence against binary effect: LRT (Model 1c vs Model 1a) p-value 0.03			

Independent of the effect of distance to the closest delivery care, there is an effect of the level of care offered (Tables 19 and 20). In the 2002 dataset, this effect is very strong already for a minimum of services available, with the odds of facility delivery being more than fourfold if the nearest facility is BEmOC-4 / BEmOC-2 as opposed to substandard care, adjusting for distance and all confounders (Model 1a). In the 2007 dataset, this effect is weaker and fairly linear over categories: for each step improvement in the level of care that the closest facility offers, the odds of facility delivery increase by 36%, controlling for distance and all confounders (Model 2b). The confounders were the same as described for the distance effects, no additional variables confounded the level of care relationship. Results from interaction tests are shown in the following section (3.3.6).

Table 21 shows the independent effects of distance to delivery care and level of care offered according to Model 2b for 2007, calculating ORs for different combinations of distance and level of care. (Log-distance of 1 corresponds to e^1=2.72 km, log-distance of 2 corresponds to e^2=7.39 km and log-distance of 3 corresponds to e^3=20.09 km.)

Table 21: Odds Ratios of distance to care and level of care (from Model 2b)

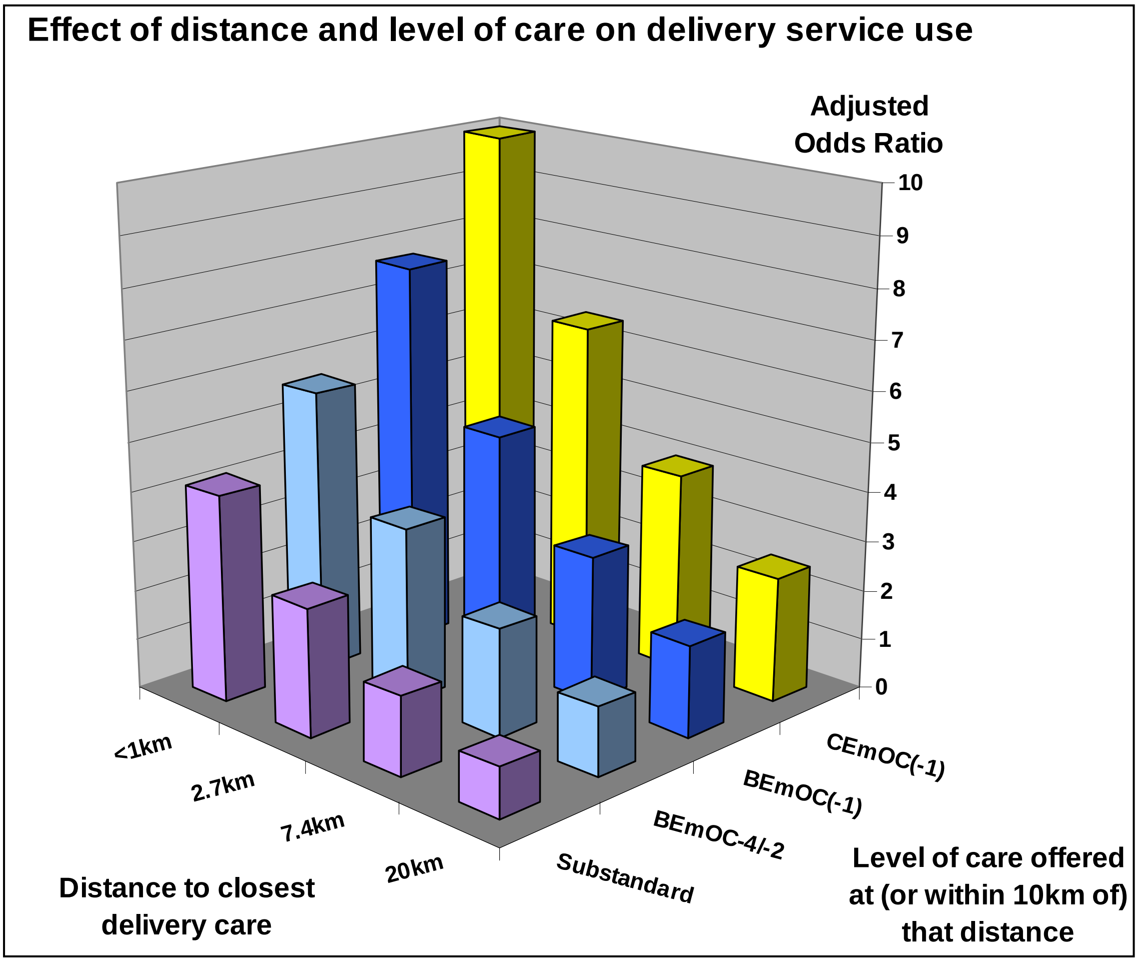
	Distance <1 km	**Distance 2.7 km**	**Distance 7.4 km**	**Distance 20 km**
Level of care CEmOC(-1)	1×1.36^3 = 1 x 2.52 = **2.52**	0.62×1.36^3 = 0.62 x 2.52 = **1.56**	$0.62^2 \times 1.36^3$ = 0.38 x 2.52 = **0.96**	$0.62^3 \times 1.36^3$ = 0.24 x 2.52 = **0.60**
Level of care BEmOC(-1)	1×1.36^2 = 1 x 1.85 = **1.85**	0.62×1.36^2 = 0.62 x 1.85 = **1.15**	$0.62^2 \times 1.36^2$ = 0.38 x 1.85 = **0.70**	$0.62^3 \times 1.36^2$ = 0.24 x 1.85 = **0.44**
Level of care BEmOC-2/-4	1 x 1.36 = **1.36**	0.62 x 1.36 = **0.84**	$0.62^2 \times 1.36$ = 0.38 x 1.36 = **0.52**	$0.62^3 \times 1.36$ = 0.24 x 1.36 = **0.33**
Level of care Substandard	1 x 1 =**1**	0.62 x 1 = **0.62**	$0.62^2 \times 1$ = 0.38 x 1 = **0.38**	$0.62^3 \times 1$ = 0.24 x1 = **0.24**

Choosing the group with the lowest facility deliveries as our baseline (those at 20 km from a substandard facility) instead of the category with a substandard facility at 1km (as done in the model), ensures that all other ORs are above one (Table 22 and Fig. 63).

Table 22: Odds Ratios for distance to care and level of care

Level of care	Distance to closest delivery care			
	<1 km	**2.7 km**	**7.4 km**	**20 km**
CEmOC(-1)	10.5	6.5	4.0	2.5
BEmOC(-1)	7.71	4.79	2.92	1.83
BEmOC-2/-4	5.67	3.5	2.17	1.38
Substandard	4.17	2.58	1.58	1

Figure 63



3.3.6 Effect modification of distance

There is no evidence that season of birth, mother's education, household transportation means and household wealth modify the effect of distance. Neither is there any evidence that mother's fertility attitudes and relationship autonomy interact with distance.

While the interaction term is significantly different from zero in some of the models, this is not consistent across the four distances and two surveys for any of the variables. For example, there is a suggestion that distance has a bigger effect among the poor in the 2002 survey, while in the 2007 survey there was no interaction at all for distance to any delivery care and distance to BEmOC-4 and a suggestion that the distance effect is weaker among the poor for distance to BEmOC-1 and CEmOC-1. P-values are below 0.05 for distance to BEmOC-1 in both surveys, but effects go in opposite directions.

There is also no evidence for interaction between the effect of distance to delivery care and level of that care (indicator variable described in section 3.3.5). The p-values for an interaction term between distance to the closest delivery care and the binary indicator variable for level of care is 0.24 in the 2002 sample and 0.35 in the 2007 sample.

3.3.7 Intra-cluster correlations

Births to the same mother are highly correlated in terms of their place of delivery with intra-cluster correlation coefficients (ICC) of 0.75 in 2002 and 0.65 in 2007 (Table 23), and a certain amount of this variation is explained by the explanatory variables added to the model (ICC drops to 0.60).

Births in the same DHS cluster are also more similar to each other in terms of delivery place than to births from other clusters, much more so in 2002 (ICC 0.45) than in 2007 (ICC 0.27). It is unclear why that is the case. A substantial amount of the variation between clusters can be explained by the variables entered into the model (Table 23).

Table 23: Intra-cluster correlation coefficients

	Mother ICC	Cluster ICC
DHS 2002 model without covariates	0.75	0.45
DHS 2002 model with covariates	0.60	0.30
DHS 2007 model without covariates	0.65	0.27
DHS 2007 model with covariates	0.60	0.15

When comparing ICC in clusters that are at short, medium and long distance from delivery care (all three groups comprising similar numbers of clusters and births) using a two-level model, there is a clear indication in the 2002 dataset that cluster membership plays a lesser role among births to mothers living further away. However, this is not the case in the 2007 dataset (Table 24).

Table 24: Cluster ICC, by distance from delivery care

Cluster ICC	**Distance from closest delivery care**		
	<5km	**5-10km**	**>10km**
DHS 2002 model without covariates	0.53	0.43	0.31
DHS 2002 model with covariates	0.32	0.29	0.15
DHS 2007 model without covariates	0.24	0.19	0.30
DHS 2007 model with covariates	0.14	0.07	0.26

3.3.8 Population attributable fractions

Table 25 presents population attributable fractions (PAF) for distance to BEmOC-1, as well as for three other determinants of delivery service use (education, wealth and women's autonomy). The PAFs reflect the absolute importance of these risk factors in rural Zambia (or rather in my non-representative sample), by taking into account both how common the risk factor is (prevalence) and its relative importance (confounder-adjusted odds ratio), both of which are included in Table 23.

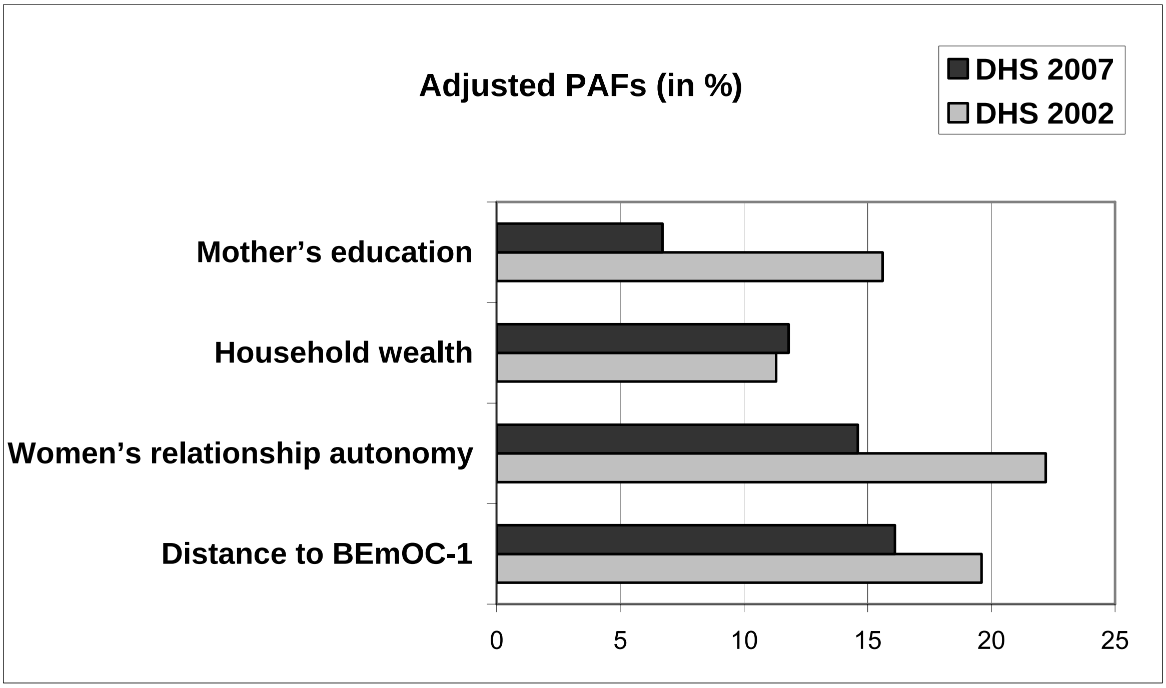
Table 25: PAFs from multivariable logit model

	Zambia DHS 2002 (n=3317)			Zambia DHS 2007 (n=3594)		
Variables	**% per category**	**aOR***	**PAF in % (95%CI)**	**% per category**	**aOR***	**PAF in % (95%CI)**
Distance to BEmOC-1		p=0.04			p<0.001	
< 5km	4.5	1	–	7.4	1	–
5-15km	21.1	1.80	3.2 (-1.3-7.5)	21.3	1.50	2.7 (-0.1-5.3)
> 15km	74.4	2.50	16.4 (0.0-30.0)	71.3	1.90	13.4 (5.7-20.4)
Education		p<0.001			p=0.001	
Any secondary school	11.7	1	–	12.9	1	–
Complete primary school	16.6	1.65	2.2 (0.6-3.8)	19.0	1.09	0.5 (-1.1-2.0)
Incomplete primary school	51.9	1.97	8.7 (4.0-13.3)	50.2	1.26	3.3 (-0.6-7.1)
No schooling	19.7	3.09	4.7 (2.7-6.6)	17.9	1.89	2.9 (1.3-4.4)
Household asset score		p=0.008			p=0.008	
40-88	5.3	1	–	6.1	1	–
30-39	9.7	1.08	0.2 (-1.1-1.5)	9.1	1.03	0.1 (-1.2-1.4)
20-29	23.9	1.46	2.4 (-0.8-5.4)	25.1	1.43	2.7 (-0.4-5.8)
10-19	38.6	1.77	5.2 (0.3-9.8)	37.8	1.63	5.4 (0.9-9.6)
0-9	22.5	2.06	3.5 (0.7-6.3)	22.0	1.80	3.6 (0.9-6.2)
Women's relationship autonomy		p<0.001			p=0.001	
High	17.3	1	–	12.1	1	–
Medium	37.3	2.07	7.4 (0.2-14.2)	39.8	1.50	5.0 (-0.3-10.1)
Low	34.8	3.78	11.2 (4.5-17.4)	34.6	1.84	6.1 (1.6-10.4)
Very low	10.7	5.17	3.6 (1.4-5.7)	13.5	2.74	3.5 (1.6-5.3)

*aOR: adjusted Odds Ratio. Adjusted for all other variables that are independent determinants of delivery service use in at least one of the two datasets: mother's age at birth, ethnic group, fertility attitudes, family composition, exposure to media health programmes, birth order, previous stillbirth, previous C-section, previous newborn death, twin pregnancy, mother's occupation, husband's occupation, whether getting money is a big problem for care-seeking, men's average fertility attitudes in the cluster and women's average care seeking autonomy in the cluster.

Under the assumption that the associations are causal, the PAFs estimate what proportion of home births could be avoided if women were in the lowest risk groups (within 5km of BEmOC-1, secondary education, least poor, highest female relationship autonomy in the cluster). In the 2002 DHS sample, 19.6% of all home deliveries could be avoided if all births were to women living within 5 km of BEmOC-1, and in the 2007 sample 16.1%. This is a comparable order of magnitude as the PAFs for wealth, education and female autonomy. (Figure 64)

Figure 64



CHAPTER 4

DISCUSSION

The discussion consists of four parts and the conclusions. In the first part I summarise the literature review findings, discuss the methodological challenges of the review and draw conclusions from it. The next three parts relate to the three results chapters: EmOC functioning of facilities, population coverage and the influence of distance to facilities on their use for delivery care. In each part I start with a brief summary of the findings, then discuss how methodological strengths and limitations may have influenced the results, and finally interpret the findings in the light of previous knowledge. In the conclusion I draw all the parts together and discuss implications for future research, service provision and policy.

4.1 Determinants of skilled attendance in the literature

4.1.1 Summary of findings

Findings in previous studies of determinants of skilled attendance can be summarised in three groups: 1) Determinants that have been studied frequently and are consistently associated with skilled attendance in one direction, 2) determinants that are also consistently associated in one direction, but adjustment for which may be inappropriate, and 3) determinants that have not been studied well.

The four factors most consistently associated with receiving skilled care in multivariable analysis are maternal education, higher household economic resources, low parity and higher maternal age. These sociocultural and economic factors are studied frequently, perhaps because they are relatively easily measured and are included in large surveys such as the DHS, Pan Arab Project for Family Health (PapFam), CDC Reproductive Health Surveys and UNICEF's Multiple Indicators Cluster Surveys (MICS).

Facility use for the previous delivery and ANC use are also nearly always highly predictive of health facility use for the index delivery, however, this may be because they are confounded by service availability and other unmeasured factors which influence prior service use. Similarly, the strong differentials in skilled attendance usually observed between rural and urban areas and between different regions are probably in large part due to differences in infrastructure, health care quality, social, economic and cultural factors that are not accounted for. Adjusting for these variables may therefore not be appropriate.

Four factors have been identified that have not been studied well: complications, women's autonomy, quality of health services and distance to services.

