

Spatial Data Analysis Project

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Abstract

This paper investigates several ways in which Spatial Data Infrastructures can improve service delivery in the health sector. The study conducts a review of the literature in this area and a spatial analysis of the central region in Kenya consisting of the Central and Nairobi provinces. The study finds that SDIs are a critical investment for the improvement of the health sector. They would contribute to an improved healthcare framework, better access to health services, easier management of emergencies, and keen government oversight of the sector. At the same time, the study suggests that the government should take legislative measures to regulate the role of SDIs in the health sector.

Introduction

Health is one of the key functions of any government in the world. In Kenya, the ministry of health in the national government supports the respective departments in county governments to provide healthcare services to citizens. Collectively, the government is responsible for protecting the individual right to healthcare. It carries out this task by apportioning a fraction of the annual budget for healthcare, enforcing quality standards in healthcare facilities, directing quarantine mandates, taking measures to mitigate health crises and epidemics, providing reliable information, and making direct investments in healthcare (Altman & Morgan, 1983). In the pursuit of these responsibilities, the Kenyan government has become the biggest stakeholder in the health sector, running about 51% of the healthcare facilities in the country (Chuma, et al., 2012).

Spatial Data Infrastructures (SDIs) are defined as “a framework of data, technologies, policies, standards, and human resources that are necessary to facilitate the sharing and use of geographic information”, (Gupta, et al., 2020). Their benefits include the efficient management of emergency medical services, determination of key areas for healthcare investment, and improved access to medical services. Spatial data infrastructure is already applied in a wide variety of sectors in the country and is even leveraged by the government in various functions such as planning, devolution, and revenue allocation. However, the government is yet to effectively tap into this resource for the purpose of healthcare provision.

Regardless of the advantages that spatial data infrastructure would provide, it also poses a significant number of risks to Kenyan citizens. These risks arise from matters such as the ethical implementation and use of GIS functions for medical services (Keller, 2023). Another ethical risk that arises from this is the disenfranchisement of certain regions in the country due to misguided or corrupt implementation of the framework. Given the critical importance of the government's

role in protecting the right to privacy among others, it is critical that the government promotes and regulates the role of spatial data infrastructures in the digital transformation of the healthcare sector in the country, for policy and decision making.

This study seeks to explore the potential of spatial data infrastructures as a key aspect of the digital transformation of the health sector in Kenya. The study looks into how the government, as a key stakeholder in the healthcare sector, can leverage the technology to provide better healthcare services to its citizens, and at a lower cost. Further, it critically evaluates how this technology would facilitate the oversight role in the healthcare sector as a whole, as it is required to do. Its main objectives are to analyse the state of the health sector, specifically, the degree of access to healthcare for the citizens, to evaluate the potential benefits of implementing spatial data infrastructures in the delivery of healthcare services as reasons to promote their role and weigh them against the concerns of this implementation as reasons to regulate it.

Methodology

It is crucial to understand the potential of spatial data infrastructure to improve the delivery of healthcare as well as the concerns it poses to infer the appropriate course of action for the government in overseeing its implementation and use. To thoroughly assess this, the paper leverages the use of spatial data analysis and visualization rendered through RStudio to demonstrate the current distribution of healthcare facilities in different regions in Kenya. The data used for the study is well referenced and the code is presented along with the maps. The paper also delves into the existing literature on the topic. It builds upon other studies in this niche and develops arguments by showing how the concepts discussed can be transferred to the Kenyan

health sector. The thorough review of the literature and the spatial analysis support the conclusions drawn in the paper.

Discussion

Healthcare Policy

To fulfil its mandate to the people, the Kenyan government needs to build systems and frameworks that ensure the delivery of high quality but affordable healthcare services (Boulos, 2004). The decisions that would facilitate this kind of progress would need the consideration of a number of factors ranging from socioeconomic aspects to the congruity of the jurisdictions they would affect. This way, the decisions made for one areal unit would not negatively affect another. Health-oriented SDIs would leverage health and non-health data to shape decisions made about healthcare policy in the country. Therefore, SDIs are a crucial tool in the development of healthcare policies and systems that are more resilient to emergencies, epidemics, and even systemic abuses.

