Modeling the Impact of Traveling Time on the Utilization of Maternity Services Using Routine Health Facility Data in Siaya County, Western Kenya

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Abstract In Kenya, no studies have attempted to use routine health facility data disaggregated by level of care, to find out if there is a significant statistical relationship between physical accessibility and utilization of maternity services at the ward administrative level. A cross-sectional study design used publicly available geospatial data in combination with routine data from the web-based district health information software (DHIS2) platform. AccessMod (version 5.2.6) was used for travelling time analysis. ArcGIS (version 10.5) and R (version 3.5.3) sufficed for the preparation of geospatial input and the manipulation of AccessMod results respectively. The associations between the independent and dependable outcome was computed using a Zero-inflated Poisson regression model at 95% confidence level. The findings in Siaya County revealed a higher likelihood of a skilled delivery 35% (0.353; CI: 0.349–0.357) and 16% (0.164; CI: 0.162–0.167) respectively, for every unit increase in the proportion of pregnant women who could reach a hospital and health centre within an hour of walking, as compared to being within an hour of a dispensary 4.6% (0.046; CI: 0.045–0.048) using motorcycle transport. Simply advising women to opt for motorized transportation schemes to improve their access to low quality facilities, may in fact, result in diminishing returns. The immediate implication is that policy makers need to upgrade lower tier maternity health services in Siaya County, as pregnant women may value quality of services regardless of the distance. Future research should consider looking at the relationship between skilled delivery and the capacity of existing maternity health services.

Keywords Maternity services, Geographic information systems, Traveling time, Routine health facility data, DHIS2

1. Introduction

Achieving the sustainable development goals (SDG) target of a global maternal mortality ratio (MMR) of fewer than 70 maternal deaths per 100,000 live births by 2030 will require high-quality data to track progress and achievement (United Nations, 2017), so that no country should have an MMR greater than 140 maternal deaths per 100,000 live births, a number twice the global target (WHO, 2015). According to a 2016 United Nations (UN) report, about 830 women die from pregnancy- or childbirth-related complications around the world every day (Alkema et al., 2016). Almost all of these deaths occurred in low-resource

settings, and most could have been prevented (Say et al., 2014; You et al., 2015). More importantly, the SDGs further amplify the importance of local data to assess progress and allocate resources to reduce inequalities within high burden regions like Sub-Saharan Africa, where about 60 percent of maternal deaths occur during childbirth and the immediate postpartum period, with 50 percent of such deaths occurring within the first 24 hours after delivery (WHO & UNICEF, 2015).

On the other hand, more data on coverage of safe delivery indicators are collected, yet little is used to inform policy decisions in high burden countries like Kenya, where the MMR of 362 deaths per 100,000 live births currently remains well above the global rate of 210, despite the country falling short of its Millennium Development Goal (MDG) target of 147 per 100,000 (MoH, 2016). Data processing and analysis is usually centralized which often fails to provide feedback to lower organizational units, yet sub-nationally, only about half of mothers residing in rural areas of the country reportedly received skilled care or

delivered in a health facility compared to 82 percent of mothers residing in urban areas (KDHS, 2014). Nevertheless, despite devolution of healthcare and the introduction of free maternity services in Kenya, the use of skilled attendance at birth remains low in many places because of cultural reasons and because health facilities are inaccessible or services are perceived to be of poor quality in the lower middle-income country (KDHS, 2014; Ministry of Health (MoH), 2016; S. O. Nyangueso, P. Hayombe, & F. Owino, 2018). As such, methods that allow for better use of existing disaggregated data at the local level may be more useful for planners and decision makers, since aggregated maternal health indicators even at subnational level can often conceal important inequities, with the rural poor often least well represented (MoH, 2016).

Furthermore, only 15 out of 47 counties in Kenya accounted for 98.7% of the total maternal deaths in the country (UNFPA, 2014). Yet Siaya, the worst of six counties in Nyanza region, Kenya, with an unacceptably high MMR of 691 maternal deaths per 100,000 live births, also received the best ranking in terms of its overall readiness to provide maternity health services according to a previous service availability and readiness assessment mapping (SARAM) around the same period (Gok, 2014; UNFPA, 2014). However, use of routine health-facility data to assess coverage and prevalence of maternal and child health indicators, for example, has recently been recognized as an opportunity to provide more precise numerator estimates (Maina et al., 2017). As such, there is urgent need to move beyond summarized national and even subnational coverage estimates, and use local data to make programmatic decisions in priority settings where emphasis is currently placed on data aggregation and reporting.

Additionally, in settings like Kenya, nationally representative cross-sectional surveys such as Demographic and Health Surveys (DHS) and Multiple Indicator Cluster Surveys (MICS) will continue to provide vital statistics (Corsi, Neuman, Finlay, & Subramanian, 2012) at least at the first administrative level (provinces, regions or counties), even if sample sizes used in such perennial surveys do not meet the current demand for local coverage data, both in terms of timeliness and disaggregation (Alegana et al., 2017), despite recent progress in the implementation of electronic web based reporting systems that allow for easier and faster reporting and better data quality control and feedback for monitoring trends down to even the lowest administrative level (e.g. wards) (Maina et al., 2017). Today, district health information software, version 2 (DHIS 2) is the world's largest health management information system (HMIS) platform, in use by 67 low and middle-income countries, including national-scale deployments in 46 countries (DHIS2, 2019).

More importantly, in recognition of the key impact that Emergency Obstetric Care (EmOC) can have on maternal mortality and safe birth outcomes, global health policy experts like WHO categorically recommend the local use of Geographic Information Systems (GIS) based on travel time cost surface models, rather than unrealistic straight-line distances, in measuring physical accessibility to maternity health services, as time is a more comparable measure (e.g. between countries) than distances (Munoz & Källestål, 2012; Ray & Ebener, 2008; WHO, 2016a). AccessMod platform for instance, is a free and open source WHO developed spatial model which estimates the most efficient travel time to a health facility along established roads, walking paths and landscape barriers and has emerged as one of the most robust analytical spatial techniques applied in maternal health towards universal health coverage (UHC) (Ebener et al., 2015; Roth et al., 2016; Schmitz et al., 2019). Hence, in examining physical access to maternity health services or predicting skilled birth attendance, the application of geographic approaches and GIS to measure inequities in maternal health outcomes is critical to assess the situation and needs and guide policy decisions (Ebener et al., 2015).