Complications are an indicator of need for services and as such are associated with high levels of use of facility care and skilled attendants. This applies to current complications, but complications in previous pregnancies may also influence care-seeking in the index pregnancy. Despite the obvious importance of obstetric complications in stimulating care-seeking, their role is rarely investigated, probably "in part because population-based surveys such as the DHS typically do not collect sufficiently detailed information to permit such an investigation” [80]. Survey data on reported complications are usually regarded as invalid in terms of capturing prevalence of medically-diagnosed complications [83]. However, even women’s perceived need could be taken into account in order to differentiate between women using delivery services for preventive reasons and those seeking emergency care, as influential factors are likely to differ and so will the necessary interventions to improve care-seeking.

Women’s autonomy and status were also found to play a role in influencing use of delivery care, but investigating them is hampered by difficulties in measuring the various aspects of autonomy and by the context-specificity and likely effect modification by other factors. The impact of marital status is also dependent on the context, and findings show associations in either direction.

Quality of health services is identified as an important determinant of care-seeking by numerous qualitative studies; however it has rarely been included in quantitative analyses. This is due in part to a lack of variation in health care quality in small-scale studies covering few facilities and to a lack of such supply-side information in large household surveys like the DHS. Gathering quality of care data from household respondents can lead to "courtesy bias" and bias due to unequal knowledge on quality between women who have given birth in a facility and women who have not. Women cannot be expected to report on the technical quality of care. Therefore, a recent study concluded: “It is recommended that the design of future surveys enables facility-level data on the quality of care to be linked to individual-level data on care-seeking behaviour.” [107]

Similarly, a lack of good geographical data linked to household data hampers the investigation of the role of distance and potential interactions of distance with other factors despite wide acknowledgement of the importance to take service availability into account. Where distance data are gathered, mostly through community questionnaires, they are often restricted to the respondents' immediate surroundings and to the nearest facility of any kind – which is not necessarily one that offers delivery services. Nevertheless, the vast majority of studies investigating the role of distance find it to be a strong deterrent of delivery service use (Table 2). Limitations of previous distance studies will be discussed in more detail in section 4.3.3.2 in the context of this study.

4.1.2 Methodological limitations

The breadth of topic, its context-specificity, the lack of comprehensive index terms and the vast differences in methodology employed renders the option of doing a systematic review of this literature in its entirety extremely difficult, if not impossible. Systematic reviews of observational data are useful when trying to estimate an effect of interest that can be assumed to be independent of context (which is true for most biological effects) or when trying to explore heterogeneity that is thought to be due to a limited range of factors. It is only feasible when looking at a narrow range of clearly defined exposures. My aim instead was to explore the range of what has been done in the field so far and give an overview of findings, rather than estimating any specific effect or even attempt a meta-analysis. While I could have restricted the review to a limited number of exposures, years or countries, this went contrary to my desire to work out the scope of what has been explored in the literature.

While some common findings in this literature could be summarised, I did not synthesise the results from the reviewed studies into general conclusions about the relative or absolute importance of the various determinants of skilled attendance use or even attempt a formal meta-analysis. There are three reasons for this. Firstly, researchers use different study types, sampling techniques and inclusion / exclusion criteria. Skilled attendance is operationalised in different ways and exposure variables are classified differently, which makes the magnitude of effects hard to compare. Secondly, the selection of exposure variables included in the models varies widely and studies use different analysis techniques. Some studies fail to control for important confounders or to adjust for clustering, while others inappropriately include variables on the causal pathway, all of which makes results very hard to compare. It is doubtful whether a systematically applied subjective judgement about the general quality of the studies reviewed would be helpful in making a comparison more informative [165].

The third reason is more fundamental and relates to context-specificity. Even if all methods were identical, it would be naïve to expect the effect of, say, distance in Malawi and Peru to be the same, given that infrastructure, transport options, education level, norms around place of delivery and many other factors differ. In fact, the highly complicated web of relationships and interactions between factors, many of which are hard to measure (e.g. informal payments, staff motivation and community cooperation) makes even exploration of heterogeneity difficult. In particular, the existence of complications may modify the effect of many other determinants but is rarely known. In different settings, the proportion of preventive versus emergency care seeking will vary and thus the importance of the various determinants.

In order to take context into account when synthesising results, one would need to identify the most important context factors. These could include the average level of care offered in the health facilities accessed (from mostly in dysfunctional health posts at one extreme to mostly in hospitals offering comprehensive emergency obstetric care at the other), the level of development in the area (influencing infrastructure, in particular transport options) and the presence of a disadvantaged culturally distinct group (e.g. indigenous population in Latin America). This would however be extremely difficult to achieve since most of this information is not readily available from the studies.

4.2 Emergency Obstetric Care functioning

4.2.1 Summary of findings

Of the over 1400 health facilities captured in the Zambian Health Facility Census, 1131 provide delivery care, but only a small proportion of these actually function on a level that is able to save lives in an obstetric emergency (Fig. 21).

While nearly all of the 90 hospitals that offer delivery services provide the basic signal functions, 20% do not offer C-sections and 13% lack blood transfusion services (Fig. 10). 52 hospitals have less than 3 doctors registered and 32 only employ one doctor (Fig. 11), which makes it difficult to provide 24 hour emergency surgery. Only 30 of the 90 hospitals fulfill the combination of criteria used for full CEmOC and 37 even fail to fulfill the less stringent CEmOC-1 criteria (Fig. 12 and 13).

The situation of the 1040 health centres and health posts offering delivery care is even more alarming. Most claim to provide injectable antibiotics (74%) and to perform manual removal of placenta (71%), but few seem to provide injectable anticonvulsants (44%) or perform assisted vaginal delivery (42%) (Fig. 14). Only 11% state that they provide all BEmOC signal functions (and 18% when excluding assisted vaginal delivery). Half of all health centres and posts offering delivery care have only one or no health professional registered and hence are unlikely to provide 24 hour care, and less than a third of health centres employ at least three (Fig. 15).

Only 57 (6%) of the 1040 health centres and posts with delivery services fulfill BEmOC(-1) criteria, and 461 (44%) fail even the BEmOC-4 criteria and thus are classified as substandard. The remaining 522 (50%) health centres and posts with delivery services offer very limited emergency obstetric care functions.

Given that most health centres cannot deal even with complications that theoretically could be handled at that level, referral links are all the more crucial. A vehicle for referral is provided only by half of health centres, however, and most do not own one, so it is unclear how well the referral is really working. Only slightly more than half of all health centres have a functioning telephone or radio communication, casting doubt on whether help can be arranged in case of emergencies that cannot be dealt with on site (Fig. 15).

4.2.2 Strengths and limitations

The biggest strength of the Health Facility Census is that it is a census, i.e. that it attempted to capture *all* Zambian health facilities. This does not matter so much for the descriptive results on the national level described above – a representative survey with a focus on delivery care may even be more suited for that purpose – but it allows calculation of national and subnational population coverage and linkage to a population survey like the DHS. Very few low-income countries have such detailed data including geographic location on all their health facilities.

A limitation is that private for-profit facilities were not included in the HFC, but given that the vast majority of the population, particularly in rural areas, cannot afford to use these, this is not a serious limitation as the focus of this study is on rural areas. Private facilities are planned to be captured separately, and it will be interesting to compare their services and staffing levels to the public and mission facilities then.

The HFC was not specifically geared at determining facilities' EmOC functioning and it was probably out of its scope and impractical to actually check whether each signal function had been provided in the previous 3 months, as recommended in the UN guidelines [26, 33]. Therefore, I used additional criteria besides the questions on signal functions to determine the likely EmOC functioning. This was limited by the information available in the census. There was no information on number of births per facility and the equipment data was unfortunately not usable. Also, there were no details on whether a health professional provides delivery care and on their EmOC skills. Therefore, giving the benefit of the doubt, all health professionals that could have such skills were considered in the minimum numbers, i.e. doctors, nurses/ midwives and clinical officers. The question on 24 hour service specifically asked about doctors or midwives present or on call, so this criterion helped to correct the above overly optimistic assumption to some degree. It was used for all EmOC categories except for the least strict

BEmOC-4, where “any health professional with midwifery skills” was counted as well. It is not clear who these other health professionals are, possibly assistant midwives who possess a limited set of skills.

The dataset contains various inconsistencies, some of which could be corrected, but there may still be other mistakes in the data which may have lead to misclassification of facilities’ EmOC status. For instance, 9 facilities, including 5 hospitals, had no doctors or medical licentiates registered or present, but answered affirmatively on whether they provide C-sections. Similarly, three hospitals reported presence of the signal function "assisted vaginal delivery" but neither forceps nor vacuum delivery were reported available. This emphasises the point made in the UN guidelines (see 1.2.2.1) that simple yes/no questions often only find out what the facility is supposed to do rather than what it really is doing, and thus highlights the importance to check actual provision or at least, as done here, use a set of criteria to judge EmOC status. A comparison to the hospitals sampled during the UNICEF assessment [21] revealed a substantial number of discrepancies in the provision of signal functions, mostly with the HFC claiming availability where UNICEF did not find them functioning, but also vice versa.

4.2.3 Interpretation

The EmOC classification is based on limited data and makes several assumptions, so it is probable that many facilities have not been classified correctly. The criteria could certainly be improved with local knowledge and refined with additional data that may be available meantime in the Health Management Information System (HMIS) that builds on the HFC.

Nevertheless, the results clearly point to a serious lack in the provision of EmOC in Zambia, and provide some information on where the problems lie. Probably the real situation is even grimmer, given that most assumptions were optimistic. For instance, the UNICEF-funded national EmOC survey in the same year did not classify a single health centre out of 175 as BEmOC, finding that none provided all six basic signal functions [21]. The EmOC survey in Central Province in 2006/07 also did not find a single facility that provided all six signal functions out of 29 health centres offering delivery services [38]. The manual functions were particularly found to be absent in the UNICEF survey, which contrasts with the result of the HFC that most health centres claim to provide manual removal of placenta. The survey in Central Province, in line with the HFC, found that confidence among providers in performing manual removal of placenta was high, while assisted vaginal delivery was the least provided signal function [38].

However, it could be also argued that perhaps some signal functions are not appropriate for the level of a health centre and certain complications should rather be referred. There has been some debate on assisted vaginal delivery in this context, which is not being promoted in a number of countries. It would be useful if future research could clarify which signal functions are appropriate to be performed under which circumstances.

Furthermore, given the low case load in many rural health centres, the criterion of a signal function only considered present if performed at least once in the previous three months has been challenged and alternative criteria have been suggested and used, as well as other than binary classifications of BEmOC status [31, 38]. The approach used in this study is in line with these more pragmatic approaches.

The UNICEF EmOC assessment and the EmOC survey in Central Province also examined aspects of quality of care, which was found to be substandard in most facilities with qualified staff and essential drugs being in short supply [21, 38]. Other studies in Zambia have described a similarly disturbing picture, for instance Stekelenburg and colleagues in Kalabo district in Western Province where more than half of hospital deliveries were not supervised by a doctor or midwife [91]. This implies that even where services are available, they may not be of the quality needed to ensure women's safety or save their lives, for instance when a woman with eclamptic seizures cannot be treated because magnesium sulfate is lacking or the nurse is not confident in its use.

The HFC clearly shows that a lack of sufficient numbers of qualified health professionals is a major reason why facilities do not meet the EmOC criteria, both at the level of health centres and at the level of hospitals. Frequently, a single health professional is meant to provide all services including 24 hour EmOC, or none is available at all. The UNICEF assessment confirmed these findings and specified that midwives in particular are in short supply and that many health professionals found on site lack EmOC skills, including doctors [21].

Furthermore, a large proportion (78%) even of health centres with at least two health professionals still do not offer all five BEmOC-1 signal functions. The reasons may include qualification of staff and availability of drugs and equipment. While the HFC had no information on drug availability, the fact that many fewer facilities provide injectable anticonvulsants as compared to injectable antibiotics suggests that magnesium sulfate is in short supply or staff are not trained to use it. The lack of necessary drugs and equipment were also highlighted in the UNICEF report and the study in Central Province [21, 38].

In summary, it seems that the vast majority of health centres cannot deal with the most common obstetric complications and that tools for making referral links are rarely available. It may be reasonable to assume that even when women reach a hospital, it is far from certain that their lives can be saved there. It is not surprising that maternal mortality is estimated at 591 per 100,000 live births at national level in Zambia in these circumstances despite of 47% of deliveries occurring in health facilities with a ‘skilled attendant’ [6]. In remote areas, maternal mortality is likely to be substantially higher, as suggested by a hospital-based study in two districts in Northern Province [166].

Without a reliable system to monitor health facility functioning, it is difficult to imagine how safe motherhood programs can make decisions and action plans to improve the situation.

4.3 Emergency Obstetric Care coverage

4.3.1 Summary of findings

All three approaches to evaluate EmOC coverage – number of facilities, number of health professionals and geographical access – reveal deficits, but to different degrees and at different disaggregation levels.

All nine Zambian provinces meet the benchmark of 1 CEmOC facility per 20,000 births (Fig. 22), but nearly half of the 72 districts have no CEmOC services (Fig. 25), i.e. no functioning district hospital. All provinces except Eastern Province meet the benchmark of 5 EmOC (= at least BEmOC-1) facilities per 20,000 births (Fig. 22), while a third of the 72 districts fail that benchmark (Fig. 26). In Luapula, Eastern and Northern Provinces, more than half of districts fail at least one benchmark (Fig. 27).

There are around 10 nurses/midwives/clinical officers and 1 doctor per 10,000 population in Zambia, or 90 nurses/midwives/clinical officers and 9 doctors per 3,600 births. Copperbelt and Lusaka provinces have many doctors, but four other provinces and half of all districts employ fewer than 3 doctors per 3,600 births. 13 districts have no doctors at all (Fig. 28 and 31). All provinces, and nearly all districts, employ more than 20 nurses/midwives/clinical officers per 3,600 births (Fig. 29 and 32). However, assuming that only a third or a quarter of these work in delivery care, several provinces and three quarters of districts fall short of the World Health Report 2005 guideline of 20 midwives and 3 doctors for 3600 births.

86% of the Zambian population live within 15km of a facility offering delivery care and nearly half live within 15km of a facility offering EmOC. While populations in urban areas have very good access to EmOC (over 90% within 15km), nearly two thirds of the Zambian population live in rural wards. 80% of the rural population live within 15km of delivery care, but only 22% within 15km of EmOC (Fig. 35).

Disaggregating geographical access subnationally shows big differences between individual provinces and districts (Fig. 36 and 39). No district has less than 40% of its population within 15 km of delivery care, with most covering between 60% and 100%. Coverage in mainly urban districts is generally good, with nearly all over 90% (Fig. 42). While more than half of the mainly rural districts meet the UN indicator benchmark of at least 5 EmOC facilities per 500,000 population or 20,000 births, none achieve a high population coverage with EmOC, mostly ranging between 10% and 50% of the population living within 15 km of an EmOC facility (Fig. 46).

4.3.2 Strengths and limitations

I have both facility and population census data for a whole country and at subnational levels, a privilege few studies have had so far. This allowed me to check "on the distribution of E[m]OC services throughout the country", "in areas smaller than the country as a whole – the smaller the better" as suggested in the UN guidelines [26]. Given the uneven geographical distribution of health services, only this type of approach will reveal how many people and where in the country actually have access to EmOC.

When looking at facility density, "the smaller the better" is only sensible down to a certain level, however. On the one hand, there remain inequalities in distribution inside provinces and districts which make aggregates misleading. On the other hand, 40% of Zambian districts have a population of less than 100,000 (or around 4000 births annually) (Fig. 43), which means they need less than 1 facility to meet the EmOC benchmark. Such benchmarks certainly do not make sense at constituency or ward level where populations are even smaller. Furthermore, facilities may be close to administrative borders and be used by people from the neighbouring wards/ constituencies/ districts. The lower down the level, the more borders exist and distort estimates. Having geographic coordinates allows one to analyse coverage by calculating the proportion of the population living within a certain distance of services, which overcomes this problem.

In addition to the limitations mentioned for the health facility classification, the coverage analysis is also affected by limitations of the population census data. Population figures and birth numbers for 2005 are estimates based on projections by district and crude birth rates by province. Where birth rate trends have changed considerably since the 1990s, and where birth rates in a district differ substantially from its provincial average, these estimates will be incorrect and lead to over- or underestimation of population coverage with

EmOC. Moreover, the urban/rural status of wards was corrected for some obvious errors, but there are almost certainly further incorrect classifications. However, despite these misclassifications, the differences between urban and rural areas are stark.

In terms of geographical access, remaining mistakes in the health facility coordinates as well as some missing coordinates will have influenced coverage estimates to some degree. Furthermore, the data on water bodies and national parks are not entirely accurate, which may have affected the estimates. More serious probably are the mistakes introduced by assuming that the population is evenly distributed inside wards. As the population is likely to cluster in those parts of the ward where the health facilities are located, assuming the population is evenly distributed will lead to an underestimation of the proportion within 15 km distance, although finer population data would allow more accurate estimates.