Kenya is ranked 85th in the world by the Global Health Security Index (Global Health Security Index, 2021). As such, there is a great room for improvement. This means that the government needs to review its policy on various matters in the sector. Health policy covers matters such as immunization, quarantine mandate, and even sanitation. For effective policies regarding all these issues, health-oriented SDIs are critical in providing the required context (Richardson, et al., 2013). For instance, immunization efforts would be greatly aided by identifying cases of disease for seasonal vaccinations such as flu and polio. Similarly, quarantine mandates can be more effective after considering the settlement and logistical patterns in the area affected. This way, SDIs would facilitate more effective immunization campaigns.

Access

Apart from quality, the government is also responsible for maintaining easy access to healthcare services. In the effort to facilitate this, it has made billions of shillings worth of investments in the sector, building key facilities which range in their size and medical scope from dispensaries to national hospitals. Despite the government's efforts, the budget proportion that goes to healthcare remains lower than the 15% stipulated by the Abuja Declaration Recommendation (Witter, et al., 2014). As such, there is a need to restructure the healthcare system to make healthcare services more accessible. According to a 2011 study, Kenya's health system is inequitable and the efforts to change this, largely unsuccessful (Chuma & Okungu, 2011). However, the Kenya Constitution, 2010, stipulated the devolution of the health function to the county governments. However, given the challenges that have plagued most of the 47 counties in the development and implementation of healthcare policy, the health system remains out of reach for millions of Kenyans who need it. Using Spatial Data Infrastructures, the executive arms of both the national and local government can avail the required facilities to various communities. For example, a Healthcare SDI would facilitate the operation of mobile medical facilities, such as the vehicles used by the Beyond Zero initiative to support safe childbirth, to reach even the most remote parts of the country (Wasunna, 2015). It would be a cost-effective way to reach those who need healthcare services.

Emergency Services

Emergency Medical Services are a key aspect of any health system. They provide assistance for a wide range of medical emergencies ranging from treating an allergic reaction to conducting search and rescue missions after terror attacks and fire emergencies. However, the EMSs available in Kenya are not always available with the urgency in which they are needed. This has led to the culture of using taxi services to ferry patients to medical facilities which increases the casualty

rates in road accidents and similar situations. The 911 and 999 hotlines associated is not always quick to provide aid as the communication is hindered by the use of descriptive locations (Nicholson, et al., 2017). In order to remedy this state of affairs, it would be appropriate to create a wide network of Emergency Medical Technicians on a national level. It would be backed by an SDI that incorporates GIS data to assign a caller the nearest EMT and enable them to track the caller. This would enable the EMTs to reach people in danger and provide the urgent assistance at the earliest possible time. Using a well-resourced SDI would also factor in other aspects besides proximity that affect the time taken to get a patient to the hospital such as traffic and the type of emergency. This would save many lives by bringing urgency to the health sector.

Oversight

In addition to availing the aspects of healthcare above, the government is required to provide oversight over private institutions. This would facilitate the establishment of a health system that is equitable and affordable. The result of effective oversight by the government would be an improvement from the currently stratified health system where one needs to pay twice or thrice as much as they would in a public hospital to access quality healthcare in private institutions. Further, government oversight would see the burden of public health spread out to all the facilities that can avail them. For example, immunization campaigns and emergency responses would be more successful if they engaged the agility of private institutions as well as public ones. As a result, better and more standardized services would be offered to the benefit of patients (Uneke, et al., 2012).

Concerns About SDI

As demonstrated above, spatial data infrastructures present an invaluable asset in the digital transformation of the health sector in Kenya. They would facilitate more informed decisions

regarding the healthcare policy in the country, better access to healthcare services, more efficient emergency responses, and more effective government oversight in the sector. However, there are key concerns that arise with the consideration of this technology. The main concern with the incorporation of SDIs in the digital transformation of healthcare is that like all other technologies, they can be abused at the point of implementation. This has been noted in numerous other examples such as racially biased facial ID software (Raji & Buolamwini, 2019). However, with public participation as the legislative procedure requires, the data models implemented in the health system would be refined to a level that is acceptable with regard to equity. Another concern is the lack of existing IT standards which can be enforced to ensure clarity, accessibility, and effectiveness of the adopted models for use in healthcare (Martin, et al., 2004). For this reason, it is critical that the government regulates the role of SDIs in the digital transformation of the sector.

