Optimizing Access to Primary Health Care Services in Rural Communities using Geographical Information System (GIS): A Case of Atwima Mponua District of Ghana

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ABSTRACT
Equitable and easy access to health care facilities is often considered one of the main objectives of many health care systems. Inequality in the spatial distribution of health facilities as well as lack of proper health care infrastructure planning standards has led to disparity in spatial accessibility to healthcare by communities in Atwima Mponua district.

In this study, location data (coordinates) for all the 180 communities together with the coordinates of the existing health facilities in the study area were collected using a Geographic Information System device (GPS). The road network and other "river bodies" geographical data were traced and copied from Open Street Map online. Using an 8km radius, the data were then analyzed using ArcGIS network analysis model as per the research objectives. Output from the ArcGIS analyzed data were then described and quantified with the help of stata and population data collected.

The study revealed that 61 out of the 180 communities had no health care facility available within 8km radius. A large proportion of the residents have to travel a long way to access health care facilities given the criteria that health facility should be accessible to population within 8km distance from the facility. On the average, patient in the district travel a minimum of 6.62km and a maximum of 21.20km with a standard deviation of 4.33km to access health care. More so, the study showed that 26.39% of the district population were residing beyond the 8km service area criteria.

In reality, absolute equal spatial accessibility is not always achievable but it is possible to plan and build an optimized health system. This study has been able to optimize accessibility to healthcare services in the study area based on the WHO standard of 8km distance (to healthcare site by people) with the application of GIS technology. This can therefore help to improve equity as well as spatial accessibility to healthcare by the people of Atwima Mponua.

Keywords
ArcGIS, Geographic Information System device, GPS, Open Street Map online, spatial accessibility

1. INTRODUCTION
Proximity to a health facility is an important element of a health system. It has an effect on the burden of diseases which mostly affect developing countries especially Africa. Measuring proximity therefore affect the performance of health system and contribute to the improvement of policies. [1]

Differences in geographic accessibility to health services usually arise because of the arrangement of these parameters in space. Health care services are positioned at a defined point but serves people living within different areas with differences in their distance from the service area [2]. There will always be inequality among people accessing healthcare services available at a particular area because of the current spatial distribution and the available transport infrastructure. It is therefore viable to monitor scenarios that hinder optimization of access between residents and the health care delivery points during health care system planning [3]. Availability of computer systems such as the Geographic Information Systems (GIS) is very essential and has the potential for improving health care planning and the distribution of its facilities equitably among populations, especially in the rural communities. Geographic Information systems has been applied in many field of study including environmental health management, communicable disease mapping and management of the health sector. It has the potential to maximize and improve many field of study [4]. The ability to interact with various sites of interest is also termed as accessibility [5]. GIS has the ability to analyze proximity to health care by local residents. Optimization of physical accessibility to health care services correlates with improved health outcome of people especially in under developed countries [6]. Bullen and his associates measured proximity of service provision points to people by including barriers to their movement. GIS has been used to quantify the health needs of people by analyzing health care accessibility among groups [7].

In the past decades, there has been a significant reduction in the number of maternal, child and infant deaths but many countries are still racing behind time to achieve the health related Millennium Development Goals (MDG 4 and 5). The world's attention has been to identify effective and evidence based intervention to improve health care [8].

Improving access to health care is estimated to reduce by 45 and 38 of still and neonatal deaths respectively. This can also prevent 75 percent of maternal mortality [8]. The immediate challenge for policy makers often involves a poorly equipped health system, has a skeleton staff, equipment malfunction. This is also not optimized to improve access to majority of the people. The provision of health care closer to the people is therefore essential to attain the three health related NDGs

(reducing child mortality, improving maternal health and fighting HIV / AIDS, malaria and other disease conditions) [9].

Accessibility to healthcare in Ghana is an active area of research [10]. Ultimately the Ghana government wants to achieve the highest level of care within budget constraints. Despite years of trial of different strategies to achieve "health for all" in the 1980s, research showed that, in 1990, over 70% of all Ghanaians still live more than 8 km to the nearest health care provider [11] and infant mortality rate in rural areas doubled compared to urban rates. Improving the provision of health remains a central objective of health reform. President John Mahama and his ministers has committed a portion of their salary to help improve PHC by building CHPS compounds to address the accessibility gab. There is a considerable body of empirical research that shows that people are more likely to report satisfaction with services and use the service if they are closer [12].