In summary, the wider use of routine health facility data within the Kenyan context via robust and open source platforms like DHIS 2, may indeed provide an unprecedented opportunity for local decision makers to employ the power of existing GIS able to combine information on theoretical physical accessibility to maternity services, with more accurate and timely reporting on the numerators of the coverage for safe delivery indicators-to locate, measure and address the needs of most vulnerable pregnant women. Therefore, based on current GIS best practices from literature (Ebener & Stenberg, 2016a; Makanga, Schuurman, von Dadelszen, & Firoz, 2016; Schmitz et al., 2019), in combination with data on the actual use of available maternity services from DHIS2, the current study estimated how different transportation modes (walking and/or motorized) affected women's ability to utilize maternity health services at the ward administrative level. Thus, the urban areas population were spatially excluded and facilities were disaggregated by level of care (hospitals, health centres and dispensaries), towards a more realistic representation of the magnitude of the relationship between physical accessibility and utilization of existing maternity health services in rural Siaya County.

2. Materials and Methods

Study Area

Siaya is one of six counties in the Nyanza region of Kenya. It has a land surface area of approximately 2,530 km^2 and water surface area of approximately 1,005 km^2. It approximately lies between latitude 0° 26´ South to 0° 18´ North and longitude 33° 58´ and 34° 33´ East. The county consists of six sub-counties and thirty wards. Alego Usonga, Bondo and Gem sub counties have six wards each; Rarieda, Ugenya and Ugunja sub counties have five, four and three wards respectively; Alego Usonga is thus the largest sub county with an approximate area of 605.8 km^2, while Ugunja is the smallest with an approximate area of 200.9 km^2 (Siaya

County, 2018).

The female reproductive population was estimated at 222,846 representing 22.7 per cent of the population and was projected to increase to 238,527 and 273,276 persons in 2022 and 2030 respectively. The county's population density of 318 per square kilometer is further anticipated to increase to 415 and 476 in 2022 and 2030 respectively. In terms of the population distribution by residence, 89 per cent of Siaya County residents currently live in the rural areas. As of 2017, the county had 434.2km of bitumen standard roads, 1297.41km of gravel, 532.78 km of earth and a further 1,170 narrow roads. The main development challenges include poor infrastructure, inadequate water supply, erratic electricity supply, high prevalence of HIV/AIDS and high unemployment; as a result, about 47.5% of the total population in the county currently lives below the poverty line (Siaya County, 2018).

Moreover, by 2018, the number of health facilities registered in the county were 220, comprising 11 hospitals (level 4), 50 health centres (level 3) and 159 dispensaries (level 3). (S. O. Nyangueso, P. O. Hayombe, & F. O. Owino, 2018). The County's uptake of Antenatal care and skilled Birth Attendance was higher than the national average, but it is not certain whether all the demand was met within or there was spill over to neighboring Counties. According to last demographic and Health Surveys (DHS), percentage mothers receiving antenatal care from a skilled provider in the county was 98.5% as compared to 95.5% nationally (KDHS, 2014). Similarly, percentage mothers who delivered in a health facility was 66% compared Kenya's 61.2%, yet the demand for the maternal services in 2018 was 38,972 annually, as depicted in the **figure 1** below (Samuel Ouma Nyangueso et al., 2018).
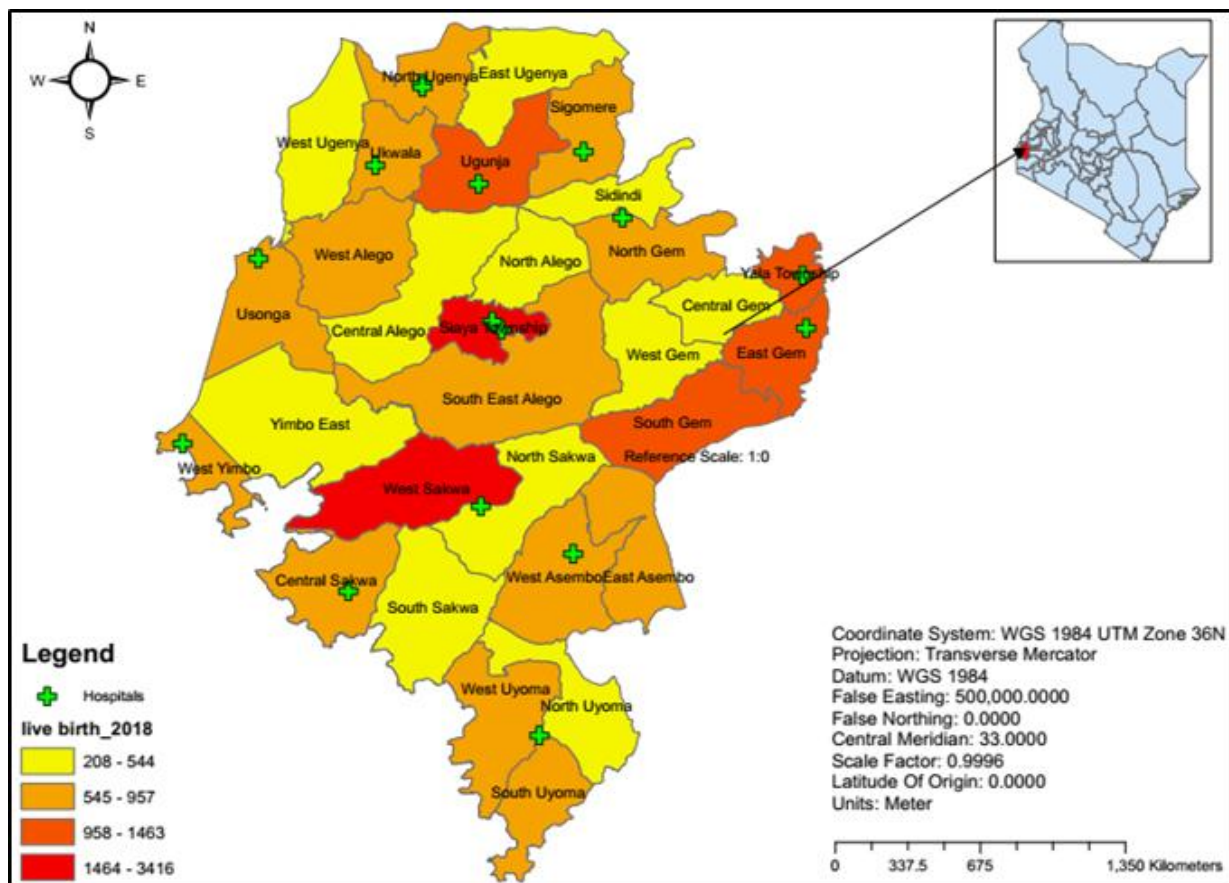