Some of the anomalies in the data, e.g. that two mainly urban districts have less than 80% of their population within 15 km of an EmOC facility, may be explained by data problems. Several wards in those two districts were classified as urban although only a small part of the ward contains a town while the rest is rural. Counting these “semiurban” wards as urban leads to a higher proportion of the population considered urban. Since the population is presumably clustered in the urban corner of wards, assuming an even population distribution will underestimate coverage particularly in these cases.

Having circular coverage areas (e.g. within 15 km) is also clearly another crude approximation as it does not take road transport, rivers and terrain into account. However, a more sophisticated analysis in terms of the shape of catchment areas is merited only with more detailed geographical data than currently available. As long as the population data are only by ward, the mistakes introduced by circular coverage areas are probably small in comparison.

The analysis did also not take into account that health facilities have varying capacity. Some may not be able to handle the volume of births generated by the population living within a 15 km radius, while others additionally provide care for women referred from further away. Taking account of capacity can also explain the apparent inadequacy of facilities in Lusaka, considering the enormous size of the University Teaching Hospital. A more sophisticated analysis allowing different buffer zones or catchment populations for different facility types would be possible with data on the number of births currently handled in each facility, but these were not available to me.

4.3.3 Interpretation

4.3.3.1 Benchmark performance

The UN guideline's benchmarks for number of EmOC facilities are met at the national level and mostly met at the province level in Zambia, but not in a large number of districts. While the results for individual districts should not be overinterpreted, as populations may be small (40% of districts have populations below 100,000, see Fig. 43) and some facilities' EmOC status may be misclassified, the overall picture highlights how aggregates at higher-level geographical units can hide discrepancies within.

This finding agrees with the UNICEF 2005 EmOC assessment that also found that the benchmark of 1 CEmOC facility per 500,000 population was met in all provinces except Lusaka which had fewer (but larger) CEmOC hospitals [21]. None of the health centres sampled by UNICEF were found to provide all basic signal functions and thus none were classified as BEmOC and all provinces failed the EmOC benchmark [21]. There is no information on how many may have fulfilled BEmOC-1 criteria. The UNICEF survey did not disaggregate figures by district, probably because samples were too small to give reliable estimates at this level.

With 10 nurses/midwives/clinical officers and 1 doctor per 10,000 population, total staffing levels are very low in Zambia, especially for doctors. In Sweden there are 30 times more doctors per population, in Honduras, Malaysia and Sri Lanka still 6-7 times more [163]. Zambia thus falls far below the threshold of 23 health professionals (doctors, nurses and midwives) per 10,000 population mentioned in the WHR 2006 [167]. Given that skilled attendance coverage at birth is below 80%, Zambia is thus defined as having a "critical shortage" of health professionals [167]. Furthermore, the existing staff are very unevenly distributed over the country, and inside provinces, which only becomes apparent when breaking down figures by district (Fig. 33).

In terms of nurses and midwives, the figure in the HFC of around 8,500 is less than half of the WHO Statistical Information System (WHOSIS) figure of 22,000 [163] and somewhat more than the figure of 6,100 nurses (probably excluding midwives) given by Schatz in a 2008 Lancet article on “Zambia’s health-worker crisis” [168]. The WHOSIS figure of 22,000 originates from the WHR 2006 Annex where it is disaggregated into 19,000 nurses and 3,000 midwives [167], so inclusion of non-professional health workers such as nursing assistants does not explain the discrepancy. Migration of health workers is a huge problem in Africa including in Zambia [167-169], but according to the WHR 2006, the figure comprises only nurses and midwives working in the country, and excludes another 1,200 who have migrated to OECD countries. The fact that the HFC omitted most private for-profit facilities does not seem a sufficient explanation either, unless very large numbers of health workers work in these or run small private practices. “Internal brain drain” to NGOs and foreign aid agencies [168] may also accounts for some of the difference between the WHO figure and the nurses and midwives registered in Zambian health facilities. The WHO Global Health Atlas, however, gives a newer figure of 8,370 for 2006 (alongside 22,000 for 2004), which is exactly in line with the information in the HFC and seems to suggest that the higher figure in the WHR 2006 is simply wrong.

It is difficult to judge the degree to which current numbers of nurses/midwives/clinical officers are sufficient to provide skilled attendance, as we lack information on how many of them conduct deliveries and have EmOC skills. It would be useful to estimate that proportion in future research, even if only approximately.

The fact that geographical coverage with delivery care is generally good while coverage with EmOC is poor (Fig. 35 and 42) reflects the fact that only 12% of health facilities in Zambia fulfill at least BEmOC-1 criteria. The exact coverage percentages should be treated cautiously, but even considering errors and a general underestimation of coverage due to the assumption of even population distribution in wards, it is clear that the proportion of the population within reach of EmOC facilities is very low in rural areas. This is in line with findings in other low-income countries as summarised in a review on the geographical imbalances in the distribution of the health workforce: “There are many examples of poor countries that provide good coverage of their territory with health facilities yet limited access to services, because facilities lack the personnel needed to function normally.” [169]

When comparing the different coverage measures (Fig. 46), there is mostly agreement for urban areas, but not for rural. 8 of the 11 mainly urban districts both meet the benchmarks and have high population coverage. Lusaka is the only district that fails the EmOC benchmark while having high (close to 100%) coverage, which can be explained by the fact that it has fewer (but large) facilities. Two mainly urban districts have less than 80% of their population within 15km of an EmOC facility: Kalulushi, a district with 70% (semi)urban population that is concentrated in two cities while the countryside has no facilities, and Kasama with 55% (semi)urban population. It is somewhat surprising that despite the low proportion of health facilities satisfying EmOC standards and in contrast to the low geographical population coverage in rural areas, 60% of the 61 mainly rural districts still meet the UN EmOC benchmark, which calls that benchmark into question.

<u>4.3.3.2 Benchmark implications</u>

Investigation of Zambia's performance on various benchmarks raises a number of questions on the appropriateness of the benchmarks and which benchmarks make the most sense.

The UN guidelines suggest that it is more practical to define the benchmarks "in relation to population rather than births because most health planning is done in relation to population" [26]. As birth rates are usually lower in urban than in rural areas, this will disadvantages rural areas in terms of planning. There is also considerable variation in crude birth rates, internationally ranging from 8 births per 1000 population in Japan to 52 in Niger [7], thus leading to vast differences between the two definitions. Benchmarking with births is also useful to get some idea of what the case load per facility is going to be in a given scenario. The UN guideline benchmarks are given per 500,000 population and alternatively per 20,000 births, implying a CBR of 40 which is approximately the Zambian average.

The World Health Report 2005 [35] provides its estimates for a district of 120,000 inhabitants, claiming this fits the reality of African district sizes better than the 500,000 standard in the UN guidelines. Indeed, 71 of the 72 Zambian districts have far less than 500,000 population and many have around 100,000 (Fig. 43). The WHR 2005 then provides facility and staffing benchmarks for 3,600 births, assuming a CBR of 30; for a CBR of 40 that number of births would be generated by a district of 90,000 inhabitants.

The WHR 2005 estimates that one midwife can on average assist 175 births per year and thus 20 midwives are needed for 3600 births. They suggest that 9 or 10 could work in a district hospital and the remaining be distributed over other facilities in the district, or working in several “smaller birthing facilities, with perhaps 5 midwives each” [35]. This contrasts with the UN guidelines’ minimal recommendation of 1 EmOC facility for 100,000 population that would then handle an average of 4000 births, assuming all births occur in EmOC facilities which should be the goal. If the WHR 2005 was trying to challenge and revise the UN benchmarks, this was not picked up widely, and the updated UN guidelines from 2009 still repeat the 5 EmOC per 500,000 population benchmark. Obviously, the UN EmOC benchmark is not meant as an ideal level, but rather a “minimum acceptable level” [26] that needs to be adjusted according to population density and terrain. Nevertheless, the Countdown to 2015 estimates use it as their 100% benchmark [9].

There were an estimated 11.4 million inhabitants and 412,000 births in Zambia in 2005. The available 135 EmOC facilities in Zambia (meeting at least BEmOC-1 criteria in my classification) would each need to handle around 3000 births to cover all Zambian births. This is in line with Zambia overall meeting the UN guidelines’ minimum requirements that imply an average of 4000 births per facility. However, except for the larger hospitals, most of the Zambian EmOC facilities are not built or staffed to handle that quantity of births, and, furthermore, most people do not live within reach of these facilities.

Population density in rural Zambia is low, with only about 100 to 1000 births occurring annually in the 700km^2 area around a health facility (15km radius) in most districts (Fig. 44). A study calculating catchment populations and their expected annual delivery rates for a random sample of health centres in Zambia’s Central Province found similar numbers: the expected annual births per health centre were 334 on average, ranging from 49 to 1082 [38]. Less than half of all districts and wards generate 500 births per 700km^2 (Figures 44 and 48). Population densities sufficient to generate 4000 births occur only in four mainly urban Zambian districts. This means, that most women would need to travel from much further than 15 km if all births were to be handled in the available EmOC facilities.

In countries like Zambia, where much of the population is distributed sparsely over large areas and where transport links are weak, for an average rural district of around 100,000 population, it is probably more strategic to have several smaller facilities rather than one large facility. If accessibility were not an issue, it would be more efficient to just have one big facility, given that in a large team, a midwife can handle more than the average 175 deliveries per year, and therefore fewer midwives overall would be needed. If facilities are very small, this raises issues of 24 hour availability and of quality assurance as midwives may lose skills not frequently practised [35]. Having midwives practise outside of health facilities is even less efficient and raises additional concerns around how enabling the environment is [5, 170].

Thus, a balance has to be struck between accessibility, efficiency and quality. Depending on the context (population density, transport, available staff), this will for most districts be somewhere in between having all midwives concentrated in one facility and having them spread out separately in tiny facilities or even doing home deliveries.

For example, in a district with 3,600 births and a density of say 600 births per 700 km^2, 6 health centres with 3-4 midwives each, or one larger health centre in the district capital (or a district hospital) with maybe 8 midwives and a further 4 health centres staffed with 3 midwives each may be a reasonable compromise. For districts with less than 200 births per 700km^2 circle, one may station single midwives in small health facilities, assisted by other health professionals with (limited) midwifery skills who can help provide the needed 24 hour coverage. This is similar to what was suggested in the WHR 2005 [35] and more practically helpful for planning than the UN guidelines' benchmark of 5 EmOC facilities per 500,000 population. In very low density areas, one may furthermore attempt to improve community transport links, establish maternity waiting homes, as well as ensuring good availability of supplies and functioning communication tools and referral transport.

It is clear that the current number of EmOC facilities needs to be substantially increased to ensure universal access in Zambia. As the overall number of health facilities in most of the country is sufficient, what is needed is mainly upgrading of existing facilities that currently fall short of BEmOC-1 standards, and perhaps very limited new construction of facilities in some areas. For facilities fulfilling BEmOC-2 and BEmOC-4 criteria, upgrading may be relatively cheap, requiring some additional staff, training and/or equipment. It is difficult, however, to ensure both coverage and quality, especially when on a tight budget, given that in most of Zambia population density is too low to generate a sufficient number of births (500) within the catchment area of a health facility (700 km^2) to keep three midwives busy (Figures 44 and 48).

Concerning CEmOC, only a small proportion of women will need these services. Assuming that 5% of births need a C-section (including foetal indications), and another 2.5% need CEmOC attention for other reasons, suggests that roughly 7% of births may need CEmOC attention. Interestingly, this is the same proportion (around 7%) that the WHR 2005 suggests, estimating that 15% of deliveries have complications half of which will require CEmOC care. The WHR further assumes that 9-15% of newborns need back-up care [35]. These estimates do not have a strong empirical basis, however, and there is much debate on what proportion of deliveries require back-up care, ranging from 1-2% if only including life-saving interventions for the mother to over 20% [35, 171]. For a population base of 500,000 with 20,000 births, a 7.5% estimate results in 1500 cases yearly, or on average 4 daily in need of CEmOC services. For a population of 90,000 and 3600 births, the figure is around 270 yearly. Counting neonatal emergencies as well at least doubles these figures.

To ensure 24 hour availability, the WHR 2005 suggests that at least “one full-time equivalent doctor and his or her supporting team” is needed per district to provide comprehensive back-up care [35]. Obviously, “a single gynaecologist-obstetrician per district is not a viable option” and instead, one needs to improve the “skills of all-round medical staff or specialized technicians” covering “both obstetric and neonatal care” [35]. The “district benchmarks for annual maternal-newborn care needs” in the policy brief to the WHR 2005 recommends a minimum of 3 doctors at the district hospital, who are spending part of their time on EmOC and newborn emergency care [172].

These WHR recommendations are again not in line with the UN guidelines’ benchmark of one CEmOC facility per 20,000 births: A single facility per 20,000 births handling around 1500 obstetric complications per year as compared to one facility in each district with 3600 births handling 270 such complications yearly.

A district hospital covering 90,000 inhabitants, with an average of 0.7 obstetric emergencies requiring CEmOC attention daily and 0.9-1.5 neonatal emergencies may be considered busy enough to employ 3 doctors – taking into account that doctors also have various other emergencies to attend, be it surgical (e.g. accidents, appendicitis, etc.) or medical (e.g. meningitis or severe malnutrition) besides non-emergency duties. On the other hand, one could argue that from an obstetric caseload point of view, it is not necessary to have a CEmOC facility in every single district – if there is a sufficient number of BEmOC facilities in the district and a well-functioning CEmOC facility in the neighbouring district, if distances are not too far and referral links working well.

Those areas located far from back-up CEmOC facilities, or even completely cut off during the rainy season, should at least have facilities offering the best quality BEmOC possible with experienced staff that can handle a large range of complications – even if they would not merit such a facility due to a low case load. The opposite is the case at the moment with facilities in areas remote from CEmOC less likely to offer a meaningful level of services (Table 6, Figure 49). Any upgrading activity should prioritise these areas.

Overall, there seems to be a need to define meaningful and realistic benchmarks adapted to the conditions in different areas, such as terrain and population density, that can guide investments and will result in decreased maternal and neonatal mortality when met.

4.4 Effect of distance on health facility use

4.4.1 Summary of findings

Less than a third of rural births in the analysed sample are delivered by health professionals in facilities: 28% of 3357 births in the 2002 sample and 30% of 3680 births in the 2007 sample. Over 60% of births are to mothers living at a distance of 2-10 km from delivery care, but less than 30% are within 15 km of a BEmOC-1 facility.

In the crude analysis, further distance from health facilities is strongly associated with a decrease in facility deliveries, showing a clear trend: A one-unit increase in log-distance is associated with a 40-60% decrease in odds of facility delivery (Tables 12 and 13) which translates into a reduction by a third up to a halving in odds of facility delivery for each doubling of distance. Availability of motorised transport means at the household is also associated with facility delivery, but less than 1% of births are to households owning any. Of the potential confounders, mother's education, fertility attitudes, relationship autonomy, media use and household wealth show the strongest associations with facility delivery. Several cluster-level variables are also strongly associated with facility delivery, namely women's media use, women's relationship autonomy, women's and men's fertility attitudes (Table 14).

After adjusting for all confounders, there are still strong effects of distance on health facility use for delivery for all four levels of care examined: For each additional unit increase in log-distance, the odds of delivering in a facility setting decrease by around 30-40% in most models (Tables 17 and 18), translating into a reduction of the odds of facility delivery by about a quarter for each doubling of distance. If one could ensure that all women were within 5 km of a facility offering at least BEmOC-1, assuming causality, this could avoid nearly 20% of home births, an effect of similar magnitude as for education, wealth and women's average autonomy in the cluster (Table 25).

Independent of the effect of distance to the closest delivery care, there is also a strong effect of level of care offered: Women have more than double the odds of delivering in a facility if higher levels of emergency obstetric care are offered there as compared to substandard care (Figure 63).

There is no evidence that the strength of the relationship between distance and delivery care use changes depending on availability of household transport means, season of birth, mother's education, household wealth, fertility attitudes or relationship autonomy.

4.4.2 Strengths and limitations

The ability to link national health facility census and national household survey data allowed me to analyse the role of distance in influencing place of delivery over a wide range of distances and in conjunction with level of care offered, thus addressing a need identified by many and responding to the recommendations in the literature and UN guidelines [26, 31, 33, 34, 107]. This and the large number of appropriate confounders controlled for are clear methodological strengths of this study.

Unfortunately, there is no information on which health facility exactly women used for giving birth. So when looking for example at the effect of distance to a facility offering at least BEmOC-1, the outcome is still delivery in any facility including substandard ones, not just delivery in a BEmOC-1 facility or better. This makes the link between exposure and outcome less specific and may have diluted associations. It also prevented an analysis of the extent to which less functional facilities are by-passed, a very common phenomenon [173].