The use of Geographic Information system can determine and improve the spatial distribution of health services. This can be done in a scientific and a rational way to improve health system planning and resource allocation in developing countries.

2. LITERATURE REVIEW

It has been established that GIS can be used to optimize access to health care. Various literatures has talked about measuring spatial and the outcome of spatial measurement of accessibility as well as methods and theories of measuring spatial accessibility to health care

2.1 Access, Accessibility and Spatial Accessibility

2.1.1 Access

Four aspect of access requires a thorough evaluation. Being able to obtain access to health care depends on the availability of the service. Barriers such as financial, social, cultural and organizational may also hinder access to health care by people in a community. Affordability and availability of services increases its utilization. Adequacy of a service also increases its utilization but the relevance of the service may also affect the population positively. All this factors must be considered according to the health needs and the diversity of the population. Equity is mostly measured as per the availability, the utilization and outcomes of the services. All the dimensions of equity must therefore be considered [13]. Kham argues in 1994 that physical access to health care have various definitions which are mostly assumed. It can be considered as a noun and as a verb. It is referred to as the potential for the utilization of health care as well as the act of using or receiving health service. The concept of access becomes clearer if it is considered as stages and dimensions (see fig. section 2.7). Two broad stages exist, potential to deliver care and the realization of care. Populations mostly coexist in space and time to make service delivery easy to access by the users. All barriers to access should be overcome to make access realized [14].

2.1.2 Accessibility

Vickerman in 1974 defined accessibility as having two things; location on the earth's surface (appropriate destinations), and characteristics of the mode of transportation which connect points on the earth's surface. It can also be defined similarly as the concept of access since it has both spatial and temporal properties that may constraint an individual ability to access a specific destination [15]. It is measured by Euclidean distance by travel time or cost or by travel impedance between the location of people and health care delivery points [14]. Guagliardo (2004) argues that accessibility and availability are not similar terms and that accessibility may depend on availability of the services. In cities, where multiple points of service are currently available, accessibility and availability should be considered simultaneously [14]. Regarding the use of health services, accessibility is generally influenced by the location of healthcare delivery points and the demand for health care which are not evenly distributed [16].

2.1.3 Spatial Accessibility

Access can generally be referred to as an entrance into or the right of entry to, or the use of an available facility. Spatial accessibility therefore refers to the ability of a person to reach a preferred location, or being able to reach another location easily [17] [18]. The relationship between the location of health facilities and the location of its target population considering the transportation network can also be termed as spatial accessibility. Spatial accessibility and geographical accessibility are mostly used as a similar term in most literature. This is because the two terms are location based and spatially constrained. Khan in 1992 collaborated to this claim. Some scholars declare that they used the term 'spatial accessibility' because they want to gain the favour and supported by the literature published in health care geography category [19] [20] [14]. The spatial accessibility has been studied and developed mainly in Geography, Mathematics and Social science but not limited to physics, planning, public health, transportation, civil engineering etc. Spatial accessibility is a critical consideration in the provision of both public and private services [21]

Stewart (1942) discussed population-over distance relationship or population potential as a generalized notion of accessibility. According to the concept of population potential, Hansen (1959) conducted an empirical examination of the residential development patterns [22]. Many other empirical studies have since been conducted and new concepts have been developed. The development of computer, mathematical and spatial statistical approaches and Geographic Information System (GIS) added new dimension in the development and application of accessibility measures in many different disciplines. In the literature, the terms 'spatial accessibility' and 'spatial patterns of accessibility' are sometimes used with no discrimination [23], but majority of the researchers has taken the term 'spatial accessibility' to mean physically be able to reach from a potential location of the health care user's to a health care facilities location via a transportation network, and the term 'spatial patterns of accessibility' to mean the spatial distribution of certain spatial accessibility measures.