Figure 1. Study Area

Study Design

The current cross-sectional study used publicly available geospatial data in combination with local routine health facility data at the ward administrative level from the web based DHIS2. Traveling time to the nearest maternity health services was simulated using a travel time cost surface models in line with previous spatial accessibility studies based on Tanahashi (1978) framework of evaluating health service coverage (Ebener & Stenberg, 2016b; Munoz & Källestål, 2012; Ray & Ebener, 2008; Schmitz et al., 2019;

WHO, 2016b).

Zero-inflated Poisson model was then used to check if indeed there was a significant statistical relationship between skilled delivery coverage and physical accessibility of maternity services in the rural parts of Siaya County-based on walking / motorbike traveling time, albeit disaggregated by level of care. The target population consisted of all pregnant women living within the administrative boundaries of mainland Siaya County in 2018. The study inclusion criteria consisted of only pregnant women who delivered in

Tier two and three facilities offering free maternity health services. Private and/or for-profit facilities offering maternity health services including women living outside the administrative boundaries of mainland Siaya County were excluded from the study.

Accessibility Analysis Software

Modelling of geospatial data was made possible via AccessMod version 5—an open-source and standalone spatial model developed by the WHO (WHO, 2016a, 2016b), which is freely accessible through the AccessMod official web site (https://accessmod.org) and comes with a user manual and a sample dataset to guide users on the use of its different modules. Moreover, a third-party GIS software, ArcGIS (version 10.5), in combination with a free software environment for statistical computing and graphics, R

(version 3.5.3), sufficed for the preparation of input data and the manipulation of AccessMod results respectively.

Sources and Preparation of Input Data

Traveling time analysis using AccessMod 5 required several data sets (see **Table 1** below). Both raster and vector data were used as inputs, but the latter were transformed into raster data during the analysis. To mitigate potential resolution issues and ensure compatibility between the different sources of GIS data, and in order to produce accurate results, it was important that an equal-area projection was used for the data in order to avoid strong biases in the surface of the modeled catchment areas, and that meters were used as map units, so that travelled distances were correctly linked to the user-defined travelling speeds expressed in km/h.

Table 1. Characteristics of the various Input Geospatial Datasets

	Data Layer					
	Land Use Grid	Hydrographic Network	Road Network	DEM	Population Distribution	Health Facilities Coordinates
Data Format	Raster	Vector	Vector	Raster	Raster	Vector
Year	2016	2015	2015	2010	2018	2018
Spatial Resolution	30m	N/A	N/A	30m	100m	N/A
Source	Regional Centre for Mapping of Resources for Development (RCMRD)	Humanitarian Data Exchange (HDX)	Humanitarian Data Exchange (HDX)	Shuttle Radar Topography Mission (STRM)	WorldPop	DHIS2 and KMHFL
Description	Spatial distribution of the different categories of land use on which travelling speed may be different.	The hydrographic network layers (both lines and polygons for major rivers and water bodies) which act as barriers to movement.	This shapefile has different types of roads that can be incorporated and combined with the land use grid.	Altitude distribution used to derive slopes and correct travelling speeds in the case of walking scenario.	Spatially explicit distribution of population over the study area.	This point shapefile contains the geographic locations of the existing network of health facilities.

In particular, the traveling time analysis required to have the following GIS layers at disposal: 1. Administrative boundaries down to the ward level sourced from the Database of Global Administrative Areas (GADM); 2. Geographic point location of all existing facilities offering free maternity health services based on DHIS2, corroborated by the Kenya Master Health Facility List (KMHFL); 3. Road network and 4. Hydrographic network (major rivers and water bodies) were sources from the United Nations Humanitarian Data Exchange portal; 5. Land use/ land cover were sourced from Regional Centre for Mapping of Resources for Development (RCMRD); 6. Digital Elevation Model (DEM) was sourced from Shuttle Radar Topography Mission (STRM) digital elevation model data, at a spatial resolution of 30 meters (1 arc-second), from the U.S. Geological Survey; 7. A 2018 dataset of the spatial distribution of the population for Kenya was obtained from the WorldPop Project (Worldpop, 2019).

Moreover, all the geospatial datasets in raster format were homogenized in terms of projection and 30 m spatial resolution of the digital elevation model (DEM) raster. The Universal Transverse Mercator (UTM) projected coordinate system was sufficient, as the data needed to be projected in a metric system when performing the different geospatial analyses. Even if the urban areas population were spatially excluded using urban extent vector data from Global Rural-Urban Mapping Project, towards a more realistic representation of the magnitude of the relationship between existing geographic inequalities and utilization of free maternity health services. All input geospatial datasets were ultimately cropped to the administrative boundaries of mainland Siaya County.

Moreover, user defined tabular data for each transportation mode with a corresponding travel speed for every combined land cover class, under each travel scenario (walking and/or being carried on a motor cycle), was

specified in line with a recent study in Kigoma Region, Tanzania (Chen et al., 2017). This was important to simulate real-life travel experiences in which travel time may vary by terrains, road types, and transportation used. As such, various sources were used to ascertain the transportation-specific travel speed for each land cover type in the dry season, including a motorcycle analysis conducted in Hanoi, Vietnam (Chen et al., 2017; Oanh, Phuong, & Permadi, 2012).