As there is also no information on intended (versus actual) place of delivery, it was not possible to analyse how much of the distance effect is due to distance being a disincentive to seeking care and to what extent women who are intending to use facilities cannot reach them at the time of delivery. Furthermore, there is no reliable information on complications, so we cannot tell preventive and emergency care-seeking apart. I would expect that distance effects are stronger when seeking preventive care compared to when seeking care in an emergency.

Furthermore, the HFC contains no information on costs of care. User fees have only been abolished in rural facilities in Zambia in 2006 [156], so most of the births considered in this analysis happened before that date and fees charged may have influenced care-seeking. Inofficial fees or the need to bring own supplies may also play a role but would be even more difficult to capture.

There are a number of reasons why the distances measured could be wrong: These include using the cluster centre instead of the location of individual households, GIS errors remaining in the location of facilities and clusters, missing facilities, missing facility coordinates, GIS data scrambling by the DHS, and using straight-line distance as an approximation. As it seems reasonable to assume that all these errors occur independent of the outcome, such non-differential misclassification is likely to have led to an underestimation of the effect of distance.

The 2002 and the 2007 DHS data suffer from different GIS errors but the findings are nonetheless quite similar for both analyses, which increases confidence that the distance effects are not due to some systematic bias. The error introduced in the 2007 data by the scrambling to protect confidentiality is quite peculiar in that it affects shorter distances more than longer ones, i.e. particularly where it matters most. Unfortunately, we do not know the true distribution of distances in Zambia (the 2002 DHS has too many errors to be used), so there is no straightforward way to calculate the size of the bias, e.g. with regression calibration. Another option would be simulation extrapolation, a method that repeats the error generation many times and then extrapolates back. However, this is not easily implemented in this case, where each time coordinates need to be mapped in a GIS to calculate the apparent distances.

Besides making a number of assumptions in terms of actual provision of EmOC, the health facility classification relies on a one-time visit in 2005 while the births extend over 5-year time periods from 1996-2002 and 2002-2007 respectively. In particular for the 2002 DHS, it is likely that the facility landscape at the time of many births was different from what was found in the 2005 census. Potential opening and closing of facilities over the years will have contributed to misclassification of distance to any facility, while misclassification in facilities' EmOC status will have affected distance to certain levels of care.

An analysis of distance effects always needs to look at distance to *something*: any facility or a facility offering a certain level of care. I analysed the effect of distance to 7 different levels of care, thus keeping level of care constant in each model. Alternatively, the distance was fixed at 15 km and the effect of level of care analysed. Neither of these approaches is satisfactory when trying to look at the effects of distance and level of care simultaneously. To some degree that problem was overcome by using distance to any delivery care and an indicator variable for level of care (Tables 19 and 20). However, this still does not take the whole service environment (distances to multiple types and numbers of facilities in the surroundings) into account.

Since distances to higher levels of care tend to be much larger, a comparison between the effects of distance to different levels of care does not exactly compare like-with-like when using distance as a linear effect. However, the log-transformation goes some way in making them similar given that it shrinks large distances disproportionally.

This study also has limitations in terms of generalisability and possible selection bias. The sample that could be used to analyse the effect of distance is not representative of rural Zambia as a whole, since it only includes births to women who lived in rural areas at time of birth and who did not move afterwards. It would have been wrong to keep births of women who moved after the birth in the analysis, since the distance from the cluster at interview is not the one relevant at time of birth, which would have lead to misclassification of distance.

Mothers who moved after a birth differ from non-movers in a number of characteristics, e.g. their education level. It may however be plausible to assume that conditional on all these measured characteristics, knowing the true distance to a health facility at time of giving birth would not tell us anything additional on whether a mother was more or less likely to move. Assuming such missingness at random (MAR), one could have performed an additional analysis using multiple imputation to account for the missing distance variables among movers.

Those who move are more likely to have delivered at a facility; however, after controlling for education level, household wealth, men’s fertility attitudes in the cluster, etc., whether or not a woman delivered at a facility is no longer predictive of moving (data not shown). Therefore, since we are controlling for all these covariates in the final analysis, we don't expect there to be a bias in the estimate of the effect of interest, even in the "completers only" analysis performed. This is a consequence of the fact that when covariates are missing, even if missingness is not at random, if, conditional on the covariates, the propensity to be missing is independent of the outcome, a "completers only" analysis (as conducted here) is valid [174, 175]. For this reason, it was deemed unnecessary to carry out the multiple imputation analysis.

Another issue that may have caused selection bias is that the DHS only gathers information on place of birth for live births, thus excluding stillbirths. Stillbirths are estimated to be over 30 per 1000 deliveries in Sub-Saharan Africa [176] and are often a consequence of a complication that is treated too late. It seems plausible to assume that stillbirths are equally likely among home births close and far from a facility and among preventive care-seekers from close and far, but that they are more likely among those seeking emergency care for complications from far away than among those seeking emergency-care from close-by, due to the delay in reaching care. Excluding stillbirths will thus disproportionally exclude facility deliveries from further distances which will lead to an overestimate of the effect of distance on health facility use. Furthermore, one can postulate that the deterring effect of distance is probably stronger for preventive care-seeking than for emergency care-seeking for complications. Excluding stillbirths will reduce the proportion of complicated births which again will result in a strengthening of the distance association.

Even though I considered a very large number of confounders, it is possible that there is residual confounding due to omission of important confounders that I did not have any data on (e.g. cultural attitudes towards facility delivery) or due to imperfect measurement of included confounders. Many of the potential confounding variables, such as ability to pay or aspects of autonomy are not very clear conceptually and hard to measure in a survey. As most of them were not asked specifically for delivery care, e.g. decision-making power on health care seeking, they are only proxies for the target concept. Incomplete adjustment for confounding could have lead to either over- or underestimation of the effect of distance, with the first being more likely here.

On the other hand, given that many confounders are proxies for a whole range of overlapping concepts, including remoteness, I may have “overadjusted” for access to some degree. Adjusting for ability to pay by using an asset score, for example, may have implicitly controlled for infrastructure as certain assets are more likely to be present where infrastructure is good. I tried to limit this by excluding assets clearly linked to infrastructure such as electricity. Furthermore, for this reason I did not adjust for variables such as ANC use or previous facility use for delivery. If distance was measured perfectly, this would not be an issue, but given the measurement error, some confounders can potentially be better proxies for geographical access to delivery care than the distance variable itself, as they also incorporate issues such as public transport availability.

To avoid confounding by factors associated with place of residence, the analysis was restricted to rural births. Distances in urban Zambia are mostly short and levels of facility deliveries are much higher than in rural areas (Figures 50 and 51). Including urban births and controlling for place of residence was not considered a satisfactory approach, as it may overadjust for accessibility for the reasons mentioned above. Including urban births and only adjusting for other measured confounders would pose problems of residual confounding as factors differing between urban and rural mothers, such as modern attitudes, are not captured satisfactorily.

It is interesting to observe that there are some notable differences in the associations of potential confounders with facility delivery in the two surveys examined, and also which of these variables feature as important confounders of the distance relationship. For example, women's media use is a strong confounder in the 2002 dataset but much less so in the 2007 dataset. While this suggests that a cautious interpretation of the importance of individual variables is advisable, the fact that the distance results are nevertheless similar between the two surveys enhances one's confidence in them. Concerning the exploration of potential interactions, the availability of two surveys and a variety of distance measures provided a safeguard against falsely claiming effects.

A strength of this analysis is that it explicitly takes account of the hierarchical structure of these data – births clustered within mothers within villages (clusters) – by using a three-level random effects model. As the outcome is binary, the interpretation of the effects changes somewhat when moving from a marginal to a conditional model by adjusting for cluster-specific and mother-specific effects. The odds ratio has to be interpreted as the change in the odds of facility delivery for births to a particular mother in a particular village, if that mother/village was at a different distance. The model assumes that the odds ratio is the same for any baseline odds of facility delivery.

The calculation of PAFs gives some idea of the public health importance of distance, but obviously makes a range of strong assumptions. Although I controlled for confounding, one has to be cautious when making causal inferences. One also needs to consider that the calculated PAF is only approximate for several reasons. The sample is not representative of Zambia as a whole or even of rural Zambia due to missing coordinates and movers, and it was not possible to weight for the sampling design before calculating PAFs. The latter, however, only caused minor changes in the odds ratios of the model. Furthermore, the PAF estimation had to be done from a model that ignores clustering because the software did not allow that. The odds ratios for all the determinants of interest are smaller than in the three-level model, which means that their PAFs are underestimated. The relative size of the distance PAF in comparison to others should not be much affected by this. However, relative sizes would be affected by misclassification that leads to imperfect control of confounding. As distance is the variable most likely to be misclassified, its importance in relation to education or wealth is likely to be underestimated.

4.4.3 Interpretation

4.4.3.1 Interpretation of study findings

The distributions of distances in the sample are largely similar between surveys, except that the proportions of births at a distance of 5-10km from a facility offering limited levels of care are much higher in the 2002 survey. The more spread-out distribution in the 2007 survey may be due to the scrambling performed on the cluster coordinates as this disproportionally affects shorter distances.

The crude decline in facility delivery by distance is more pronounced in the 2002 data than in the 2007 data, mostly because the proportion of facility deliveries in those very close to a facility is lower in 2007. This may also be partly caused by the scrambling. However, p-values are lower in the 2007 survey despite this, because births inside the same cluster are less similar in the 2007 data compared to 2002, which means there is less of a design effect due to cluster sampling and the effective sample size is larger. The reasons for this are unclear. The sampling technique and cluster sizes were very similar between surveys.

In the 2002 dataset, the linear effect of log-distance to a BEmOC facility is weaker than that to facilities offering delivery care but not BEmOC, and the effect of distance to a comprehensive EmOC facility is even weaker. As only 42 facilities were classified as BEmOC and 54 as CEmOC(-1), this may be due to these facilities not being relevant in most cases, as for most women the distance to less functional facilities in their proximity determines their use. However, in the 2007 dataset, the various distance effects are more homogenous, with just the effect of distance to a CEmOC facility being weaker.

Women who live further away from a facility are more likely to report that distance is a big problem for their ability to access care. Surprisingly, there is a substantial proportion who do not report distance as a problem although they live more than 15 km away, and conversely, some report distance as a problem despite living within 2 km of a facility. Some of this discrepancy may be due to misclassification of the distance variable, or because long distances pose less of a problem where transport links are good. It may also be attributable to the fact that the question does not ask about a specific type of care. Women may think about mobile health posts or clinics in their vicinity instead of their closest facility when answering this question, or they may refer to other facilities further away if the closest one cannot address their particular health problem. Furthermore, if people do not perceive a need to seek care, they also may not report that distance poses a problem to them.

There is virtually no association between perception of distance as a problem and distance to a BEmOC-1 facility. As only 12% of facilities qualify as BEmOC-1, the facility that most women relate to when answering this question is likely to be of a lower standard and closer-by.

While most variables examined as possible confounders show an association with facility delivery, many of those relating to perceived need/benefit do not, interestingly not even multiple pregnancy. One would have expected that twin pregnancies are detected at ANC and women advised to deliver in a facility due to the much higher risk in such births. However, advice may not be given, or when given, women may not manage to follow this advice due to early and unexpected labour. This does not cast a very positive light on the quality and effectiveness of antenatal care. Other potential confounders just show a significant univariate association with facility delivery because unmarried women form their own category (e.g. in 2007, several autonomy questions were not asked to this group).

It is also noteworthy that several crude odds ratios do not match with what would be expected from the percentages presented (e.g. for previous newborn death in 2002, Table 14b). This is due to the fact that the model used to compute the odds ratios takes the clustering into account (see sections 1.2.6 and 2.5.6).

After adjusting for all potential confounders, strong effects of distance on facility delivery remain for all four distance variables examined in both surveys (Tables 17 and 18). There was also a strong effect of level of care independent of the effect of distance to the closest delivery care (Tables 19 and 20), and no evidence that distance only matters for certain levels of care (which is also evident from the fact that all four distance variables are important determinants) or that level of care only matters at certain distances. The effects of distance and level of care thus seem to be well described by a multiplicative model (Figure 63).

Nor was there convincing evidence of other interactions, either by season of birth, transport availability or other factors. In some models, the poor seemed to be more affected by distance, but the opposite was the case in other models. The lack of consistency over surveys and models suggests that these are probably chance findings and should not be over-interpreted.

The PAFs show that distance plays an equally important role as mother's education or household wealth, two factors very frequently studied and emphasized, and as women's average relationship autonomy, which is rarely studied. Assuming causality, if all women were within 5 km of a facility offering at least BEmOC-1 while everything else was left unchanged, the models estimate that around a sixth of home deliveries could be avoided. The absolute numbers should not be over-interpreted, given that the data hierarchy is not explicitly modelled, that some PAFs vary substantially between the two surveys, and that confidence intervals are wide.

While the PAFs for distance are similar between surveys, those for education differ quite substantially. The small improvement in mothers' education between surveys cannot explain this difference. The reason lies mainly in the less steep gradient in facility delivery between educational groups in the 2007 survey: while women without education interviewed in 2007 had higher levels of facility delivery than in the 2002 survey, those with secondary education had lower levels. It is unclear why this change occurred.

4.4.3.2 Comparison to other studies

While many studies on the determinants of delivery care use have not considered geographical accessibility at all, some have done so (Table 2), but most of these suffer from a variety of limitations with regard to setting, distance measurement, facility information, statistical modelling of clustered data and adjustment for confounders. This study has attempted to overcome these limitations as far as possible.

In general, studies either have detailed household and facility data in small areas, e.g. from a surveillance site, or they use large-scale or national survey data but then lack objective information on distance to facilities and services offered. While studying small areas is a valid approach, findings may be very specific and not easily generalisable. Furthermore, certain risk factors may not emerge as important due to a lack of variation in that setting, e.g. if geographical access is good overall in the area [85, 127]. The trade-off between scale and detail also partly explains why there are “surprisingly few studies examining the effect of the level of functioning of health centres on utilisation of maternity care” [132]: either there are only few facilities in the study area and thus not enough variation to study the effect of quality, or data on many facilities is available, but without sufficient detail to judge their quality.

This problem is also highlighted in a review concluding that “the context within which utilization occurs – the role of the environment and provider-related factors – has been largely neglected” and that “a key barrier to the inclusion of contextual variables is the lack of these variables in data sets that also include individual-level utilization data” [177]. The authors suggest that “one solution to the lack of contextual variables is to merge databases that include detailed patient-level utilization data with databases that include environmental or provider characteristics” [177] – which is exactly the approach chosen for this study. To my knowledge, no previous study on delivery care has linked national household and facility datasets.

Most larger-scale studies so far have used the DHS Service Availability Module which “relies on key informants to provide information on the nearest facility of a certain type to each DHS cluster” [146]. “Although the full module includes a validation of the community information by visiting the facility, […] few countries carried out the facility survey and hence the information […] [mostly] relies on measures of *perceived* distance to services.” [146] “In a refinement of this method, GPS units can be used to collect more objective information of the distances between the centre of the DHS cluster and facility, rather than relying exclusively on community report.” [146]

On the one hand, travel time as reported by communities may be preferable over objective distance measures since it takes local transport means and difficulty of terrain into account. On the other hand, “perceived availability may not be a reliable proxy for actual availability” given that “low perceived availability of services may reflect either actual low coverage or a lack of community awareness of services provision – problems that need to be addressed by fundamentally different programme strategies.” [146]

In some instances, the community questionnaire only inquired about distance to the closest facility of a certain type (hospital, health centre, etc), without asking about service provision. This leads to misclassification of distance to delivery care as not all facilities provide such care. Furthermore, the “assumption implicit in this approach […] [that] the nearest health facility most accurately reflects the health service environment available to any community” [146] may not hold, given that people sometimes bypass the closest facility to use a better facility further away, an issue we attempted to address.

The fact that hardly any DHS service availability module included a facility survey not only precluded validation of reported distance to services, but also prohibited the study of the effect of facilities’ functioning on their use, as the detailed information necessary cannot be gathered from community surveys. It may be worthwhile finding out why the module and in particular the associated facility survey has not been used more widely.

While being more expensive, a national facility census with detailed data on service provision and geographical coordinates, as conducted in Zambia and used for this analysis, is an even better approach than collecting facility data in the areas surrounding DHS clusters. Firstly, there is no need to restrict facility information to those institutions within a radius feasible for data collection around the cluster (e.g. 30 km), which allows to investigate the effect of very long distances to certain levels of care. Secondly, besides providing service availability data for the DHS clusters, a facility census provides full national and subnational information on the situation in all health facilities, as opposed to an unrepresentative sample, and can form a routine part of a Health Management Information System (HMIS). Thirdly, the facility census data can be additionally linked to population distribution data for service provision planning. This study tried to demonstrate these possible additional applications.