2.2 GIS And Healthcare

Methods of spatial analysis offers tools which enables the description and the understanding of the spatial arrangement of health care and examines the relationship that exist between health outcomes and access so as to improve health care delivery. GIS as a computer based system aids the integration and analysis of geographically referenced data. It has the ability to process data collected, store and retrieve data when needed, analyze and display data as maps. This enables the visualization of patterns and generating of new ideas [24]. Application of GIS has helped improve the management of land and natural resources. Its application in

health is novel and needs further research. It is mostly used in health geography and epidemiological studies and also aids in keeping the knowledge base of health informatics. The application of GIS technology in health can precisely mapped up disease outbreaks as well as measure geographic disparities in health. Previous application of GIS to understand access to primary health care have been described by several authors, including a summary in previously ESRI conference proceedings. Currently, integration of GIS in primary care research has been encouraging due to the improvement of GIS technology, making it suitable and understandable by healthcare researchers. Many studies has describe the results of access barriers to health care and its effects on health outcomes. This studies are important to better understand and to modify how the planning of health care is carried out [25]. Although there have been many studies on the rational use of primary health care in developing countries, there are few studies that examine exclusively the potential accessibility of a target population to maternal, child or infant as well as family planning services. World Health Organization strongly encourages the integration of these functions in the delivery of primary health care. For example, Ayeni et al. (1987) examined the distance to maternal health centers and other primary healthcare facilities.

2.3 Measuring and Outcome of Measuring Spatial Accessibility

Spatial accessibility is primarily concerned with the relationship between the geographic distance of a target population and the point of health care provision. The health of a population is affected negatively by distance to health service. Information about the impact of distance to health care is limited due to lack of quantitative information pertaining to that [14]. It has been established that increasing travel distance reduced the usage of healthcare services. Also, Mede and associates in 2002 demonstrated that, the shorter the distance travelled to a radiation oncology facility, the higher the number of people accessing the facility. Also Goodman in 1994 associated the distance from hospital with the likelihood of admission for discretionary conditions.

The ability of a population to achieve a set of healthcare services is mostly concerned with the availability and access to health services [26]. It is therefore important to develop and make maps available to identify health care facilities. This is a major application of GIS in Public health. Health care mapping is mostly concerned with the proximity of PHC centres to the potential users. The maps are necessary to determine the distance between settlements and health care delivery points, the road networks and the types of transport service available.

In addition, application of GIS studies in health deals with the placement of health facilities and its accessibility to the users of the facility. Health care planning in developing countries must therefore take into consideration accessibility of the services to the potential users. Geographic Information systems was use to estimate the travel time and distance to hospital in South Africa. This was done to quantify accessibility and also provided comparisons for different environment. In this study, it was realized that measuring spatial accessibility to health care focused on increasing access and coverage to health services by the users. The Methods produced two results. The first variable is able to achieve improvement in access by a target population by targeting a crowded area with access to care. It neglects a sparsely settled areas [27]. Tanser proposed in 2006 that there is a need for a quantitative way to help health planners to find suitable locations to set up new health care delivery points and assess the merits and demerits of the various competing communities. He developed a new way to use GIS to optimize accessibility effectively to health care services. PHC seeks to achieve health for all and requires a system of health care that puts people at the center of affairs. PHC remains the system of health care for developing countries because it provides reliable, evidence base and preventive response to health needs in the social context. Health care facilities are not distributed equitably throughout the country. Most rural communities are without access to health care services. Their study also revealed that, Most Ghanaians on the average cover a distance of 16km before they can get access to health care. Also according to them, half of Ghanaians live within a 5km radius to a health facility. The other half of the population cannot access healthcare within 5km which is equivalent to a walking distance of 1 hour. The health system of Ghana was reformed in the early 1990s so as to improve and optimize access and improve the quality of services. This could not optimized health care in the country. Health system can be described as planning, management and the delivery of the right health care which ensures optimized patient access.

2.4 Methods and Indicators for Measuring Spatial Accessibility

There are a number of publications on the method of measuring of accessibilities to health care, however these methods have been categorized into four [14] namely: Population-to-provider ratio, distance and average distance measures as well as gravitational method.

Population to provider ratio or the supply ratio are determined from a specified area like counties, states and health service catchment areas. It is the mostly used measurement to determine spatial accessibility to health care since its data sources are always available and doesn't require the application of GIS. The numerator indicates the capacity of the health system whiles the denominator is the total population of the catchment area (e.g. population to nurse ration). The catchment area is then analyzed to determine the association between the provider and the population of the area. This measurement is beneficial and policy makers rely on it to set standard of supply and identify underserved communities [28]. This method cannot determine patients who cross borders to seek care and it is also blind and cannot determine variations in geographical accessibility within the specified area. Supply ratio does not measure distance or travel impedance [29].