Data Analysis and Results

The population data used was collected from World Resources Institute, an open-source repository with reliable census data from the 2009 census (World Resources Institute, 2009). Given that the data was used to show population density, this was deemed sufficient. The data on healthcare facilities was collected from a world bank-backed study that provided more updated information (Antoine, et al., 2018). To narrow down the area under investigation, the study focused on the combined region covering central and Nairobi provinces as they were defined in the old constitution. It then identified all the healthcare facilities in the region. This revealed a well distributed pattern over the entire area below.

```
ckenya <- read_sf("C:/Users/kagir/OneDrive/Documents/My Documents/Finals/Data/kenya_health.shp")
facilities <- filter(ckenya, PROV == "CENTRAL" | PROV == "NAIROBI") %>% st_transform(7761)
```

```

facilities_centroids <- facilities%>%st_centroid()

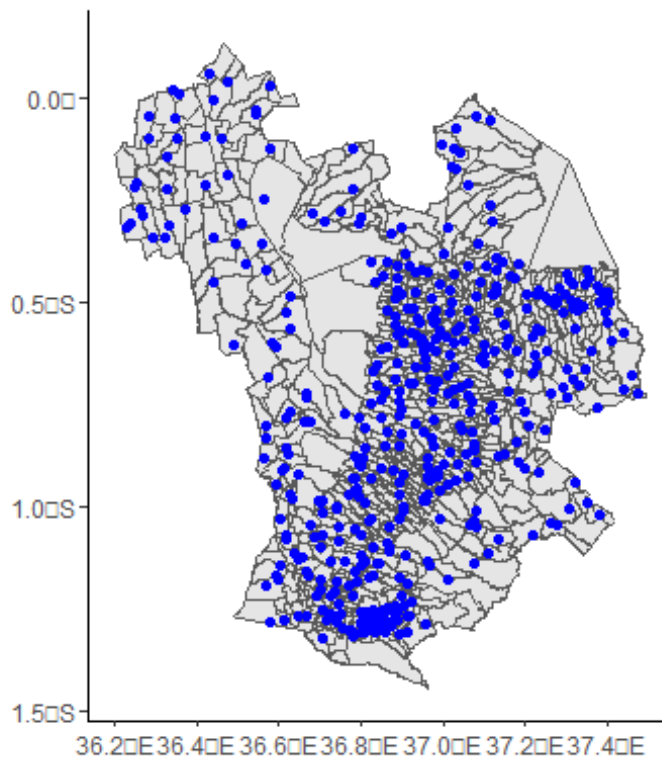
## Warning in st_centroid.sf(.): st_centroid assumes attributes are constant
over
## geometries of x

Map <- read_sf("C:/Users/kagir/OneDrive/Documents/My Documents/Finals/Data/Population_HH_2016.shp")

Central_Border <- filter(Map, FIRST_PROV == "CENTRAL" | FIRST_PROV == "NAIROBI")

Central_Border %>% ggplot() + geom_sf() +
  geom_sf(data = facilities, color = 'blue') +
  theme_classic()

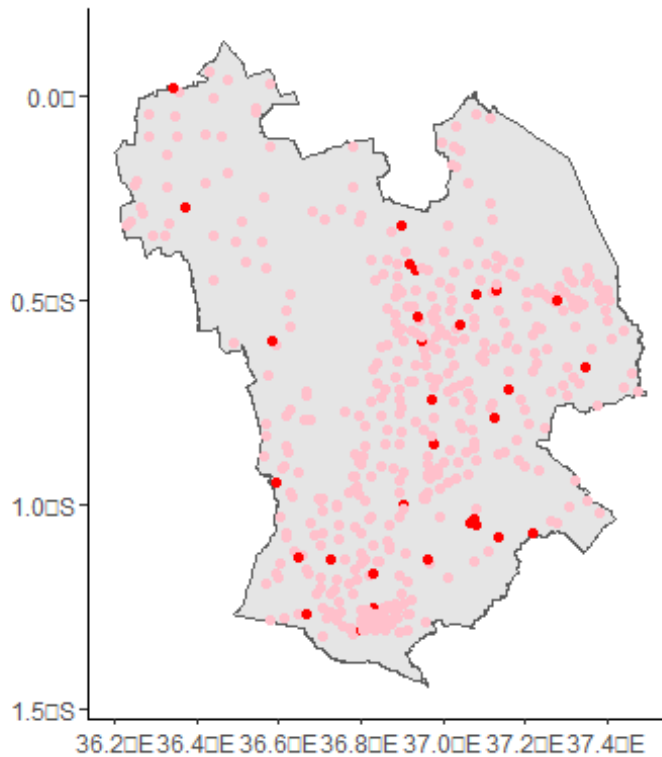
```