Another limitation common to nearly all previous studies of the effect of distance on use of skilled attendance is that they fail to consider that some of the births occurred while the mother lived in a different place than where the interview was conducted and where the distances apply to – a circumstance that I considered in my analysis. The exceptions comprise a study in Laos that only interviewed women who had been living in the village of the study area during the latest pregnancy and delivery [121] and two studies by Gage who adjusts for duration of residence in an attempt to deal with this problem [107, 108]. Including births that occurred elsewhere leads to misclassification of distance. The proportion of movers and thus the misclassification is likely to be substantial when including births that occurred several years prior to the study, as is the usual practice. Gage dismissed the option to "exclude women who had lived in the neighbourhood for fewer than 5 years before the analysis" partly because "this would have resulted in a loss of about 15 per cent of the sample" [107]. In this study, date of birth and duration of residence were compared and only births where the mother moved afterwards were excluded, thus resulting in a 11% and 13% loss of sample size, respectively, in the two surveys.

It is essential to control for confounding when trying to elucidate the effect of distance on use of delivery care, as women living far away from facilities are also more likely to suffer several other disadvantages (lack of education, financial resources and autonomy for example) that independently reduce their chances of receiving professional delivery care. Some studies completely fail to control for confounding, for instance, Stekelenburg in Western Zambia [91], and these were not included in Table 2. Other studies controlled only for a limited number of variables [109, 146, 150], which makes residual confounding likely. This study attempted to adjust for as many confounders as possible, based on the information on determinants gained in the literature review. It probably included more potential confounders than any other study in the field.

Confounding control in this study was done in two steps, first adjusting for individual and household factors, and then additionally adjusting for cluster-level factors such as women's average relationship autonomy in the cluster. While the odds ratios for distance in the eight models studied (4 models in each survey) became on average 9% weaker (range 4%-17%) when adjusting for individual and household factors, they were attenuated on average by another 24% (range 19%-33%) when additionally adjusting for cluster-level confounders (Tables 17 and 18). This suggests that not adjusting for community-level factors leads to substantial residual confounding.

However, few previous studies investigating the effect of distance on use of delivery care include any cluster-level variables besides distance itself and urban or rural nature of the community. There are many ways in which community characteristics can affect the probability of a woman delivering with skilled attendance. Besides intrinsic group-level attributes, such as community attitudes and norms concerning childbirth, for which data may be hard to get, aggregate variables can be used, for example average level of female autonomy or media use in the community, as done in this study. When investigating these aggregate variables not as confounders, but in their own right, it should be considered that the same determinant can have a different meaning and effect on the community than on the individual level and parametrised accordingly.

Considering community-level determinants requires a different way of thinking. A recent review of the main conceptual models on health-seeking behaviour [178] emphasised that we need to understand health-seeking as a "socio-structural phenomenon" rather than one of individual rational choice. The authors write: "What seems to be missing in much of the literature is a sense of how the process of 'seeking' extends over physical and social space, time *and* the health system in complex ways, and cannot be picked out as something intrinsic to the individual” [178].

Even when controlling for a wide range of individual-, household- and community-level confounders with the best of intentions, residual confounding is likely to occur. Hounton and colleagues pointed out that “distance to [a health centre or] hospital also captures other aspects of remoteness such as […] poor communication between communities, poverty, limited access to information, strong adherence to traditional values and other disadvantages that are difficult to measure quantitatively" [132]. These aspects are extremely difficult to disentangle from distance. Including various cluster-level variables, such as on modern fertility attitudes and average media use, may control for confounding by non-distance aspects of remoteness at least to some degree.

Community-level variables are often proxies for a variety of overlapping concepts that are hard to measure precisely, and thus are "mixed bag" variables as described earlier. This means it is difficult to define what the actual determinant comprises and how it acts. This poses difficulties for a multivariable analysis that aims to not just be descriptive but to understand which factors are most important. For instance, when adjusting for rural or urban place of residence, this may imply adjusting for accessibility as well as sociocultural and economic factors. Unless these have been well measured and included into the model, it will remain unclear which determinants really are most important and which will emerge as statistically significant in the model.

When the focus is on distance and thus other variables are merely of interest as confounders, overlap only matters insofar as it is overlap with geographic accessibility. For this reason, it may be unwise to adjust for average level of secondary education among women in the cluster, as done in Haiti [107], given that this may be a very good proxy for physical access to a bigger town, capturing also transport issues. Similarly, it can be argued that, although widely done, adjusting for rural or urban place of residence is problematic. I avoided the latter by restricting to rural births.

Another common form of overadjustment found in the literature is adjustment for antenatal care use or even for previous delivery service use. When the distance measure is not perfect (and it hardly ever is), these may be better proxies for geographical access to delivery care, and thus adjustment will lead to an underestimation of the influence of distance. Furthermore, they may be on the causal pathway – shorter distance enhancing ANC use which in turn encourages women to deliver in a facility – which again makes adjustment appear questionable.

Finally, a limitation applying to many studies in the field is the failure to take the clustered data structure into account. Ignoring the dependence between births will lead to wrong, usually falsely small standard errors and thus spurious findings. Using robust standard error techniques fixes this problem, but estimates may still be misleading when the association on the cluster level differs from that on the individual level. Only explicit modelling of the multilevel data structure can deal with this issue satisfactorily. As software is becoming increasingly available, a growing number of studies apply this technique.

Various studies using multilevel models find that delivery service use is highly clustered within families, communities and districts, and that even after adding all covariates to the model, there is still significant unexplained community-level variation [80, 92, 98, 100, 104, 106, 107]. The unexplained variation could be due to measurement error in the included variables or to omission of hard-to measure factors such as health care quality, cost or health beliefs. Correlation within families is larger than within communities and harder to explain by the variables collected, while district-level variation is smallest and best explained [92, 98, 100]. The findings from this study are in line with this, variation between clusters is much better explained by the variables considered than variance between mothers (Table 23). Magadi and colleagues in Kenya found evidence for complex variation: in communities more than 10 km from a health facility, between-woman variation is larger than in those within 10 km distance, which means individual factors play a bigger role when accessibility barriers are higher [104]. While the 2002 dataset shows a similar pattern with the cluster playing a less important role for remote births and thus individual factors a larger one, the data from 2007 do not show this (Table 24), which makes it difficult to interpret.

4.5 Conclusions and recommendations

This study linked three existing national datasets and established (1) that few facilities in Zambia function at the level of BEmOC or better, (2) that most women live far away from such facilities and (3) that distance and level of care strongly influence women's use of facilities for delivery, independent of other factors. It also generated a number of recommendations for future research and policy which are summarised in Boxes 3 and 4, respectively, and described below.

4.5.1 Recommendations for research

Box 3 summarises recommendations for future research arising from this work and their methodological implications. Box 3a outlines unanswered research questions related to the functioning of facilities and their geographic distribution, while Box 3b lists research questions related to the influence of distance and quality of care on service use and health impacts.

As in many studies, I used provision of signal functions as a proxy for EmOC. Other authors have used extensive checklists of drugs and equipment or evaluated health professionals' theoretical knowledge and practical skills. Since health facility functioning is complex and multidimensional, it remains unclear how best to capture service and provider quality, and in what time intervals this needs to be repeated. It would be useful to evaluate various assessment methods and to compare each with intuitive quality assessments by both visitors and communities.

Greater clarity is also needed on the proportion of births requiring CEmOC, on the proportion of health workers active and proficient in delivery care, and on the ideal annual birth load per midwife, especially since EmOC benchmarks are based on these estimates.

Although this study focussed on the maternal and obstetric aspect of care, it would be useful in future to also include services for neonates. The health facility classification of the existing HFC data could be extended to include functions important for neonatal survival, as far as collected, e.g. neonatal resuscitation. Future facility censuses should ensure collection of a set of functions crucial for newborns, in addition to the EmOC signal functions. These are yet to be defined, but could include kangaroo mother care, breastmilk expression and cup-feeding, availability of small syringes for injection of antibiotics and provision of corticosteroids for premature delivery. For higher-level facilities, availability of oxygen could be added. The information on facility functioning in terms of Emergency Obstetric and Neonatal Care (EmONC) could then be linked to population census data in order to study the geographical distribution of EmONC services, as was done for EmOC services in this study.

Also useful would be clarifying inconsistencies between the various benchmarks for EmOC coverage and evaluating the appropriateness of their (implicit) assumptions. For instance, it may be reasonable to consistently use number of births, instead of also total population, as the denominator in the measures, as this would improve the comparability across settings with different crude birth rates, and it would be helpful to spell out assumptions on what proportion of births need EmOC and what proportion should be in EmOC facilities.

It would also be useful if all benchmarks considered the size and staffing of facilities. It may be possible to use available health facility data from well-functioning settings to define reasonable and practically useful benchmarks adapted to a range of circumstances. Obviously, what facility sizes and distribution make sense will depend on the country context in terms of geography, cultural factors, transportation and population density.

Furthermore, it would be useful to routinely consider levels of functionality other than full BEmOC (all 6 signal functions provided in previous three months), especially in contexts where very few facilities fulfil these criteria.

Epidemiological studies of the determinants of skilled attendance so far have “focused on the influence of individual and household characteristics and have largely ignored the influence of community attributes and the characteristics of the health services available” [106], in part due to a lack of adequate data [76, 106, 107, 146]. In particular, studies have concentrated on sociocultural and economic accessibility variables and neglected variables of perceived benefit/need, quality of care and physical accessibility. Geographical studies, on the other hand, have generally evaluated accessibility factors without controlling for individual-level variables [46, 47].

Box 3a: Recommendations for research on facility functioning and distribution	
Research questions	**Methodological implications**
What is the best way to assess functionality of health facilities? Use signal functions (which? time period?), checklists, intuitive complex system assessment?	Conceptual work on quality of care and functionality of services Validation of assessment methods
How often do facility assessments need to be updated to be useful for planning purposes?	Studies with repeated facility assessments
What is the ideal annual birth load per midwife in different contexts?	Compare data from low/middle-income settings with low maternal mortality
What proportion of births need CEmOC?	Review current estimates and track sources. Conduct population-based studies of prevalence of a variety of maternal and neonatal complications, perhaps in DSS sites.
What proportion of the total health staff are conducting deliveries and what proportion has relevant skills?	Compare in different settings
How are health facilities functioning in terms of neonatal emergency care and how are they distributed geographically?	Define signal functions for neonatal (and obstetric) emergency care (EmONC). Include these in future HFC.
Are current benchmarks for EmOC coverage clear, sensitive, specific, and useful in practice?	Assess inconsistencies and assumptions of EmOC benchmarks. Use EmOC coverage data from different settings to check and if necessary revise benchmarks.

This research shows that it is important to consider as many influential factors as possible in any analysis of delivery service use because an incomplete picture can lead to invalid conclusions. For instance, from the strong association between educational level and health facility use for delivery, identified in the absence of data on facility availability, some studies conclude that promotion of female education and literacy is the most effective measure to reduce maternal mortality [103, 179], as if education alone would solve the problem in the absence of adequate and accessible health care in rural areas. Although the two factors obviously act on different levels and may interact, this study suggests that distance to quality care has public health importance for facility delivery of a similar magnitude as education (Figure 64).

The increasing availability of georeferenced data provides a promising opportunity to overcome previous limitations by allowing detailed health facility data to be linked with large-scale household data in a geographic information system (GIS). Using this approach with existing data allowed me to demonstrate the strong independent influence of geographical distance and level of care offered on delivery service use, taking account of individual, household and community determinants simultaneously, and to quantify their magnitude.

For policy relevance, it is particularly important to investigate those factors that are amenable to change, in particular health service accessibility and quality. Building, staffing and ensuring functionality of health facilities, while not easy or cheap, is attainable and falls within the remit of the health sector. While it is also important to address factors such as women's autonomy and education, without accessible health services that can save lives, other efforts to decrease maternal mortality will be futile.

Further studies could try to elucidate the relative contributions of the various determinants of delivery service use (instead of just focussing on the role of distance and quality as I did). Ideally this would be done by constructing a directed acyclical graph (DAG) from a full conceptual framework depicting all relationships between variables. However, this may be very difficult given the complex interactions between factors and difficulties in accurate measurement.

For better comparability across studies, it would be helpful if a clear analytical plan was used to test specific hypotheses and collect all necessary confounding variables for that purpose instead of performing data-driven analyses. To be methodologically correct, studies should also use multilevel models rather than ignoring clustering or using robust standard errors. Moreover, contextual variables should be defined and measured to facilitate comparison of results between different settings (e.g. average level of care at facilities, general development in the area, transportation, cultural aspects). This could help interpret differences in the importance of distance across settings and clarify the circumstances that make distance a large barrier.

For the same reason of better comparability, it would also be useful to standardise how geographical access is measured. "Some countries have tried to calculate the radius around a given facility, others the distance by road, others the travel time (using the most common means of transportation), but there is no consistent methodology." [34] It may be possible to establish standards in this area to facilitate comparison between studies.

Furthermore, better conceptual development of quality of care is required as it is not measured well through quantitative studies at the moment and therefore rarely studied [180]. Future facility censuses may want to explore quality of care in more detail, e.g. by measuring competence of skilled birth attendants [22] or taking a more critical look at the signal functions, perhaps prioritising those for which epidemiologic data suggest the greatest burden. Community surveys could inquire about aspects of perceived quality of care and facility reputation, including interpersonal communication and cultural appropriateness as these can have a major influence on use, independent of medical quality [181]. The results of this study suggest that people do judge medical quality and that this is an important consideration as they use substandard facilities much less than those providing emergency obstetric care, adjusting for distance and other factors.

While this study could not compare the determinants of preventive care-seeking with emergency care-seeking for complications, this is an important area for future research. To find out which determinants are important in these two situations, researchers will need to design studies that measure complications and intended place of delivery before complications occurred in order to investigate the two distinct behaviours separately. The conceptual framework presented in Figure 6 (published recently [78]) clarifies the concepts and should promote such research.

While facility delivery and delivery by a trained health professional are virtually synonymous in Zambia, the chosen outcome is still only a proxy for skilled attendance because the DHS contains no information on actual provider skills or details on the facility used. The data from the Health Facility Census show that few facilities in Zambia offer EmOC services, a fact that suggests that most women who use facilities for giving birth probably deliver in facilities offering substandard services or very limited EmOC functions (although it is not possible to verify this in the absence of data on numbers of births per facility). The DHS often records the names of the facilities but this information is not usually released. It may be useful for DHS to routinely provide this information in the future to facilitate linkage to health facility data such as the HFC. This would make analyses such as the one presented in this thesis more specific as it would, for instance, allow using delivery in BEmOC facilities as the outcome (as opposed to delivery in any facility) when studying the influence of distance to specifically BEmOC facilities. It would also enable researchers to study the by-passing of facilities and to elucidate how people weight distance and cost of travel against a perceived superior level of care in their decision-making concerning delivery in specific facilities within their reach.

Furthermore, skilled attendance at delivery is not the final outcome of interest, but rather a process indicator on the way to achieving lower maternal and newborn mortality. The use of process indicators has been recommended by the UN guidelines [26, 33] and Countdown to 2015 [9], given that monitoring changes in maternal mortality is difficult and costly where routine data are not available or not of sufficient quality. Input data are easier to collect and provide valuable information on where the gaps are and thus what is needed to improve the situation. This research suggests this is feasible. Increasing use of health facilities for delivery is only going to have a major impact on mortality if facilities offer skilled attendance, including at least basic EmOC. Analysing EmOC functioning of health facilities and their geographic distribution in the country is therefore crucial to estimating the extent to which higher facility use can translate into reduced mortality at all.

It would also be interesting to study the influence of distance on birth by Caesarean section. This was not possible in Zambia as the numbers of Caesarean sections were very low in the DHS of 2002 and 2005, but other household surveys may have sufficient power to tackle this question.

Ultimately it would be desirable to look at health impacts and investigate the effect of access to EmOC on maternal mortality, stillbirths and early neonatal mortality. The EmONC facility data could be linked to data from the DHS and from DSS sites containing information on stillbirths or neonatal mortality to study the effect on mortality, in a similar way as done in this study for facility use. So far, stillbirths are rather neglected and few DHS collect data on them; this could be done more widely. Maternal mortality requires large sample sizes to get stable estimates in smaller areas. Special surveys could be done in areas with different EmOC implementation or before-after studies. Ideally, it might be desirable to conduct a large cluster-randomised controlled trial of the effect of improving access to quality EmOC on maternal and perinatal mortality, possibly in the context of a national gradual implementation scheme where districts could be randomised to early or late implementation.

It is also possible to use a similar approach to study other health problems, for instance the influence of distance on malaria treatment or on antiretroviral therapy.