Travel impedance to nearest service provider is one of the usually used spatial accessibility measure which is usually measured from the residence of the patient/client or center of the community. It is sometimes referred to as travel cost measured in units of Euclidean or straight line or walking distance along a road or transportation medium [14]. This measure is a suitable accessibility measure for rural areas since the choice of service providers are limited and the one very close to the user is the most likely to be used. According to Fryer and his colleagues, this measure is not ideal for urban areas. This measure considers all the potential options available to the patient making this measure a bad indicator of availability. Travel impedance combines all the effects of travel and availability to better understand spatial accessibility [30].

Average travel impedance to a service provider considers both accessibility and availability to service provision which is usually measured from the patient point of view or the population. This measure sums up the impedance to all providers in the defined area and determines the average travel impedance. This measure is not usually used in health service study. Border crossing is also a major challenge for this spatial accessibility measure since clients may be crossing geographical areas for health care services [31].

Gravity model is one of the combined indicator of both availability and accessibility. It is based on Newton's gravitational law and originally designed to predict retail travel and the use of land. This measure is suitable for both urban and rural settings. Gravity model considers all the other available service points making it the cumulative geographical accessibility measure. The simplest formula for this method is:

Ai is spatial accessibility from population I which may be a residence or the centroid of an area under study

Sj is service capacity at provider location j. it is measured as the count of professional at a health facility.

d is the travel impedance

β is a gravity decay coefficient often referred to as the travel friction coefficient.

Assumptions: it is assumed that spatial accessibility improves as the summed provider capacity increase (numerator), or the sum of travel impedance decreases. Ai value is not intuitive to healthcare workforce and policy makers, who prefer to think of spatial accessibility in terms of provider to population ratio or simple distance, despite the aforementioned difficulty of applying ratios to urban communities. Again, it only models supply. There is no adjustment for demand. Therefore, Ai at a given distance from two providers would appear to be the same, even if one service provider is serving 1,000people in her catchment area and the other were serving 5,000. Clearly the two providers are not equally accessible.

There exist various spatial statistical procedures in literature which mostly describe spatial patterns and also measure spatial relationship between demand for health care and supply of health services. Spatial statistical methods has been used in a number of studies including indicators of both local and global patterns of spatial accessibility with emphasis on local patterns. The foundation of spatial autocorrelation highly depends on Tobler's first law of geography which states that everything is related to everything else yet closer things are more related than distant ones. Global approach aid the analysis of overall spatial patterns and the trend of the data collected. It shows the correlation of variables with itself in space.

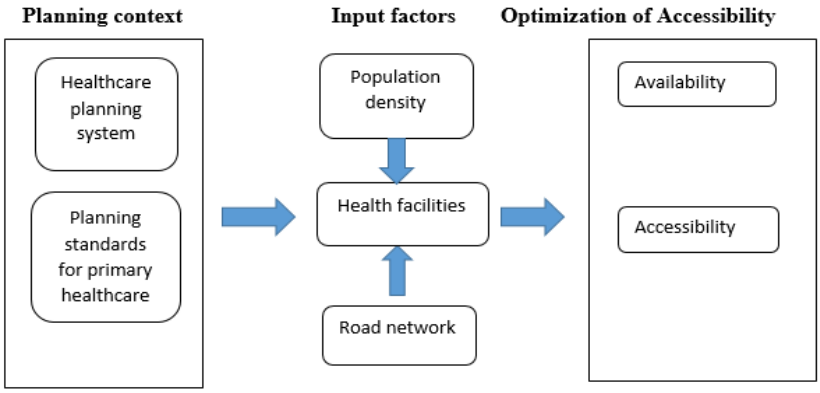

Figure 1. Conceptual Framework

3. METHODOLOGY

In implementation, I used quantitative research methodology. I employed mathematical models and theories based on the numerical data that was collected. The study is designed to test for the relationships between locations of the population and the sites of the existing health facility. It looks to reveal the relationship between a cause and an effect statistically. In this quantitative study, to map spatial variations in population, health care facilities via a transportation system within the study area, the study requires vector data set, Point/lines, which are numerical data and population attributes of the study area (population data). Global Positioning System (GPS) technique would be used to collect the vector data. Data are displayed visually before exploration of some likely patterns that will be generated after analysis. (Exploration of area data after network/proximity analysis) and possibly modeling. Simple descriptive data analyses may then be applied. This study will also employ the spatial exploratory technique to identify and explain analytically, the variations in physical access of populations to the existing health facilities in the study area and identify disadvantaged populations using the closest facility measure in ArcGIS.