For routine health facility data, the web based DHIS2 platform sufficed to collect the estimated number of deliveries or live births, including the actual number of deliveries that took place in a health facility across all 30 administrative wards in Siaya County.

Estimating Traveling Time to Maternity Services

To enable the traveling time modelling, both river and road network vector datasets, obtained from HDX, were transformed to raster datasets consisting of 30-meter gridded cells, and were then overlaid on the land cover raster dataset using the merge cover tool in AccessMod 5.0 toolbox. This created a combined land cover raster dataset with 10 unique land feature classes including 5 road land cover classes. The 5 non-road land cover classes included dense vegetation, medium dense vegetation, low dense vegetation, bare areas and built areas. For the purposes of analysis, water bodies and rivers were considered to be impassable to any form of transportation.

Moreover, a raster layer that describes the minimum travel time required to reach the nearest facility offering maternity services was created using the accessibility analysis tool in AccessMod 5.0 for each of the 2 travel scenarios (walking and/or motorbike). Furthermore, an anisotropic (slope-dependent) approach based on the DEM was used in the analysis for the walking only scenario, thus, a slope-based correction was applied to the user-defined speed as delineated in **table 2** below. This correction was based on Tobler's formula (Tobler, 1993), which basically decreases or increases the effective walking speed depending on the steepness of the slope of the terrain through the following formula:

$$V = VF * e^{-3.5*abs(s+0.05)}$$

where V is the corrected walking speed in kilometers per hour (Km/h), VF is the walking speed on a flat surface, and S is the slope in hundredth of a percent. On a flat terrain, this works out to 5 Km/h, with the speed decreasing to 0.7 Km/h for a 30° rise in slope. For the current accessibility analysis however, the upper limit of the estimated travel time was thus set at 1 hour, based on national recommendations for access to public health facilities in Kenya. Therefore, "good geographic access" was operationally defined as a woman's travel time to maternity services within 1 hour, while "poor geographic access" was defined as a woman's travel time to maternity services beyond 1 hour. Each scenario-specific travel time raster layer was represented by a single travel time zone (up to 59 minutes) based on each of the primary

transportation modes and health facility types (dispensary, Health Centres or Hospital). Therefore, all 1-hour service catchment areas for each corresponding travel scenario were mapped in ArcGIS 10.5 to show the distribution of areas within which one can reach maternity services in less than 1 hour).

Table 2. Travel Speeds, per Land Cover Type, by Travel Scenario

		Travel Speeds (km/hr)			
	Land Cover Type	Walking Scenario (Scenario 1)		Walking + Motorcycle Scenario (Scenario 2)	
1	Dense vegetation	1	WALKING	1	WALKING
2	Medium dense vegetation	1.5	WALKING	1.5	WALKING
3	Low dense vegetation	2	WALKING	2	WALKING
4	Bare areas	2.5	WALKING	2.5	WALKING
5	Built areas	2.5	WALKING	20	MOTORIZED
6	Bound surface	2.5	WALKING	40	MOTORIZED
7	Loose surface	2.5	WALKING	25	MOTORIZED
8	Dry weather road	2.5	WALKING	35	MOTORIZED
9	Main track motorable	2.5	WALKING	50	MOTORIZED
10	Other tracks and footpaths	2.5	WALKING	2.5	WALKING

Moreover, the zonal statistics tool in AccessMod 5 was used to calculate Accessibility coverage for each of the 30 wards in Siaya County using the corresponding administrative boundaries vector layer. Therefore, accessibility coverage was calculated using the total number of pregnant women per administrative ward as the denominator, and the proportion of pregnant women who can access maternity services within 1 hour of travel time in each ward administrative level as the numerator. More specifically, the estimated total number of people per grid-cell was used as a proxy measurement for the distribution of pregnant women in Siaya County, which is the target population of maternity health services, since expected births or pregnancies comprise 0.04 (4%) of the total population annually (Republic of Kenya, 2014b). A dataset of the 2018 spatial distribution of the population for Kenya was however obtained from the WorldPop Project (Worldpop, 2019). The value of each 100-meter gridded cell represented the estimated number of people in an area of 100 square meters in 2018.

Estimating the Likelihood of Skilled Birth Attendance

Delivery by Skilled Birth Attendant Coverage was the main outcome variable, this indicator was calculated using the number of women who actually delivered in a health facility as the numerator, and the total estimated deliveries as the denominator, albeit for each health facility type

(dispensary, Health Centres or Hospital) and across all the 30 administrative wards in Siaya county.

Zero inflated Poisson regression was used to model the statistical relationship between (the independent variable), accessibility coverage by walking / motorbike traveling time scenario, and Delivery by Skilled Birth Attendant Coverage (dependent variable) at the ward administrative level, albeit for each health facility type (dispensary, Health Centres or Hospital). The zero-inflated model was considered due to the excess number of zero cases of skilled delivery coverage, due to pregnant women's lack of and/or preference for particular facility types in some administrative wards in Siaya County.

The model was formulated as follows:

Suppose that for each administrative ward level number of skilled deliveries (Y_i), there are two possible outcomes for cases. The first case occurs when the count is zero. Nevertheless, the second case is generated when non-zero counts are registered and occurs with the probability $(1-\pi)$ assuming that the first case occurs with a probability of π where $0 < \pi < 1$ (Cameron & Trivedi, 2013; Zeileis, Kleiber, & Jackman, 2008). Thus, the probability of zero-inflated Poisson variable yi can be written as:

$$pr(Y_i = j) = \begin{cases} \pi_i + (1 - \pi_i)\exp(-\mu_i), & \text{if} \quad j = 0 \\ (1 - \pi_i)\dfrac{\mu_i^{y_i}\exp(-\mu_i)}{y!}, & \text{if} \quad j > 0 \end{cases}$$

Where μ_i is a rate parameter expressing the rate of ward level skilled deliveries.

The likelihood function prob (Yi=j) was then used as the family of the generalized linear model (glm). Moreover, for the zero inflated model, maximum likelihood estimation method was used to obtain the slope parameter estimates. Significance of the slope parameters were assessed using probability (p) value computed at 95% confidence level.