Box 3b: Recommendations for research on distance and quality of care	
Research questions	**Methodological implications**
What is the influence of distance on facility delivery? What is the influence of other factors at individual, household and cluster level on facility delivery?	Construct conceptual framework (DAG?) including all important variables and develop clear analytical plan. Use multilevel models. Consider linking different datasets in a GIS.
How does the influence of distance on place of delivery vary between different settings? On which context factors does this depend?	Standardise how geographic access is measured to facilitate comparison between studies. Document contextual variables of the study area.
How does quality of care (medical and interpersonal) influence use of facilities for delivery in different settings?	Develop better measurement of quality of care at facility level and in terms of community perception. Include measures in facility and community surveys.
Are the determinants of preventive care-seeking different from those for emergency care-seeking?	Ask about intended place of delivery. Measure complications.
For facility births, what is the influence of distance and quality of care on which facility was actually used?	Provide and use information in DHS on which facilities were used exactly.
What is the influence of distance on birth by Caesarean section?	Link facility data with suitable household data (with sufficient power) from DHS or Demographic Surveillance sites
What is the influence of distance on stillbirths and early neonatal mortality?	Collect information on stillbirths in all DHS. Link facility data with suitable household data from DHS or Demographic Surveillance sites
Does improving accessibility of EmOC (by improving quality and ability to deliver EmOC in selected existing facilities and by building and staffing new facilities) decrease maternal mortality?	Mortality surveys in areas with different implementation or before-after studies Cluster-randomised controlled trial of districts with early and late implementation
What is the influence of distance on facility use for other services, e.g. malaria or HIV treatment?	Can use similar approach as in this study, linking data on facility service provision with data on household service use.

4.5.2 Recommendations for policy and practice

In terms of conclusions for policy and practice, I will first make some suggestions for Zambia and then some more general recommendations for international policy.

In rural Zambia, both distance and quality of services influence use substantially adjusting for other factors. Use decreases strongly with distance, but women travel further for better facilities. The HFC in Zambia is a rich source of useful information for health service planning to address the above findings. Some crucial information is lacking, however, for instance the number of births per facility. This information is available in the HMIS and can be combined with the HFC data and the census data on population density to guide decision-making. For instance, it is possible to construct maps for each district picturing population density and health facilities, with different symbols or colours describing their size and level of functioning. These could be useful tools to identify underserved areas and to detect where the biggest gaps are, as well as being effective advocacy tools [33].

If the ultimate goal of Zambian policy is to have nearly all births happen with a skilled attendant in an environment (a facility) able to provide BEmOC, this would mean that many more facilities need to be upgraded to EmOC standard, since the current EmOC facilities would otherwise have to handle an unrealistic number of births. Moreover, the distances to reach them are too far for most women unless transport is improved significantly. For some facilities it may be possible to upgrade with relatively low cost inputs. Equipment and commodities needed for provision of signal functions are inexpensive, but ensuring ability to provide them may have training implications. In other areas, additional facilities may need to be built. It may make sense to only establish new facilities that can provide EmOC, instead of first increasing access to substandard quality facilities and then upgrading later (Figure 41: diagonal arrow).

Upgrading of certain facilities to provide BEmOC is already under way in Zambia. Knowing which facilities provide at least some signal functions (BEmOC-2, BEmOC-4) and only lack few additional health workers, drugs and equipment is an important piece of information for cost-effective planning. While the data from the Health Facility Census 2005 is a good starting point, planning of facility upgrading would probably require updated facility information. The AMDD program recommended that "[p]otential EmOC facilities should be examined carefully to determine if the investment should be made to upgrade them (are they strategically located? do they have or could they have a reasonable volume of patients?) or if they should be encouraged to refer all serious complications" and concluded that "[m]apping the geographical area when deciding which facilities to upgrade is an excellent tool." [27] This tool could increasingly be used to inform the upgrading strategy.

It is also crucial to ensure that backup facilities providing CEmOC are functional and strategically placed. Only a reliable referral system with comprehensive backup care can ensure that women with serious complications survive. Lack of medical doctors in rural areas is a big challenge. The options to overcome this challenge include limiting CEmOC services to few centres and ensuring optimal functioning there while strengthening referral links with improved emergency transport, or alternatively, extending the current program of training experienced clinical officers to become medical licentiates able to perform C-sections and using incentives to retain doctors in rural areas.

The overall low numbers and uneven distribution of qualified health workers in Zambia is one of the key challenges to be addressed [168]. The issue of health worker shortages has received increasing attention in recent years and the World Health Report 2006 was dedicated to this topic [167]. Solutions will not be simple but may involve educational reforms, rural recruitment of students, new educational tools such as distance learning and telemedicine, regulatory measures, financial and other incentives as well as international regulations [169].

Unfortunately, "the geographic distribution of EmOC facilities, one of the six UN process indicators, remains globally under-used or misused. Lacking the technology (digital maps, geographic information systems), most projects have difficulty in assessing and expressing this important indicator of equity." [34] While lack of technology may have been a reason in the past, it is no longer true that "collecting and analysing the data necessary to do this would consume a disproportionate amount of time and resources", as stated in the 1997 UN guidelines [26]. The 2009 UN handbook acknowledges this and points out that while in the past determining distances was cumbersome, "geographic information systems make calculations much easier" now [33].

Conducting a health facility census with GPS is the best way to acquire the needed data.

A number of countries, including Zambia, Malawi and Bangladesh, have already collected detailed information on all their health facilities including geographic coordinates. So far, these data have not been fully analysed in terms of EmOC functioning and distribution. Putting them in the public domain could increase their use. This study shows what can be done. It would also be desirable to ensure neonatal signal functions are added to future facility censuses (see research recommendations).

The cluster coordinates collected by many DHS allow linkage between facility and household data, thus facilitating multilevel analysis of the determinants of delivery service use, as also demonstrated in this study. To make full use of this potential, it would be necessary to ensure high quality geographic coordinates without errors or intentional scrambling. Macro International should be encouraged to reconsider their scrambling policy and if they persist, alternative approaches such as data linkage by a trusted third party should be explored.

Health facility census data should be entered into national Health Management Information Systems (HMIS) and regularly updated. It can then be used for planning of service provision and health worker allocation. Without such information it is difficult to imagine how countries and districts can strategically plan.

Finally, arguments have been made that EmOC coverage should be included as an additional indicator to measure progress towards MDG5 [182]. The reasoning being that the current process indicator, proportion of births attended by skilled health personnel, lacks information on whether an enabling environment with all relevant drugs and equipment is present, whether the possibility for referral exists and whether the provider actually possesses life-saving obstetric skills, as unfortunately, this cannot be established from the household surveys commonly used for monitoring. Adding EmOC coverage as an indicator could help to avoid “the back up system critical for treating obstetric and newborn complications” [182] being neglected. However, this would require further development of how to best summarise this into a meaningful national figure.

To conclude, this analysis has used an innovative approach linking existing national data to evaluate EmOC provision in health facilities and population coverage, as well as established the strong influence of distance and level of care on health facility use for delivery, and quantified their impact. The increasing availability of national data with geographic coordinates in countries where maternal and newborn mortality are high provides an opportunity to use such approaches to monitor health services and evaluate interventions. Major investments in countries' health systems are needed to achieve MDGs 4 and 5, and such monitoring tools will be extremely useful in guiding interventions.

Box 4: Recommendations for policy and practice

EmOC access in Zambia

1) Combine HFC data with other data in HMIS (e.g. births per facility, birth density in area) to use for service planning.
2) Construct district-level maps picturing health facilities and their functioning levels as well as population density to identify underserved areas and what the gaps are (e.g. facility numbers, staff numbers, training, equipment, drugs)
3) Strategically upgrade subfunctional health centres to BEmOC status, prioritising remote areas far from CEmOC services.
4) When building new facilities in underserved areas, ensure these function at EmOC level.
5) Ensure functioning of CEmOC backup care and strengthen referral links.
6) Address health worker shortage with variety of measures (e.g. educational reforms, rural recruitment of students, new educational tools, regulatory measures, incentives)

International

1) Encourage conducting health facility censuses with GPS to measure geographic distribution and functioning of health facilities where not done yet.
2) In future HFC, add neonatal signal functions (kangaroo care, etc.) to assess Emergency Obstetric and Neonatal Care (EmONC) functionality.
3) Put HFC and EmOC survey data in public domain to increase use.
4) Establish national HMIS that regularly update the HFC data and combine it with data from other sources.
5) Find and implement alternative solutions to Macro International's scrambling policy of DHS geographic data.
6) Include EmOC access as process indicator for MDGs.

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APPENDICES

A) Details on HFC data cleaning and coding

The component datasets of the HFC were examined and cleaned before they were merged. This included number-coding of string variables which in some cases involved summarising a large number of categories and spelling versions.

Table A1 shows the combinations of missing information in the component datasets of the census of “first-level hospitals and facilities below”.
(“–“ signifies missing, “√” signifies available).

Table A1: Information available and missing in HFC datasets

Facility	GPS	Delivery services	Human resources	Utilities	Equip-ment	Number of records
√	√	√	√	√	√	1335
√	√	√	√	√	–	10
√	√	√	–	√	√	7
√	√	√	√	–	√	1
√	√	√	–	√	–	2
√	√	√	–	–	–	1
√	√	–	√	√	√	9
√	√	–	√	√	–	3
√	√	–	–	√	–	23
√	√	–	–	√	√	3
√	√	–	–	–	–	1
√	–	√	√	–	√	1
√	–	–	–	–	–	1
–	–	√	–	–	–	1
–	–	–	√	–	√	3
–	–	–	√	–	–	3
–	–	–	–	–	√	1
1397	1395	1358	1365	1392	1360	1405

Four facilities with missing delivery services information are prison facilities, one is a mental rehabilitation centre and one a hospital in construction at the time of the census.

For 12 facilities out of the 1370 with the necessary data, instead of “yes” or “no”, “no answer” is coded for whether they offer delivery services (i.e. record not missing but information not available) and answers on the subsequent detailed delivery service questions are missing. The question whether the facility provides any maternal health services was answered with “N/A” for all but one of these, which presumable means they do not provide any such services including no delivery services. Therefore, these were coded as not providing delivery services.

In the human resources dataset from the “first-level hospitals and below”, I numbercoded medical staff cadres and grouped them into doctors, nurses and clinical officers in line with the categories in the questionnaires. No separate information on midwives is available in this dataset. Three medical licentiates, who are experienced clinical officers with an additional two-year training in surgery and thus can perform C-sections, were counted as doctors. In some cases, there were multiple lines for the same staff cadre in a facility. For those where it seemed clear what the mistake was (e.g. two lines for clinical officers with one containing 2 males and the other 10 females, but no line for nurses), these were corrected. In all other cases the option with the higher number of staff was chosen.

Concerning the utilities dataset, there is information on electricity, water source, communication means and transport means.

- For transport means an extra 137 records are missing (which amounts to more than 10% of records). It was found that only a small fraction of facilities who claim to provide transport for referral actually have their own vehicle. However, according to external information, it does not seem unlikely that they are able to get hold of a vehicle for referral nevertheless, sent from the district hospital or otherwise. Therefore, the presence of a working vehicle at the facility was not used for classification of the functioning of facilities. Instead, I relied on the information given in the delivery services dataset on whether transport is provided for emergency referral.

- Information on water access is grouped into mains, borehole and others in the dataset. Many facilities seem to have satisfying water sources other than mains and borehole (e.g. pipe from spring) and the string-coding of these sources made it difficult to judge and classify. Therefore, water source was not used in the classification system.
- The information on working communication tools (landline, cellular phone, fax, high frequency (HF) radio, very high frequency (VHF) radio, internet) was combined with the information on use of communication tools for emergency obstetric care referral in the delivery service dataset. Only if a facility both claimed to use a communication tool for EmOC referral and there was a tool available and working, was it classified as functioning in terms of EmOC communication. This may have overlooked facilities with working communication tools that do not use them but refer directly in a vehicle. However, this is not a problem since for the facility classification communication availability is always used in conjunction with transport.

The equipment dataset was not used since there is no numbercoding and there are thousands of items with various spelling versions.

The dataset for the 24 second- and third-level hospitals contains slightly different and in general more detailed information than the dataset for all other health facilities (see Box 2). For the sake of consistency, most of this additional information was not used except for checks. For example, midwives were recorded separately and all facilities had midwives, but I coded them as nurses. The facility identifiers used for the 24 large hospitals overlapped with the identifiers used in the other dataset. Therefore, I created new facility identifiers for the 24 hospitals before merging the datasets.

I performed a number of consistency checks on the data.

- One facility that provided all signal functions, was wrongly coded as not providing delivery services. This was corrected.
- Nine facilities (of which 5 hospitals) that claimed to do C-sections had no doctors registered or on duty at day of visit. (This highlights the importance of using several criteria to judge EmOC status, since performance of signal functions was not checked in depth but just reported in the HFC)

- For second- and third-level hospitals there is information on whether vacuum and forceps deliveries are performed, their numbers and the number of C-sections (presumably in the last 3 months, no time period given). One hospital reported C-section availability but 0 C-sections done. Three hospitals, where presence of the signal function "assisted vaginal delivery" was answered affirmatively, reported that neither forceps nor vacuum delivery were available. (This serves as a reminder to be careful about believing presence of this signal function in the first-level hospitals and health centre dataset as well.) The amount of missing data on these questions is very high, however, and I did not use them for classification in order to keep consistency with the other dataset.
- I examined all the facilities where registered numbers of staff were lower than those on duty/present in order to see if registered numbers should be corrected upwards. This was the case in nine facilities but it turned out that it would not make any difference to the EmOC classification in any of these cases, so no change of registered numbers was done for the distance analysis. However, for the analysis of health professional coverage by province and district (section 4.2.2), the numbers registered were set equal to those present.
- Staff cadres and sex were cross-tabulated. One facility had 6 female clinical officers and no male nurses. However, this should not matter since the classification considered both nurses and clinical officers as relevant health professionals.
- I compared my results with those in the preliminary report by JICA (percentage of facilities with delivery services offered by province, and percentage of facilities with delivery services where a doctor or a midwife are present on site or on call for 24 hours by province) and obtained the same numbers.
- Comparing the utility data to the figures in the JICA report showed similar numbers for water and electricity availability, but the percentage with communication tools differed to a large degree. The total number of facilities in the report adds up to 1700 however, which implies there must be some mistake in the report.

GPS data

There are two different versions of GPS coordinates for the Zambian health facilities, one in Excel (or dbf) tables and the other one in the ACCESS database. In the dbf version, latitude and longitude are in decimal degrees while the Access database has "degrees", "minutes" and "thousands" recorded. (Usually, GPS coordinates are either decimal or in degrees, minutes and seconds (DMS).)

For most records, the decimal dbf version corresponds to the Access version with thousands referring to thousands of minutes (decimal = degrees + minutes/60 + thousands/60 000). However, for about 10% of records, this is not the case. It appears that the decimal version in these cases was not derived from the Access version but rather entered from external information.

Furthermore, in a substantial number of consecutive records in the Access version, the "thousands" contain decimal points (sometimes only the latitude or the longitude and sometimes both) and never exceed 60 or 600. This raises the suspicion that the "thousands" are rather conventional seconds or seconds multiplied by ten.

This means there are four potential ways the GPS coordinates could be read, including three version how to treat the "thousands":

1. "thousands" = seconds (1/3600 degrees), called version2 or v2
2. "thousands" = seconds*10 (1/36000 degrees), called v2corrected or v2corr
3. "thousands" = minutes/1000 (1/60000 degrees), called version3 or v3
4. using the decimal dbf version that can disagree from v3 (and v2 or v2corr)

In order to find out which reading is correct, I checked facility locations on Google Earth, city maps, by internet searches and personal emails to mission facilities for all hospitals, facilities with C-sections and a large number of other facilities. While it is often difficult to tell which version is correct, in many cases, in particular in towns where detailed maps are available and where Google Earth has good resolution, this is well possible. In other cases, one can tell at least which version must be wrong (e.g. across the border or in the middle of a forest).

It became clear that for different facilities, different ways of reading the coordinates were correct. A pattern emerged that for consecutive facilities (in the same district) usually the same reading was correct. Therefore, I came up with an algorithm (Box A1) under which circumstances to believe which version.

The final "best guess" version was compared to the facility coordinates in the two districts where WHO's Service Availability Mapping (SAM) was done. Facilities were matched by name and type. 32 facilities existed in both the SAM and the HFC dataset and had GPS coordinates recorded in both. 29 of those had virtually identical coordinates. Of the 3 that differed, in two the SAM version seemed to be correct and the HFC off by 4km and 7.5km respectively. For the third one, an urban health centre in Kafue, the HFC located it correctly inside Kafue centre, while the SAM version located it 42km further east in a forest which seems highly implausible. Some other checks also highlighted that the "best guess" version of the HFC coordinates is not perfect and that the correction algorithm may need to be even more complicated.

Of the 1419 health facilities that had facility information and geographic information recorded, the geographic data was in fact not existent for 26 (coded as 999, many of these defence facilities, or for some facilities clearly wrong in the ACCESS database as coordinates were placed abroad and not available in the dbf table). So in total 1393 facilities could be used in the GIS analysis.