4. FINDINGS AND CONCLUSION

The study showed that, the computed average distance a patient travels to seek for healthcare (average travel impedance to provider) for the entire district is 6.63km with a standard deviation of 4.33km (see table 4.3). The network analysis performed gave the following results; 73.6% of the total population in the district comprising 66.1% of the total communities have access to health care facility. Network analysis was used since it take all road networks into consideration, without considering only a straight distance from health facility. The result of network analysis made it possible to identify new sites where additional health facility can be put up to improve accessibility of primary health care services in the district as shown in figures 4.1-4.3 below. The figure indicates the situation before and after the study. The map therefore shows the optimized health system when the findings are implemented.

Table 4.1: Descriptive statistics of population variables from the spatial analysis (output from Stata 13)

Spatial Measure	people with Access to healthcare	Percentage of people with access to healthcare	People Without access to healthcare	Percentage of people with no access to healthcare
Network Analysis	110,528	73.61%	39,626	26.39%
Proximity Analysis	134,740	89.73%	15,414	10.27%
Total Population	150,154			

Table 4.2: Descriptive Statistics of the number of communities from the spatial analysis

Spatial Measure	Communities with Access	% with Access	Communities Without Access	% without Access
Network Analysis	119	66.1%	61	33.8%
Proximity Analysis	156	86.6%	24	13.3%
Total communities	180			

Table 4.3: Descriptive statistics of the estimated average distance to nearest healthcare facility (output from Stata 13) after analysis from ArcGIS 10.1

Indicator	Number of Communities	Mean	Std. Dev.	Min	Max
Estimated distance from Settlement to Nearest Health Care Facility	180	6.636217	4.329484	.1194311	21.19984