Ethical Considerations

The study protocol was approved by the the Jaramogi Oginga Odinga University Ethical Review Board in close collaboration with the National Commission for Science Technology and Innovation and the Siaya County health department, Division of reproductive health.

3. Results

Summary Statistics from DHIS2

According to data from the web based DHIS2 platform, in terms of facility ownership, 21,810 (86%) deliveries took place in public facilities owned by the Ministry of Health, followed by 2,894 (11%) deliveries in facilities owned by Faith Based Organizations, and only 834 (3%) of pregnant women preferred Private for-profit facilities as illustrated in **figure 2** below.
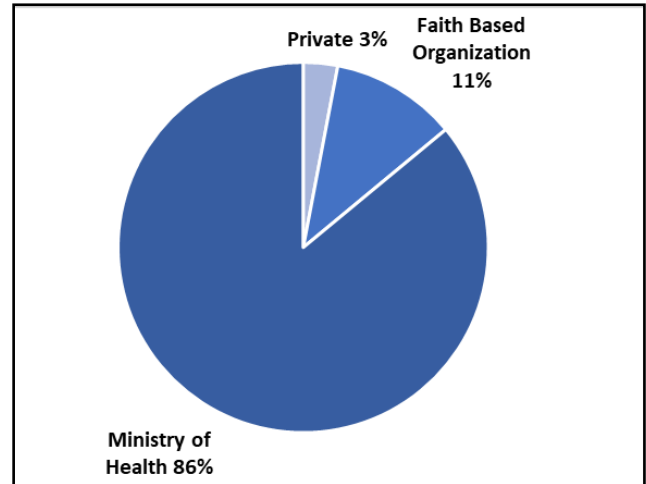

Figure 2. Comparing the proportion of total deliveries by health facility ownership in Siaya County

Furthermore, in terms of deliveries by health facility type, Hospital were the most preferred with 13,276 (52%) deliv-eries, Health Centres came second with 9,127 (35%) deliv-eries, despite Dispensaries and Medical Clinics recording only 3,140 (12%) and 212 (1%) of all deliveries respectively as shown in the **figure 3** below.
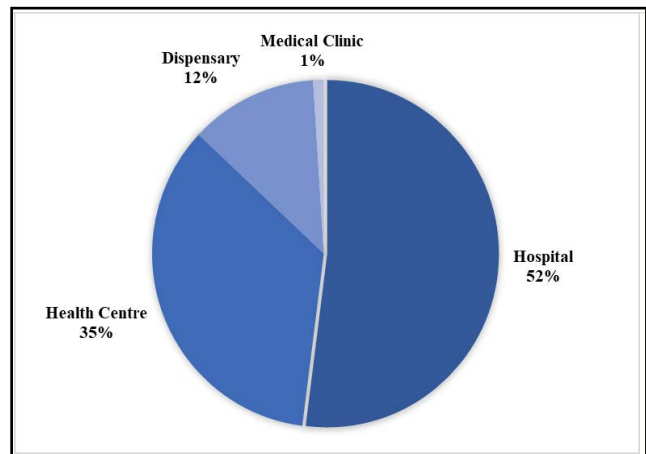
Figure 3. Comparing the proportion of total deliveries by health facility type in Siaya County

More importantly, only 25,755/38,972 (66%) facility deliveries were recorded in all private and government owned facilities in Siaya County, despite more than half (18/30) of the administrative wards in the county recording less than 50% of their estimated facility deliveries in 2018. In particular the worst performing administrative units in terms of skilled delivery coverage were Central Gem (11.9%) and Sidindi (18.5%) wards, even if Siaya Township (243%), Usonga (129%) and West Sakwa (121%) wards recorded more than 100% skilled delivery coverage as depicted in the **figure 4** below.
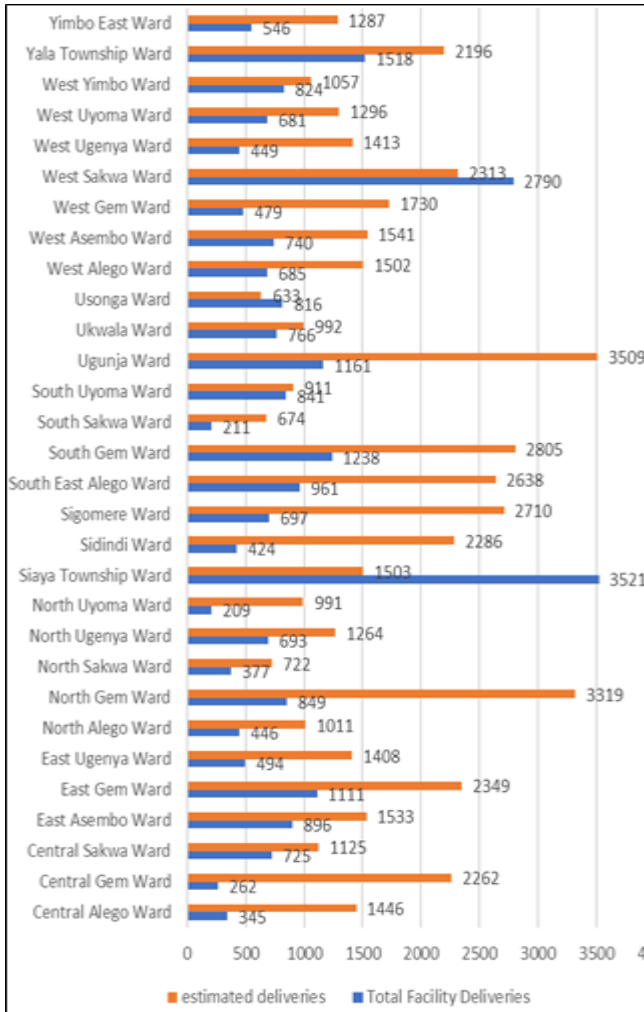
Figure 4. Showing the number of estimated deliveries versus the total deliveries that took place in a health facility across all wards in Siaya county

Traveling Time to Maternity Health Services

The current traveling time analysis involved 157 facilities; 97 dispensaries, 46 Health Centres and 14 Hospitals offering free maternity services in Siaya County as shown in **table 3** below.