Box A1: Algorithm to identify the (most likely) correct GPS coordinates

1.) Is the third column of the “DMS”, i.e. the “seconds” sometimes larger than 600 in this district?

If yes: This means the third column is thousands.

2.) Is the dbf version the same as v3 (i.e. DMT)?
If yes: Use the dbf=v3

If no: 3.) Is there an obvious mistake in the Degrees or Minutes? (map!)
If yes: Correct the DM and use v3
If no: Use dbf since it is probably an improved version with external information

If no: This means the third column is probably either seconds or seconds*10.

2.) Is the dbf version the same as v3?
If yes: Use v2 or v2corr (i.e. treat the third column as seconds or seconds*10)

If no: 3.) Is there an obvious mistake in the Degrees or Minutes? (map!)
If yes: Correct it and use v2 or v2corr then
If no: Use dbf since it is probably an improved version with external Information

B) Ward classification in urban and rural

Figure B1a and b: Mnyamazi ward in Eastern Province with Lundazi town as an example of an "urban ward" with a small town in a rural area

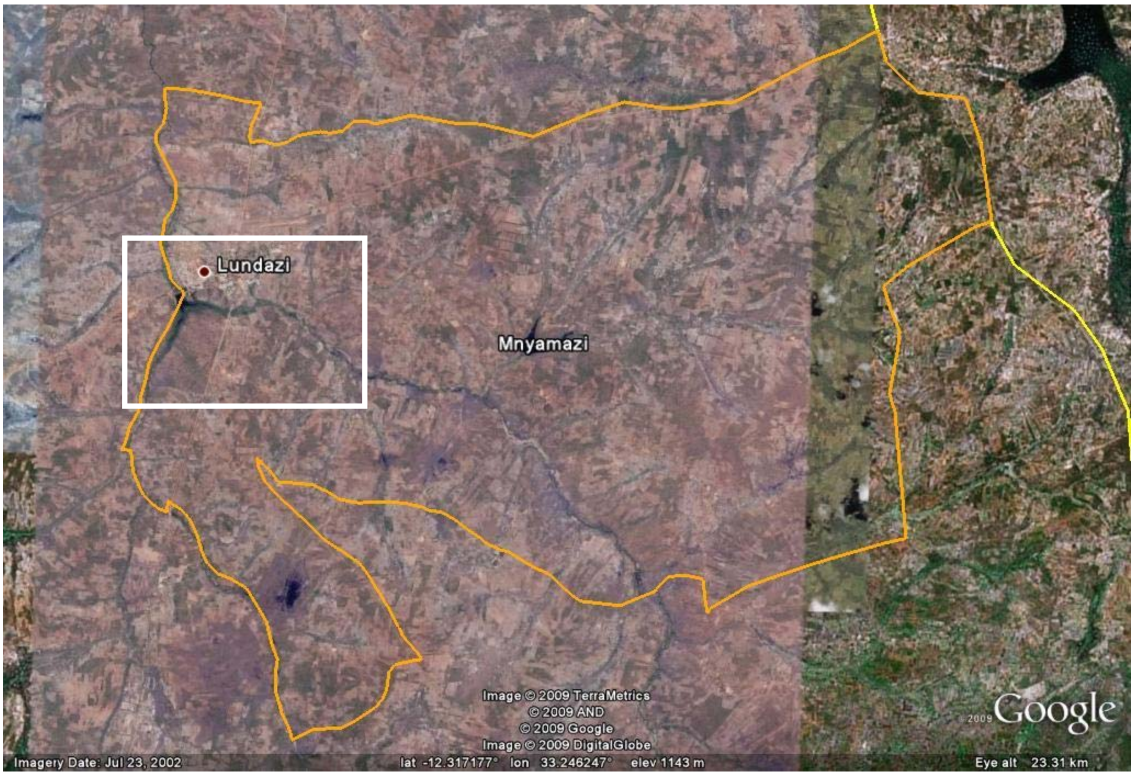
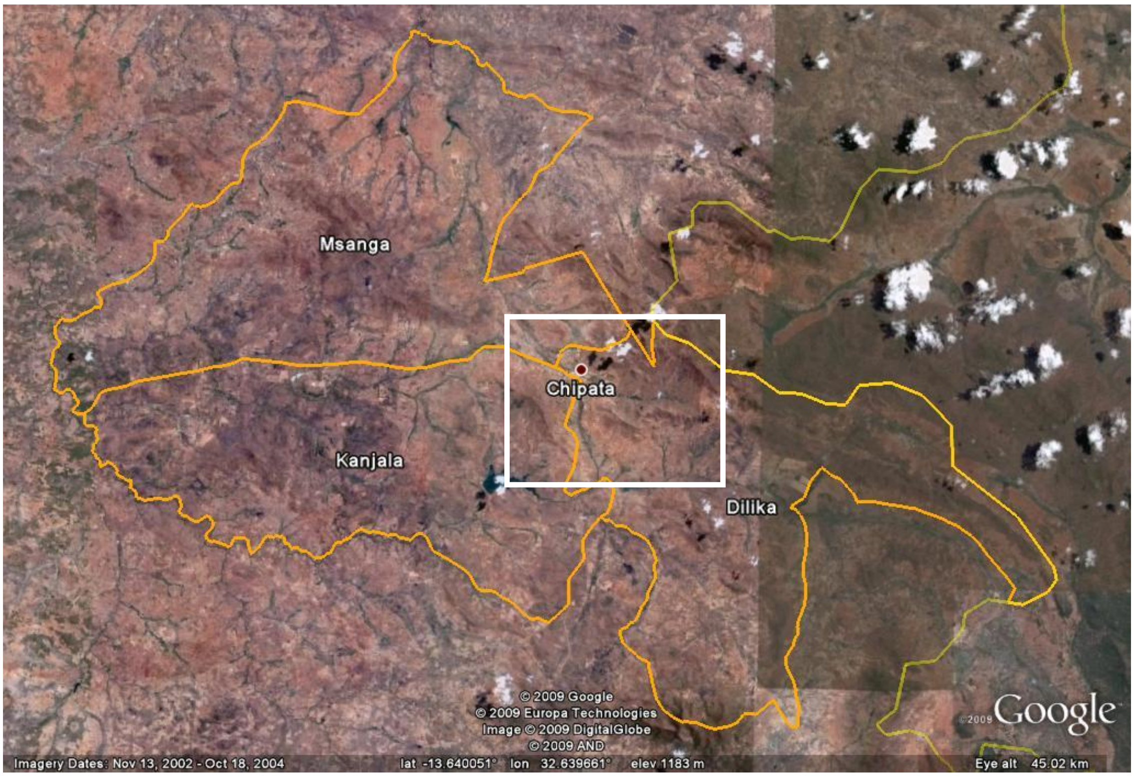


Figure B2a and b: Chipata town in Eastern Province at the intersection of three "urban wards" that each only contain a small urban part



C) Details on DHS 2002 GIS data cleaning

As explained in chapter 2.4.3, I checked whether the DHS cluster geographic coordinates were really located in the province, district, constituency and ward specified. I found that for 54 of 276 (20%) clusters the coordinates did not match with the administrative information. Further checks on these were performed in Google Earth after importing the cluster locations into Google Earth using the “Export to KLM” function in ArcGIS and also displaying ward and district borders for orientation.

Before going into detail about how I dealt with the inconsistencies between DHS cluster administrative information and DHS cluster coordinates, I have to explain why I considered the administrative information more reliable than the coordinates.

Firstly, it seems more likely that the DHS interviewers had correct information on the provinces, districts, constituencies and wards they were working in than on the geographic coordinates of the clusters. In fact, Andrew Inglis from Macro International informed me that the coordinates were entered by the Zambian government after completion of the DHS fieldwork using old census data (personal communication).

Secondly, some coordinates only have two digits after the point which suggests they may not originate from a GPS reading but were read off a map, a process which is never very accurate. This is supported by the observation that a substantial number of coordinates for the clusters were clearly located in uninhabited land, inside a mine or outside the Zambian border (mostly only a few km from a settlement).

Thirdly, there are some clusters with different administrative information (e.g. different ward names) but with the exact same coordinates, in some instances even three clusters apparently in one place, which suggests that the coordinates for some of these clusters are incorrect.

However, the administrative information on the clusters is also not entirely reliable. In the consistency check, 4 clusters were noted where the constituency (level above ward) names from the administrative information and from the projected location were not identical, but the ward names were.

Given that coordinates and ward names were consistent, I assumed that there was a mistake in the constituency name.

When checking the administrative boundary data from the census in Google Earth, I found that it mostly corresponded very well with prominent landmarks such as rivers and roads and could be relied on. However, in some places, especially in the small urban wards of the Copperbelt, the ward boundaries seemed clearly off by approximately 1 km. This was judged by landmarks and the shape of certain suburbs / wards.

Upon further examination, 7 of the 54 clusters that fell outside their wards were considered correct as being on or just across the ward border, and another 10 clusters were only 1-2 km inside the neighbouring ward. The remaining 37 cluster coordinates (of 276, i.e. 13%) were clearly located in a ward different to that indicated by the administrative information and at least 3 km from the border. 14 of the 37 clusters were 50 km or more away from their supposed location.

For example, in Northern Province, there were 6 clusters from Mbala district with coordinates in Mpika district, which is more than 300 km further south. For two wards in Kasempa district and constituency in North-Western Province, it seemed that their coordinates were interchanged as each lay in the other's territory.

While some cases were easily corrected, for most clusters with misplaced coordinates it was difficult to know where the coordinates should actually be located. Similarly, it was difficult to find the location for the 44 clusters for which the DHS data did not provide any coordinates (all Luapula clusters and some others). For small wards, it seemed reasonable to guess the coordinates, but for larger wards I could not attempt to place them anywhere and thus had to exclude those clusters.

D) Variable construction details

Numbers refer to the complete birth dataset Zambia DHS 2001/2002 and DHS 2007, including multiple births, urban births and movers

ID VARIABLES

- **Cluster** = numerical cluster id, 320 clusters in 2002, 319 clusters in 2007
- **Hhid** = numerical household id with cluster number on it (unique), 4115 HH in 2002, 3858 HH in 2007 (hhid2 is string version)
- **Mumid** = numerical version of caseid, 4495 mothers in 2002, 4148 mothers in 2007
- **Birthid** = 1,2,3, etc, giving second twins (and the third triplet) the same ID as the first baby of the multiple birth, 6767 births in 2002, 6267 births in 2007
- **Childid** = 1,2,3, etc, after sorting by mumid and within mumid by birth order, 6877 children in 2002, 6401 children in 2007

OUTCOME VARIABLES

- **Attendant** = Exact information on most qualified delivery attendant: doctor, nurse/midwife, clinical officer, TBA, relative/friend, nobody, other. (13 missing values in 2002, 20 in 2007)
- **Skilat** = Skilled attendance: doctor, nurse/midwife or clinical officer assisted as opposed to relative/friend, TBA or nobody. 41% in whole sample in 2002, 48% in 2007
- **Place** = Exact information on place of delivery: respondent's /other home, government hospital, government health centre / health post / other public, mission hospital/clinic, private hospital/clinic/other, other. (19 missing values in 2002, 16 in 2007)
- **Facdel** = Facility delivery: delivery place was a health facility of any kind as opposed to respondent's home, other's home or other (non-facility). 41% in whole sample in 2002, 49% in 2007

EXPOSURE VARIABLES

- **Danyfac, democ1-7** = Distance to closest health facility of any kind, to closest health facility offering delivery care, offering at least BEmOC-4, BEmOC-2, BEmOC-1, BEmOC, CEmOC-1 or full CEmOC. In 2002, there are 1265 missing values for births where the mother moved after the birth and an additional 863 missing values because GIS coordinates were lacking. In 2007, there are 1117 missing values for births where the mother moved after the birth.
- **Lndanyfac, lndemoc1-7** = Natural logarithm of danyfac and democ1-7.
- **Betterfac** = Indicator variable to be used alongside distance to closest delivery care (democ1) with four levels: whether the facility at that distance (or within 10km of that distance) offers substandard delivery care, BEmOC-4 / BEmOC-2, BEmOC-1/BEmOC or CEmOC-1/CEmOC.
- **Probdis** = Care-seeking for respondent herself, whether distance to health facility is big problem or no problem. (6 missing values in 2002, 7 in 2007)
- **Probtrans** = Care-seeking for respondent herself, whether availability of transport is big problem or no problem. (8 missing values in 2002, 10 in 2007)
- **Transmean** = Transportation mean available in the household: none, unmotorised (bicycle, animal cart, banana boat) or motorised (motorbike, motorboat, tractor, car or truck). (5 missing values in 2002, 1 missing value in 2007)
- **Clprobdis** = Percentage of women in cluster who say distance to health facility for own care-seeking is a big problem. (cluster average of probdis). Grouped into <25%, 25-49%, 50-75%, >75%. (no missing values)
- **Clprobtrans** = Percentage of women in cluster who say transport availability for own care-seeking is a big problem. (cluster average of probtrans). Grouped into <25%, 25-49%, 50-75%, >75%. (no missing values)

POTENTIAL CONFOUNDING VARIABLES

1) Particular pregnancy

- **Agegrp** = Mother's age at index birth (not age at interview): calculated from child's DOB and mother's DOB, grouped into 13-17, 18-19, then 5-yr groups, and 35-49 yrs, (no missing values)
- **Bordgrp** = Birth order of index birth / parity: 1, 2-3, 4-5, 6+, (no missing values)
- **CS** = C-section: Whether index birth delivered by C-section (3 missing values in 2002, 5 in 2007), 133 C-sections overall (1.9%) in 2002, 183 C-sections overall (2.9%) in 2007
- **Twin** = whether index birth was a multiple birth. In 2002, there are 109 twin births and 1 triplet birth, i.e. 219 babies are from multiple births. In 2007 there are 133 twin births and 1 triplet birth, i.e. 267 babies are from multiple births, (no missing values)
- **Wanted** = wantedness of pregnancy at time of pregnancy: wanted then, wanted later or wanted no more children (3 missing values in 2002, 19 in 2007)
- **Season** = season of birth: according to month of birth in relation to harvest season and rainy season. Nov-Feb: rainy, pre-harvest, Mar-May: rainy, harvest, Jun-Oct: dry, (post)harvest. (no missing values)
- **Resbirth** = residence place at time of birth: whether the mother lived in a rural or urban area at the time of the index birth. Constructed from current place of residence (no missing values) for those who never moved or who moved before the birth of the child, and previous place of residence (4 missing values in 2002, 18 missing values in 2007, kept current residence) for those who moved after the birth of the child. Not exact since date of moving not known. Used previous place if full years since birth > years of residence at current place.
- **Resmove** = residence place at time of birth, including whether the mother moved before the birth and if so from where to where. For those who moved after the birth of the child, same procedure as in resbirth. For those who moved before the birth of the child, created 4 categories according to rural/urban moves. (4 missing values in 2002, 5 in 2007)
- **Movegis** = moved after birth of child or is visitor at the place of interview, so that the GIS coordinates as well as other cluster characteristics are not

the same as at the time of birth of the child. In 18% of total births in 2002 and 17% of births in 2007.

- **Prevnbd** = previous newborn death: whether the mother had any newborn die before the index birth. Calculated by importing the DOB of those children who died as newborns from the individual dataset (in order to include births before the previous 5 years), and then checking whether those DOB were before the DOB of the index birth (as opposed to being the same birth or later). Coded as none, one, two or more. (no missing values)
- **Prevsb** = previous stillbirth: whether the mother had a stillbirth (terminated pregnancy at month 6 or later) at any time before the index birth (questionnaire recorded the last one only). Calculated by importing the date of the stillbirth from the individual dataset (if mothers gave not the date, but only the year, I took mid-year for those) and then checking whether this occurred prior to the index birth. (In 2002 information on gestational age is missing for 11 terminated pregnancies, in 2007 for 293 since in 2007 only asked if event was in previous 5 years)
- **Prevcs** = previous C-section: whether any birth before the index birth was a C-section. Calculated by checking whether any of the births preceding the index birth in the birth dataset were by C-section (i.e. only comprising births in the 5 years preceding the survey - since mode of delivery only asked for those). If so, then coded yes. If all births to a mother happened in the past 5 years and none by C-section, then coded no. If some births happened before (for which we lack information on mode), coded as no information.
- **Preca** = previous child's age: calculated preceding birth interval as number of months between index birth and the previous birth. Grouped into 9-17m, 18-23, 24-35, 36-47, 48-59, 60+ and first births / their twins. Then created a separate category for those cases where the previous child (or both twins) had died before the index birth. Calculated by computing date of death in the individual dataset for all children who died, then importing this into the birth dataset and then checking whether the child just before in the birth order died and whether its date of death lies before the index birth.
- **Sib7ad** = Household composition of adults and siblings under age 7: combination of sib7 and hhadult. Categories: No siblings under age 7, sibling(s) under age 7 and father / 1 other adult / 2 adults / 3+ adults / no adults besides mother. (no missing values)

- **Sib7** = Number of older siblings under age 7 alive at the time of the index birth. Constructed by importing dates of birth and death for all siblings from women dataset and calculating number of siblings born less than 72 months before the index birth that did not die before the index birth.
- **HHadult** = Adults over age 15 who are regular residents of the household at time of interview besides the mother: nobody, husband, other adult, two adults, three or more adults. Constructed in the household member dataset by counting all adult members and checking whether the second member was husband/wife for two adults-households.