However, seeing as these facilities included all types ranging from dispensaries and drug stores to national hospitals, it was essential to make the distinction. This was done using the color disparity based on the type of facility, having the major hospitals in red and the rest of the facilities in pink. In order to have a cleaner view of the distribution, the study first eliminated the internal boundaries using `st_union()`.

```
Central_Unified <- filter(Map, FIRST_PROV == "CENTRAL" | FIRST_PROV == "NAIROBI") %>% st_union()

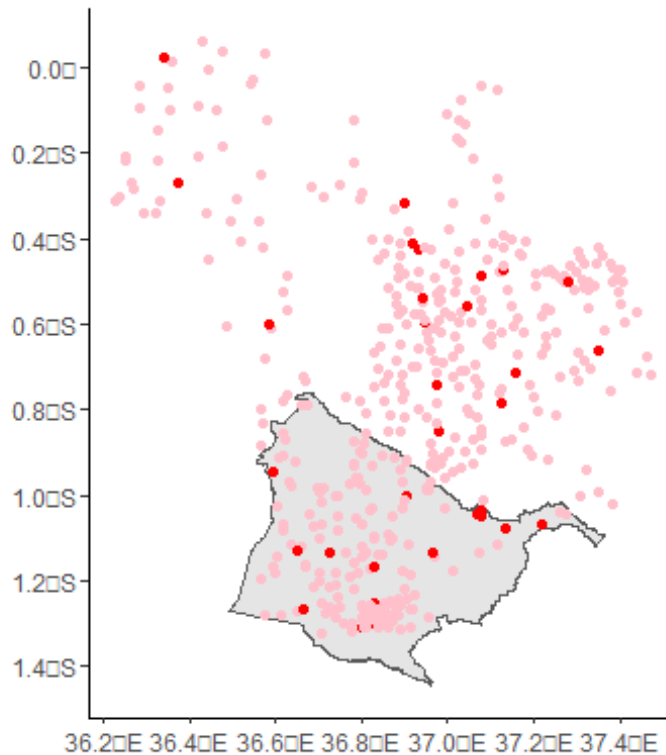
Central_Unified %>% ggplot() + geom_sf()+
  geom_sf(data = facilities, color = ifelse(facilities$F_TYPE <= 1,'red','pink')) +
  theme_classic()
```



It is important to note that the distribution of the health facilities does not at all reflect the distribution of the population. For instance, the two most highly populated counties in this region are Kiambu and Nairobi. As per the 2019 census, Kiambu had a population of over 2.4 million residents while Nairobi had nearly 4.4 million. The two counties are shown below for better context regarding their area and position on the map above.

```
Metro <- filter(Map, County == "Nairobi" | County == "Kiambu") %>% st_union()

Metro %>% ggplot() + geom_sf()+
  geom_sf(data = facilities, color = ifelse(facilities$F_TYPE <= 1,'red','pink')) +
  theme_classic()
```



In comparison, the remaining four counties in the region, namely Nyeri, Nyandarua, Murang'a and Kirinyaga had a combined population of just above 3 million residents. Therefore, the metropolitan region consisting of Nairobi and Kiambu counties is home to two thirds of the population in the region but it only has a third of the major healthcare facilities. In addition, due to the advanced level of some of the facilities in the metropolitan region, they are considered national hospitals and a significant portion of their capacity tends to the needs of the population outside of this region. This is just a demonstration of the inequity in this sector. The table below is a list of the hospitals in the two counties.

```
facilities_Nai_Kiambu <- facilities %>% filter( DIST == "KIAMBU" | DIST == "N
AIROBI")
table1 <- as.data.frame(subset(facilities_Nai_Kiambu, F_TYPE == 2|F_TYPE == 1
,
                                select = c("F_NAME", "DIVISION", "AGENCY")))
kable(table1, caption = "Tier 1 Hospitals in Kiambu and Nairobi", )
```