Table 3. Accessibility Coverage (%) by Facility Type and Travel Scenario across Siaya County

Facility Type No. (%)	Walking Scenario (Scenario 1) No. (%)	Walking + Motorcycle Scenario (Scenario 2) No. (%)
Dispensaries 97 (62)	9,971 (27)	20,871 (55)
Health Centres 46 (29)	5,923(16)	15,757 (42)
Hospitals 14 (9)	2,033 (5)	9,481 (25)

For traveling time to dispensaries, less than 30% of pregnant women in 21/30 wards in Siaya County could access a dispensary within an hour of walking. In contrast, West Yimbo and South East Alego wards had an accessibility coverage of 62.4% and 48.9% respectively, despite South Uyoma and Ukwala wards recording an extremely poor accessibility coverage of 0%, that is, no pregnant woman in the two wards could reach a dispensary within an hour of walking. Moreover, when scenario2 (walking + motorbike) was considered, over half (18/30) of the administrative wards in Siaya county achieved an accessibility coverage of more than 50%, despite 70% of pregnant women in 8/30 administrative wards having the ability to reach a dispensary within an hour of traveling with a motorcycle. In summary, only 27% of pregnant women in Siaya county could access a dispensary within an hour of walking, while only 55% could do the same if they had access to motorcycle transport as shown in the **table 4** below.

Moreover, for traveling time to health centers, none of the 30 administrative wards achieved an accessibility coverage of more than 35% based on the walking only scenario, despite the fact that less than 5% of pregnant women in 9/30 wards could access a health center within an hour of walking. Moreover, when scenario 2 (motorcycle) was considered, more than 50% of pregnant women in 12/30 wards could access a health center within an hour of traveling time with a motorcycle, despite 9/30 wards still having an accessibility coverage of less than 30%, yet less than 5% of pregnant women in 4/30 wards (Ukwala, Usonga, Sigomere and North Ugenya) could access a health center within an hour of traveling time despite using a motorcycle. In summary, only 16% of pregnant women in Siaya County could access a health center within an hour of walking, yet this proportion increased to 42% if motorcycles were opted for.

However, for traveling time to Hospital facility types, 21/30 wards had a dismal accessibility coverage of between 0-7% while walking, even if no (0%) pregnant woman in 12/30 wards (East Asembo, South Gem, West Alego, North Sakwa, East Ugenya Central Alego, West Gem, Yimbo East, Central Gem, South Sakwa, South East Alego) could reach a hospital within an hour of walking time. The situation was slightly better when scenario 2 (motorcycle) was considered, since 8/30 wards had an accessibility coverage of more than 50%, although only about 10% of women in 9/30 wards could access a hospital within an hour of traveling time, in particular, pregnant women (0%) in East Asembo, South Gem and West Alego administrative wards could not access a hospital offering free maternity services within 1 hour even if they used motorcycle transport. In summary, only 5% of pregnant women in Siaya County could reach a hospital within an hour of walking, even though this proportion increased to 25% if motorcycle transport was available as shown in the **figure 5** below.

Table 4.   Accessibility Coverage (%) by Facility Type and Travel Scenario across all administrative wards Siaya County

Administrative Wards	Estimated Deliveries	Accessibility Coverage (%)					
		Dispensaries		Health Centres		Hospitals	
		Walking	Motorcycle	Walking	Motorcycle	Walking	Motorcycle
Central Alego	1446	35.8503	71.464	1.2325	15.2949	0	4.5351
Central Gem	2262	24.0505	59.5736	30.4587	64.1948	0	16.3322
Central Sakwa	1125	12.3043	50.5569	11.1302	43.3537	11.4893	49.695
East Asembo	1533	22.2751	60.5079	31.3243	67.5324	0	0
East Gem	2349	18.2785	38.0989	25.2393	47.7148	16.1321	18.1273
East Ugenya	1408	22.7083	42.7061	11.5192	49.4801	0	1.8127
North Alego	1011	21.3124	76.2047	30.3416	88.782	5.6658	54.7772
North Gem	3319	21.6977	68.007	18.7046	77.104	3.7994	38.5314
North Sakwa	722	14.761	40.1657	11.3491	35.8705	0	1.5938
North Ugenya	1264	37.2446	75.6295	0.0107	5.3563	20.1571	63.4561
North Uyoma	991	35.0512	62.8788	1.3728	14.0983	2.2373	19.9144
Siaya Township	1503	38.0559	79.1288	1.5094	58.2181	13.6463	61.378
Sidindi	2286	16.9451	32.5043	32.6476	44.3718	7.6409	21.9593
Sigomere	2710	29.4814	67.5343	2.3697	4.5705	15.06	59.9861
South East Alego	2638	48.9334	74.9683	4.1917	47.852	0	40.5994
South Gem	2805	29.8585	34.1187	34.5764	45.5113	0	0
South Sakwa	674	17.71	58.9468	23.2517	59.7246	0	23.149
South Uyoma	911	0	10.2612	27.4969	30.8427	2.7281	9.7458
Ugunja	3509	37.5119	71.7602	28.1462	56.5601	7.5623	14.5856
Ukwala	992	0	50.6467	0.8265	1.0649	17.9266	53.5316
Usonga	633	25.7041	35.0871	3.3546	3.3546	18.9184	24.923
West Alego	1502	24.4307	45.4487	14.816	21.0556	0	0
West Asembo	1541	31.2153	39.9055	18.9656	51.0777	7.647	8.3617
West Gem	1730	10.0767	33.8151	15.1782	64.0973	0	5.73
West Sakwa	2313	13.2106	27.8068	22.1741	46.1782	5.2236	27.6365
West Ugenya	1413	23.7989	42.9299	7.4642	7.6851	0.0592	26.268
West Uyoma	1296	27.8666	74.8708	21.8044	56.0593	5.1974	58.3836
West Yimbo	1057	62.49	75.3563	0	34.2301	12.6664	13.3952
Yala Township	2196	11.1269	66.8817	29.3658	68.7178	11.8278	51.4965
Yimbo East	1287	30.0109	50.3812	11.9005	26.6008	0	10.434

Likelihood of Delivering in a Particular Health Facility Type

Zero-inflated Poisson model was used to model the statistical relationship between Accessibility Coverage (independent variable), and Delivery by Skilled Birth Attendant Coverage (dependent variable) at the ward administrative level based on walking / motorbike traveling time, albeit disaggregated by level of care (dispensary, Health Centres or Hospital). Nevertheless, for both walking and/or motorbike traveling scenarios, a computed p-value < 0.05 represented a statistically significant relationship between skilled delivery coverage and accessibility coverage of pregnant women across all levels of care in Siaya County (see **table 5-7** below). For instance, for every unit increase in the proportion of women who could reach a preferred dispensary within an hour of walking, the probability of skilled delivery coverage increased by 7.8%, yet this likelihood also increased slightly, albeit by 4.6%, if the traveling scenario involved motorcycle transport.