2) Mother variables

- **Reli** = religion: protestant, catholic or other (6 missing values in 2002, 13 in 2007)
- **Ethnic** = ethnic group: collapsed those with less than 3% of rural births in 2002 into "others", same categories in 2007. (no missing values)
- **Lang** = respondent's language: 7 different languages (Bemba most common) and "others", from questionnaire info (10 missing values in 2002, none in 2007)
- **Educ** = education in years (15 missing values in 2002, none in 2007)
- **Edmum** = highest educational attainment: none, incomplete primary, complete primary, incomplete secondary, complete secondary/higher. Combined complete secondary and higher since very few. (no missing values)
- **Literate** = ability to read sentence on card: illiterate, partly literate (can read part of sentence), literate. (11 missing values and 50 put to missing as no card available in required language in 2002; 10 missing values and 135 put to missing due to lack of card or visually impaired)
- **Media** = frequency of media use (newspaper/magazine, radio or television): not at all, <1/week, 1/week or more, almost every day. (8 in 2002 and 5 in 2007 had missing value for one media type but other two media types "not at all" – put to not at all)
- **Info** = exposure to health information in the media: consists out of score from family planning information in any media in last few months and knowledge of 4 radio health programs (or alternatively 4 television programs or a certain newspaper). Grouped into no exposure to anything,

exposure to some (1-3 informations/programs) and exposure to many (4-10). (Each of the component variables has less than 10 missing values, assumed no knowledge for those with missing values)

- **Currmar** = current marital status: never union, married, with partner, widowed, divorced or separated, (no missing values)
- **Marital** = current marital status collapsed into never married, currently married, formerly married (partner included into married)
- **Marstat** = current marital status: like currmar but separating out whether those married are living together or apart. (6 married women had no information on where living in 2002 and 8 in 2007, assumed living together with husband)
- **Occ** = Mother's occupation: Combined some small groups with similar ones. Categories: agricultural self-employed, agricultural employee, no occupation, prof/tech/manag/clerical, household&domestic, services, skilled/unskilled manual. In 2007 there is no category household & domestic, instead there is sales which was combined with services. (6 missing values in 2002, 12 in 2007)
- **Hused** = Husband's educational attainment. Same as for edmum. Not asked for 390 births to never married women. 78 don't know answers in 2002 and 99 in 2007. (6 missing values in 2002, 21 in 2007)
- **Husocc** = Husband's occupation. Same as mother's occupation. (42 missing values in 2002, 171 in 2007)
- **Aufin** = Financial autonomy. Score from variables on decision-making on large purchases and on spending of woman's own money. Two points for each if woman alone, 1 point if jointly with other person. Women who don't earn money have missing value for that variable, i.e. can get 2 points maximum. Question only asked to currently married women in 2007 (not married extra category). (For large purchase 33 values missing or "not applicable" in 2002, 9 missing in 2007, for own money spending 8 missing values for money-earning women in 2002 and 17 in 2007, put to missing if any missing.) Collapsed 3 and 4 points into "high" financial autonomy, 2 points called medium, 1 low and 0 none. (41 missing values in 2002, 20 in 2007)
- **Auhc** = Health care-seeking autonomy: Used question on decision-making on own health care (12 missing values in 2002, 9 in 2007 and only asked to currently married – separate category). High autonomy if woman decides alone, medium if together with other person, low if other person decides for her. (19 missing values in 2002, 11 in 2007)

- **Aumob** = Mobility autonomy: Decision-making for visits to friends and relatives. Two points if woman decides alone, 1 point if together with other person. Classified 0, 1, 2 points as low, medium and high. (18 missing or “not applicable” in 2002, 9 missing in 2007)
- **Aurel** = Relation autonomy: combination score using the following 9 variables in 2002: agediff, agemar, age1bir, polyg, discfp, dischiv, nobeat, nosex, fertil. In 2007 different questions were asked and the following 7 variables used: agediff, agemar, age1bir, polyg, nobeat, nosex, nego. The most autonomous answer scores 5 points (exception: 6 for age1bir and agemar, 4 for nosex in 2002, since that is number of categories there). In 2002 total maximum score thus 46, range from 2-45. In 2007 maximum score of 37, range from 2-37. Those with some components missing had their average from the others added for the missing component(s) in order to avoid too many missing values. Unmarried coded as missing (in 2002 never married, in 2007 currently unmarried not asked). Categorised version: unmarried separate, rest categorised in four groups with extreme ones smaller.
    - **Agediff** = Age difference to husband. Husband younger/same age, 1-3 years older, 3-7 years older, 7-10 years older, more than 10 years older. (20 missing values in 2002, 40 in 2007)
    - **Agemar** = Mother’s age at first marriage. Grouped into <15, 15,16,17,18,19-20, >20. (no missing values)
    - **Age1bir** = Mother’s age at first birth. Grouped into <16, 16,17,18, 19, 20-21, >21. (no missing values)
    - **Polyg** = Polygamy. Whether woman is monogamously married or polygamously married or not married. (21 missing values in 2002, 5 in 2007)
    - **Discfp** = Discussed FP with partner in last year: never, once or twice, more often, no partner. (10 missing values, only in 2002)
    - **Dischiv** = Discussed HIV prevention with partner ever: yes, no, no partner. (32 missing values, only in 2002)
    - **Nobeat** = Attitude towards justification of wife-beating. Number of reasons respondent denied that wife-beating is justified of the 5 reasons asked (goes out without telling, neglects children, cooks bad food or food is late, refuses sex, argues with him). Counted the don’t know and missing answers (2 for two reasons in 2002, 2 for one in 2007) as not denying justification. (6 missing values for all components in 2007, none in 2002)

- **Nosex** = Attitude towards wife's right to refuse sex with husband. Number of reasons respondent accepts that refusal is justified of the reasons given (husband has STI, has other women, recent birth (only in 2002), not in mood). Counted the don't know and missing answers for single components (1 in 2002, 5 and 7 in 2007) as not accepting justification. (3 missing values for all components in 2002, 7 in 2007)
- **Fertil** = Decision-making on fertility, i.e. how many children to have and when. 5 points if decision alone, 3 if joint decision with husband or someone else. (346 coded as "not applicable", 4 missing values, only in 2002)
- **Nego** = Negotiation with partner: refusal of sex possible and could ask to use condoms. 5 points if both possible, 3 points if one. (12 missing values, only in 2007)

- **Auvio** = Violence from husband. In 2002 combination of violphys and violsex: none, either, or both types of violence, never married separate. In 2007 combination of control, novioemo, novioless, noviosev, noviosex. Maximum of 5 points for each component if none of the violent behaviours experienced (6 points if none of the 6 control behaviours). Violence questions were only asked to one woman per HH and only to married women (except violsex). Unmarried coded as missing. Categorised version in 2007: unmarried separate, rest categorised none/low, medium and high. (2141 missing values in 2002, 1362 in 2007)
    - **Violphys** = Physical violence from husband: yes/no, 2 "no answer" counted as yes.
    - **Violsex** = Sexual violence from anybody: yes/no.
    - **Control** = Husband control behaviour, combined variable from jealous when talking to other men, accuses her of unfaithfulness, does not permit her to meet her girlfriends, limits her contact with family, insists on knowing where she is and does not trust her with money.
    - **Novioemo** = Emotional violence, whether husband ever humiliated her, threatened with harm, insulted or made her feel bad.
    - **Novioless** = Less severe violence, whether husband ever pushed, shook or threw something, slapped, punched, kicked or dragged.
    - **Noviosev** = Severe violence, whether husband tried to strangle or burn, threatened / attacked with weapon, hit her during pregnancy and whether there were any physical results of husband's acts (bruises, injuries, burns etc, 2 points if any of this).

   - **Noviosex** = Sexual violence, whether husband forced sex when not wanted.
- **Modatt** = Modern fertility attitudes: using ideal number of children: modern (0-3 children), intermediate (4-6 children), traditional (7 or more or non-numeric response, e.g. as many as god sends). (4 missing values in 2002, 7 in 2007)
- **Husatt** = Husband's fertility attitudes: traditional, intermediate, modern, no husband. Created using wife's information on whether he wants same, less or more children than her (5 points if wants less children, 5 points if wants same number if wife desires 0-3 children, 3 points if same and wife desires 4 children, 1 point if same and wife desires 5 children) and (only in 2002) his approval of FP in general (5 points if approves, 0 points if disapproves or does not know). Grouped into 3 groups: traditional (0-1 points in 2002, 0 points in 2007), intermediate (2-6 points in 2002, 1-3 points in 2007) and modern (7-10 points in 2002, 5 points in 2007). (4 missing values in 2002, 45 in 2007)
- **Probmon** = Care-seeking for respondent herself, whether getting money for treatment or transport is big problem or no problem. (7 missing values in 2002, 14 in 2007)
- **Insure** = Mother covered by any health insurance scheme (yes/no). (only asked in 2007, 9 missing values)

3) Household variables

- **Sesown** = Household asset score constructed using own a priori scores (best category 10 points, worst 0 points for each item). Included 9 items in 2002: floor type, toilet type, water source, cooking fuel, food sufficiency, radio, phone, sugar and mosquito nets. In 2007, 18 items were used: floor type, wall type, roof type, toilet type, water source, cooking fuel, bank account, furniture, farm equipment, farm land, lifestock, radio, phone, watch, clock, cassette player, sewing machine and mosquito nets. Did not include electricity, fridge and television due to correlation with infrastructure. If information is missing for a single or few items (In 2002: for 37 households 1 item, for 4 HH 2 items, for 1 HH all items missing. In 2007: for 33 HH 1 item, for 1 HH 5 items, for 1 HH all items missing), imputed mean score from other items to avoid missing overall sesown score. (Also imputed land score if unknown size of own land, in 295 HH in 2007.) Categorised version with cutoffs at 10, 20 and 30 points in 2002 and at 20, 40 and 60 in 2007. (no missing values – the HH without asset information did not have any births)

Item	**Scores**
Floor type	10 points if carpet/tiles/other, 5 points if concrete/cement, no points if earth/dung/mud
Wall type	10 points if cement, 5 points if bricks/other, no points if natural/rudimentary
Roof type	10 points if tiles/cement/asbestos, 5 points if metal/other, no points if natural/rudimentary
Toilet type	10 points if alone use of flush toilet/ventilated pit latrine, 8 points if shared use of flush toilet/ventilated pit latrine, 5 points if alone use of traditional pit latrine, 3 points if shared use of traditional pit latrine, no points if no facility
Water source	10 points if piped into building, 9 points if piped into plot, 8 points if communal tap, 7 points if protected well in plot, 6 points if open well in plot, 4 points if protected public well, 3 points if open public well, 1 point if spring, no points if river/rain/lake
Cooking fuel	10 points if coal/electricity/gas, no points if wood/straw/other
Food sufficiency	10 points if usually/always enough food to eat, 5 points if sometimes, 1 point if seldom, no points if never
Bank account	10 points if owns, no points if not
Furniture	10 points for all 5 types of furniture owned (bed, table, chair, sofa, cupboard), 8 points if 4 types, 6 points if 3 types, 4 points if 2 types, 2 points if 1 type, no points if none.
Farm equipment	10 points if all 3 items (plough, grain grinder, hammer mill), 6 points if 2 items, 3 points if 1 item, no points if no items.
Farm land	10 points if over 10 hectar, 8 points if 4-10 hectar, 4 points if 2-3 hectar, 2 points if 1 hectar, 1 point if <1 hectar, no points if no own land.
Lifestock	Score system: 1 for chicken/other poultry, 10 for goat/sheep, 20 for pig, 50 for traditional cattle, 80 for dairy/beef cattle, 50 for horse/donkey/mule, 2 for other animal. 10 points if score>400, 8 points if score 101-400, 4 points if score 21-100, 2 points if score 6-20, 1 point if score 1-5, no points if no lifestock.
Radio	10 points if present, no points if not
Phone / mobile	10 points if present, no points if not

Sugar	10 points if present, no points if not
Watch	10 points if present, no points if not
Clock	10 points if present, no points if not
Cassette player	10 points if present, no points if not
Sewing machine	10 points if present, no points if not
Mosquito nets	10 points if 5 or more nets, 8 points if 4 nets, 6 points if 3 nets, 4 points if 2 nets, 2 points if 1 net, no points if no net

4) Cluster variables

- **Menmedia** = Men's average media use in the cluster. Calculated by using the men's dataset (2145 men in 2002, 6500 in 2007) and averaging the media use score over men in each cluster (0-3 points for the categories, see variable media). Categorised version with low, medium and high average men's media use. (49 missing values in birth dataset due to no men interviewed in 5 clusters, no missing values in 2007)
- **Meninfo** = Men's average exposure to health information programs in the cluster. Constructed like info (not categorised but put maximum score of 5 to not advantage those with television) for the men interviewed, then averaging the score in each cluster. (less than 5 missing values for all component variables, assumed no exposure if missing). Categorised version with low, medium and high average men's exposure to health information programs. (49 missing values in 2002, variable not constructed in 2007 dataset since most questions not asked then)
- **Menauto** = Men's average opinion on women's autonomy in the cluster. Constructed similar to women's individual autonomy variables and then averaged score in each cluster. Included variables on refusal of sex (nosex), wife-beating (nobeat), decision-making in general (spending of wife's own money, large household purchases, visits, fertility) and another four variables on what a husband has right to do if wife refuses sex (get angry and reprimand her, withhold financial support, use force to have sex, have sex with other woman). No points given for "don't know" category. Categorised version with low, medium and high average men's opinion on female autonomy. (49 missing values in 2002, none in 2007)
- **Menmod =** Men's average modern attitudes in the cluster. Constructed like husatt (different in 2002 and 2007), then averaged score in each

cluster. Categorised versions with traditional, medium and modern average men’s modern attitudes. (49 missing values, none in 2007)

- **Mensupp** = Men’s support for skilled attendance at delivery in the cluster. Categorised into <75% of interviewed men support, 75-95% and >95%. (no missing values, variable only in 2007).
- **Womedia** = Women’s average media use in the cluster. Calculated by using the individual women's dataset (all women, not just those with births in last five years) and averaging the media use score in each cluster (0-3 points for the categories, see variable media). Categorised version with very low, low, medium and high average women’s media use. (no missing values)
- **Wominfo** = Women’s average exposure to health information programs in the cluster. Constructed like info (not categorised but put maximum score of 5 to not advantage those with television) for all women interviewed, then averaging the score in each cluster. Categorised version with low, medium and high average women’s exposure to health information programs. (no missing values)
- **Womaufin** = Women's average financial autonomy in the cluster. Calculated average cluster scores (using individual dataset) for variables on decision-making on large purchases and on spending of women’s own money and added for total score. 5 points if decision alone, 3 if joint decision with other person. Women who don't earn money were not asked the latter question and were not given any points towards the score. Categorised version with very low, low, medium and high average women’s financial autonomy. (no missing values)
- **Womauhc** = Women's average health-care seeking autonomy in the cluster. Calculated average cluster scores (using individual dataset) for variables on decision-making on own health care. 5 points if decision alone, 3 if joint decision with other person. Categorised version with low, medium and high average women’s care-seeking autonomy. (no missing values)
- **Womaumob** = Women's average mobility autonomy in the cluster. Calculated the average cluster score (using individual dataset) for decision-making for visiting friends and family. 5 points if decision alone, 3 if joint decision with other person. Categorised version with low, medium and high average women’s mobility autonomy. (no missing values)
- **Womaurel** = Women's average relation autonomy in the cluster. Calculated the average of each of the components of aurel (9 in 2002, 7

in 2007, see aurel) in each cluster, using data from those women to whom the question applied (e.g. unmarried put to missing for age difference), and added the averages of all components into a total score. Categorised versions with very low, low, medium and high average women's relationship autonomy. (no missing values)

- **Womauvio** = Women's average violence experience from husband in the cluster. Calculated from components (see auvio, different in 2002 and 2007) in each cluster, adding for total score. Categorised versions with low, medium and high violence levels. (no missing values)
- **Womod** = Women's average modern fertility attitudes in the cluster. Constructed in the individual dataset by averaging the modern fertility attitude score of all women interviewed in each cluster. Categorised version with traditional, rather traditional, rather modern and modern average women's attitudes. (no missing values)
- **Clhusfp** = Percentage of husbands in cluster who approve family planning. Constructed in individual women's dataset with information on husbands approval. Categorised version grouped into five groups. (no missing values in 2002, variable does not exist in 2007)