Tier 1 Hospitals in Kiambu and Nairobi

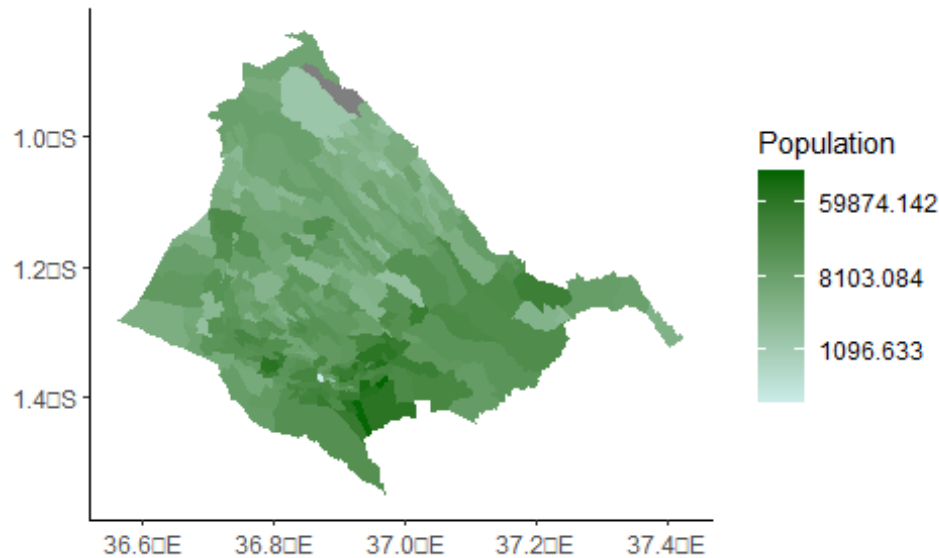
F_Name	Division	Agency
Kiambu District Hospital	KIAMBAA	MOH
Kijabe Hospital	LARI	MISS
Nazareth Hospital	LIMURU	MISS
P.C.E.A. Kikuyu Hospital	KIKUYU	MISS
Tigoni Sub-District Hospital	LIMURU	MOH
Getrudes Gardens Children's Hosp	WESTLANDS	MISS
Kenyatta National Hospital	DAGORETTI	MOH
Mater Misericordiae Hospital	MAKADARA	MISS
Mathari Mental Hospital	CENTRAL	MOH
Mbagathi District Hospital	DAGORETTI	MOH

In addition to the regional inequity, there is inequality at smaller areal units where some locations which are densely populated lack facilities which are sophisticated enough to manage emergencies that might arise because of the population density such as disease outbreaks. This is demonstrated by a comparison of the map above with the this one showing the population distribution in Nairobi and Kiambu County.

```
Ke_Demography <- read_sf("C:/Users/kagir/OneDrive/Documents/My Documents/Finals/Data/Population_HH_2016.shp")

Central_Density <- filter(Ke_Demography, County == "Kiambu" | County == "Nairobi") %>% st_transform(7761)
Central_Density %>% ggplot() +
  geom_sf(aes(fill= Population), col=NA) +
  scale_fill_gradient(low="#ccee9", high="dark green", trans = "log") +
  theme_classic()

## Warning: Transformation introduced infinite values in discrete y-axis
```



Conclusion

The regional inequity indicated supports the need at the need to invest more in healthcare in the central and Nairobi region, particularly the two counties of Kiambu and Nairobi. The use of Spatial Data Infrastructure to support this investment would prove to be a tremendous venture given the widespread use of technology in the two counties. Brands such as Uber, UberEATS, Jumia, among others which rely primarily on accurate GIS data in are used heavily in these two counties. This is a clear sign that the integration of SDIs such as Geographic Information Systems in the digital transformation of the health sector would be a revolutionary step.

In this implementation, however, the government would need to provide keen oversight to ensure that the loopholes that cannot be sealed by technology are sealed through legislation. This is to say that since it is not possible to develop a perfectly formidable system that cannot be breached, the

law should stipulate corresponding penalties for any individual or institution which uses the health SDI to abuse the rights of another. This way, the government would promote the role of SDIs in the digital transformation of the health sector for policy and decision making, while mitigating the inherent risks.

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