Table 5.   Showing the estimates of the slope parameter and corresponding levels of significance for dispensary facility type

	Estimate	2.5 %	97.5 %	Pr(>|z|)
disp_walk	1.079	1.076	1.081	<2e-16 ***
disp_bike	1.047	1.045	1.048	<2e-16 ***

Moreover, for health centres, a unit increase in the proportion of pregnant women who could walk to such facilities, would result in a slightly higher increase in the probability of skilled delivery coverage by 16%, though such a likelihood would also increase by a smaller margin of 6.8% if the same proportion of pregnant women opted for motorcycle transport to reach the nearest health centre.
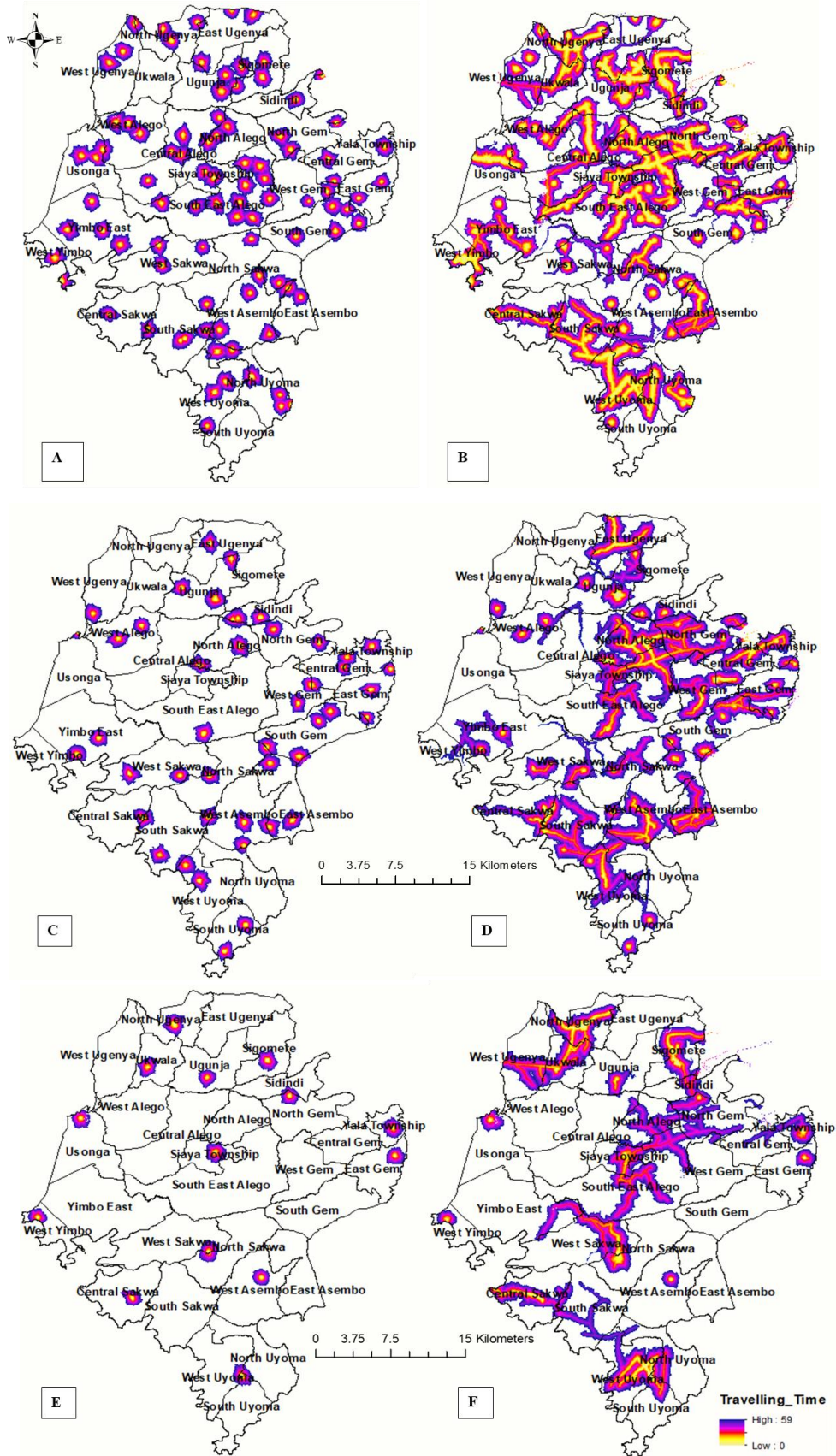
Figure 5. The distribution of dispensary level (**A** and **B**), health centre level (**C** and **D**) and hospital level (**E** and **F**) travelling time scenarios across all wards in Siaya county (**A, C** and **E**= walking scenario; **B, D** and **F**=motorized scenario)

Table 6. Showing the estimates of the slope parameter and corresponding levels of significance for health centre facility type

	Estimate	2.5 %	97.5 %	Pr(>|z|)
health_centre_walk	1.165	1.162	1.167	<2e-16 ***
health_centre_bike	1.069	1.068	1.069	<2e-16 ***

Hospitals on the other hand, would experience the highest increase in the odds of skilled delivery coverage of about 35% for every unit increase in the proportion of pregnant women with physical accessibility to such facilities via walking scenario, even if increasing the same proportion of pregnant women based on the motorcycle scenario would only increase skilled delivery coverage by 9.5%.