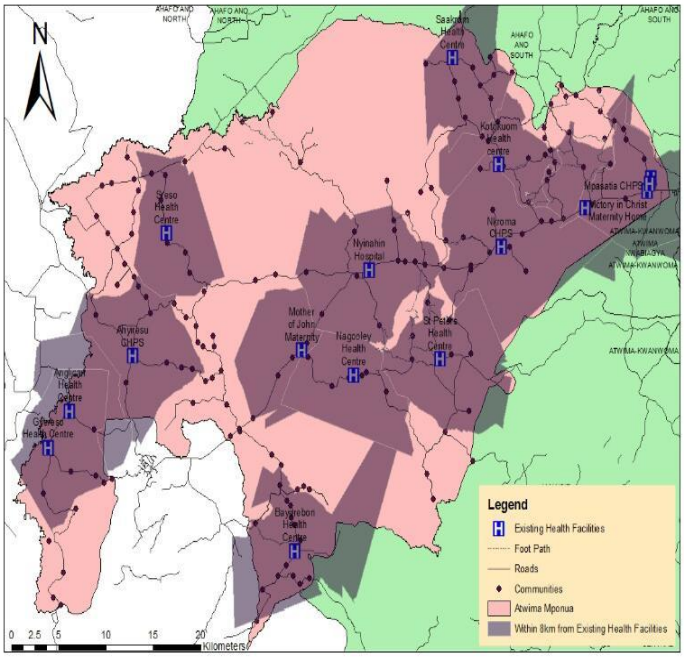

Figure 4.1: Existing Healthcare System before the study

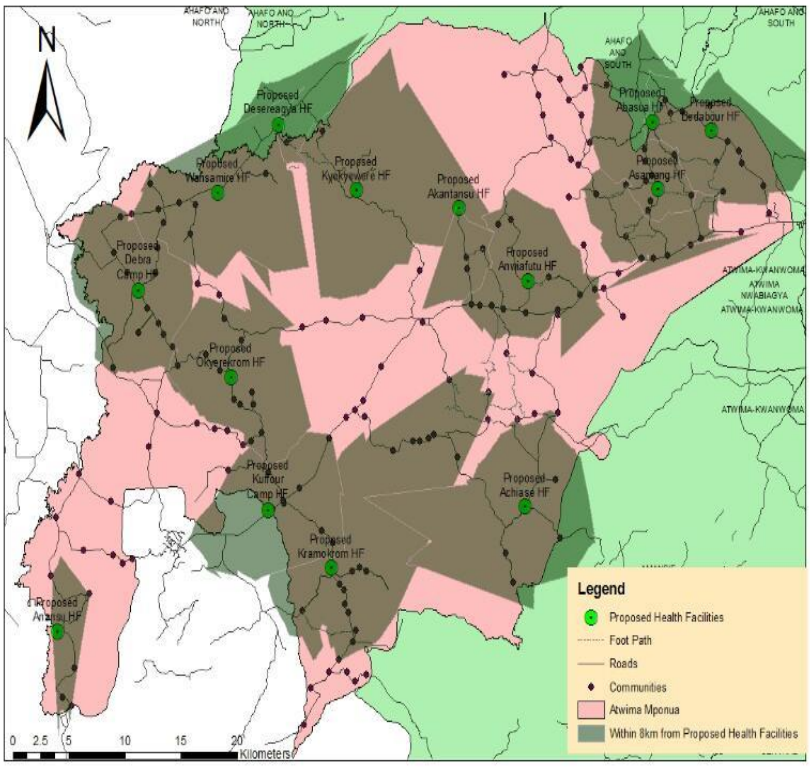

Figure 4.2: Optimized Healthcare System after the Analysis

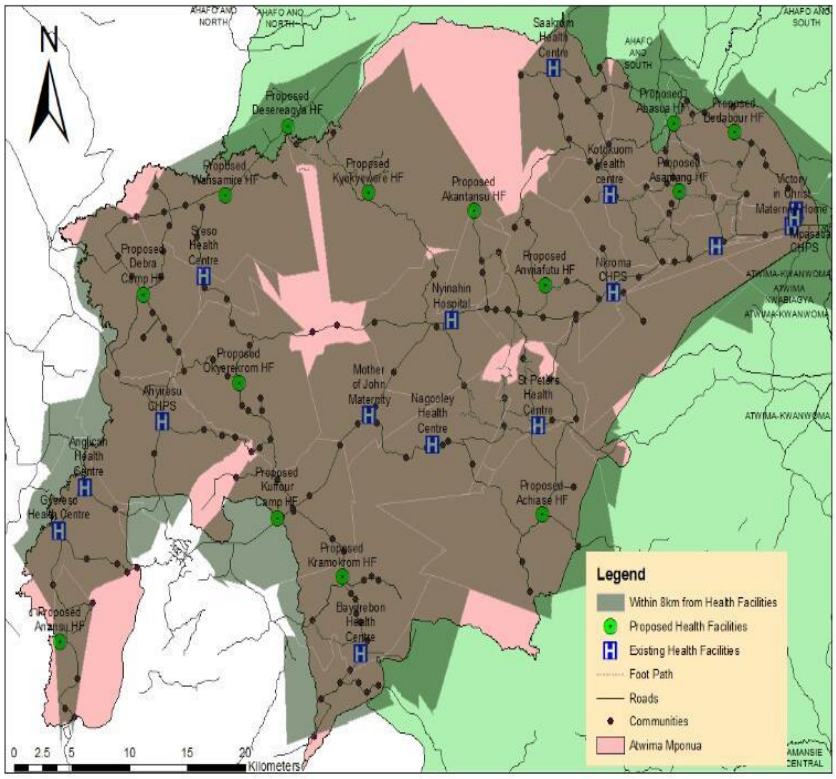

Figure 4.3: Optimized Healthcare System after the Analysis

The study investigated spatial accessibility to health care with respect to maternal healthcare services by the local communities of Atwima Mponua and developed a GIS based method to identify disadvantaged localities with respect to spatial accessibility to healthcare facilities. The study established that within the district there exists spatial disparities in the distribution of the population and healthcare services. Health care facilities were not evenly distributed within the study area.

There were 180 communities in the district and 61 of them have no health care facilities available within 8km radius. A significant number of the communities has no access to health care facilities since public transport is both inadequate and infrequent due to very bad roads. The study therefore provides the basis for planning and implementing optimized healthcare system especially in rural settings or district.

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