Table 7. Showing the estimates of the slope parameter and corresponding levels of significance for hospital facility type

	Estimate	2.5 %	97.5 %	Pr(>|z|)
hosp_walk	1.353	1.349	1.357	<2e-16 ***
hosp_bike	1.0956	1.0945	1.097	<2e-16 ***

4. Discussion

The current study demonstrates the feasibility of combining routine health facility data with existing GIS best practices to map out spatial inequalities in maternity health services utilization, as currently recommended by global policy experts like the WHO. The web based DHIS2 data platform in particular, is indeed robust in terms of its timeliness and completeness, even if reporting rates for reproductive and child health in Siaya county for the year 2018 were as high as 98.7%, and 92.3% of such reports were on time. Nevertheless, the robustness and prudence of using routine health facility data for local decision making has previously been demonstrated by a recent study in Kenya, that revealed that reporting completeness for facility data were well above 80% in all 47 counties, and the consistency of data over time was indeed good ((Maina et al., 2017). Similarly, a most recent study in Siaya county confirmed improvements in the data quality score for routine health facility statistics because of the county health management team (CHMT) identification of gaps in the reporting tools, as well as a recent update of the guidelines for collecting and analyzing such data (Millar, 2019).

Furthermore, based on summary statistics from DHIS2, the current study findings of a higher proportion of deliveries happening in facilities owned by the ministry of health, are consistent with a recent study that attributed a significant increase in the number of deliveries conducted in Kenyan public health facilities to the elimination of user fees for delivery services (Gitobu, Gichangi, & Mwanda, 2018), despite the fact that a majority of deliveries in Siaya County happened in hospitals and health centres at the expense of dispensaries, yet the number of dispensaries outnumber hospitals and health centres combined. However,

decision makers need to concentrate efforts in the 18/30 administrative wards in Siaya county where skilled delivery coverage was less than 50%, even though neighbouring wards where skilled delivery coverage was more than 100%, could suggest a need to focus on service quality due to the influx of pregnant women seeking higher quality services farther away, whilst shunning lower quality facilities that may indeed be closer to them.

In terms of traveling scenario, the current findings suggest that walking had the greatest negative impact on the ability of a pregnant woman to access the nearest facility offering maternity services. Although this finding was consistent with both previous and most recent studies (Ebener et al., 2015; Makanga et al., 2016; Schmitz et al., 2019), further analysis across higher level facility types like health centres and hospitals contrasted this finding that walking distance alone was enough to determine whether or not a pregnant woman reached, and thus utilized, a nearby health facility offering maternity services. A case in point is from a previous study of the correlates of utilization of skilled maternal health services in Siaya County, which revealed that poverty, low education, husband/ partners education and walking or using a bicycle to hospital were significantly associated with low utilization of skilled maternal health services (Omondi & Amolo, 2015), even if a comparable study reaffirmed that in the event high accessibility ratios overlap with low levels of utilization, it could suggest that physical accessibility may not be the main determinant of maternity services utilization and that other barriers might exist in areas like Siaya county with poor maternal health outcomes (Colston & Burgert, 2014).

Motorcycle traveling scenario on the other hand, was consistent with earlier studies that suggested that more pregnant women could indeed access maternity health services if they opted for motorized transportation schemes. For example, a recent study in Kigoma region in Tanzania, confirmed the importance of motorcycles and bicycles as intermediate means of transportation to improve access to health services, taking advantage of their high availability and mobility (Chen et al., 2017). Similar trends were also observed in a study that used travel time cost surface modeling to assess accessibility by various transportation scenarios in the Western Province of Rwanda (Munoz & Källestål, 2012).

More importantly, the present study also calculated the maximum likelihood of a skilled delivery across different health facility types, based on alternative traveling scenarios. The findings however, suggest a very strong relationship between physical accessibility and the probability of a skilled delivery across all levels of care (hospitals, health centres or dispensaries), regardless of a walking or motorized traveling scenario. Nevertheless, the findings in Siaya County also revealed a higher likelihood of a skilled delivery for every unit increase in the proportion of pregnant women who could reach a hospital or health centre by walking, as compared to reaching a dispensary even if they opted for motorcycle transport. This finding is

nevertheless consistent with a fairly recent study on the role of distance and quality on facility selection for maternal and child health services, albeit in urban Kenya, which found out that once a woman has to travel to a facility that is not close to her home, she is acting on her preference for a higher quality facility, even when the nearest facility is closer to her home, she may weigh her options differently before bypassing (Escamilla, Calhoun, Winston, & Speizer, 2018). Moreover, a more recent GIS based study in Siaya County reaffirmed that increasing availability of low quality and non-comprehensive health facilities is not cost effective, since they are most likely to be bypassed and rendered redundant or grossly underutilized. Thus, county governments ought to prioritize improving quality and expanding services within existing health facilities (Samuel Ouma Nyangueso et al., 2018).

5. Limitations

In contrast, a major caution for the current analysis, as well as for other studies using travel time cost surface models, is the assumption of a closed system- where women don't seek services outside the study area, yet in actual sense, pregnant women living near borders were likely to travel beyond the current administrative boundaries of Siaya County to seek maternity services. There were also minor limitations in terms of time discrepancies and different resolutions between the publicly available geospatial datasets, despite omission of the few privately-owned facilities that were not offering free maternity health services. Moreover, boat and travel by car were not analyzed, as the study area was restricted to the larger mainland Siaya County, and because rural women in such a low resource setting with poor road networks, were less likely to rely on car travel.

6. Conclusions and Recommendations

The current analysis has confirmed the feasibility of leveraging local routine health facility data to model physical accessibility and evaluate its impact on maternity health services utilization. Moreover, it should be understood that the likelihood of skilled delivery goes beyond the physical proximity of a health facility, as such, simply advising women to opt for motorized transportation schemes to improve their access to low quality facilities, may in fact, result in diminishing returns. The immediate implication is that policy makers need to upgrade the quality of lower tier maternity health services in Siaya County, as pregnant women may value quality of services regardless of the distance. Future research should also consider looking at the relationship between skilled delivery and the capacity of existing maternity health services, albeit based on local routine health facility data.

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