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# Spatial mapping of physical accessibility to Hospitals: A case study in sarawak, Malaysia

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**Abstract**
Access to healthcare is an important component of an overall health system and has a direct impact on the burden of diseases. This study focused on determining accessibility of hospitals in Sarawak by using Geographic Information System (GIS) and network analysis. Data related to healthcare facilities were gathered from the Health Information Center, Ministry of Health Malaysia. Spatial coverage for each hospital with specified amount of time to access were determined by calculating service areas and applied together with network analysis in the GIS environment. The results indicated that only 6.4% of Sarawakians could reach a public hospital within 15 minutes by driving, 12.3% and 39.6% within 30 and 60 minutes respectively. Meanwhile, to access a private hospital, 9.1% of Sarawakians could reach within 15 minutes, 27.1% and 38.8% within 30 and 60 minutes. In addition, 14.5% of Sarawakians could reach any hospital in Sarawak within 15 minutes, 32.0% and 46.1% within 30 and 60 minutes. The analysis of accessibility to hospitals in the state of Sarawak was based on GIS network analyst methods. The analyses were able to identify the best route and closest hospital to access during healthcare emergency. Therefore the findings of this study could assist healthcare policy makers and planners to understand the existing health care system of Sarawak and to identify medically underserved areas.

**Keywords:** healthcare, accessibility to hospitals, geographic information system (GIS)

## Introduction

Access to healthcare is an important component of an overall health system and has a direct impact on the burden of diseases. Assessing access across communities or even states, however, can be difficult.[1] This challenge is compounded by the task of translating the relevant data into a format that is clear and persuasive to policymakers and funding agencies. To improve access to health care, it is crucial to monitor how access varies across geography and subpopulations.[2]

The concept of accessibility to health care has at least two dimensions: geographic and social.[6] This study will focus on physical or geographic accessibility, the measuring of which poses several challenges [7], some of which are best addressed with the use of Geographic Information System (GIS). One of the difficulties of measuring physical accessibility is the question of internal validity of subjective data about distance (or travel time) to clinics, as reported by interview respondents or by ‘‘expert’’ informants.

Associating availability and accessibility coverage allows us to define spatial coverage and to analyze, concurrently, the physical accessibility of the supply and the adequacy of the supply to cover the demand. Spatial coverage concurrently takes into account the location and the maximum coverage capacity of each health facility, the landscape through which the patient needs to cross to reach the health facility, and the mode of transportation [5].

Spatial accessibility is recognized as an important component in the evaluation of a population's overall access to healthcare[3]. The ability to access places and activities provides fundamental social and economic benefits for individuals; it enables both interaction with other people and participation in necessary and voluntary daily activities. The role of geographic information systems (GIS) in accessibility analysis is increasingly important[4], and new methods for accessibility modeling are actively being developed[5].

Here, the use of a GIS, with indicators based on objective cartographic measurements, may bring improvement in internal validity over subjective assessments. Indicators based on cartography can also be useful to validate reports on travel time to clinics. They can shed light on the advantages or disadvantages of using real indicators of access instead of perceived indicators, and on the dilemma over whether to use individual measurements instead of aggregate measurements.[8]

The application of geographical information systems (GIS) for the assessment of accessibility to hospital has been investigated as an important growth pole specifically in Sarawak. The calculation of accessibility within district is essential taking into consideration the major role, as well as the magnitude of the influence exercised over its rural area. This study focused on determining accessibility of hospitals in Sarawak by using Geographic Information System (GIS) with network analysis.

**Methodology**

**Study Area**

Sarawak is located in northwest Borneo, south to the state of Sabah and to the northeast of Kalimantan (Fig. 1), between latitude 2°48′N and longitude 113°53′E. Its topography is divided into three regions; the coastal lowlands comprising of peat swamps and narrow deltaic and alluvial plains, a large region of undulating hills ranging to about 300 meters, and the mountain highlands extending to the Kalimantan border (Fig. 1), with a total area of 935.9 km2. All the native communities who lived by the river depended on it for food and water. Communities still use rivers as a mode of transport to their farms as well as other villages and towns.

Sarawak was selected because its average mean distance are highest among other states in Malaysia for public (22.4km) and private hospitals (48.4km) as according to the National Health Morbidity Survey in 2015.[6] Furthermore, the study areas are an effort to strengthen the possibilities to generalize the results. Sarawak is the largest states in Malaysia, both with regard to area and population. The level of economic development and availability of healthcare resources, as well as population are unevenly distributed throughout the province.

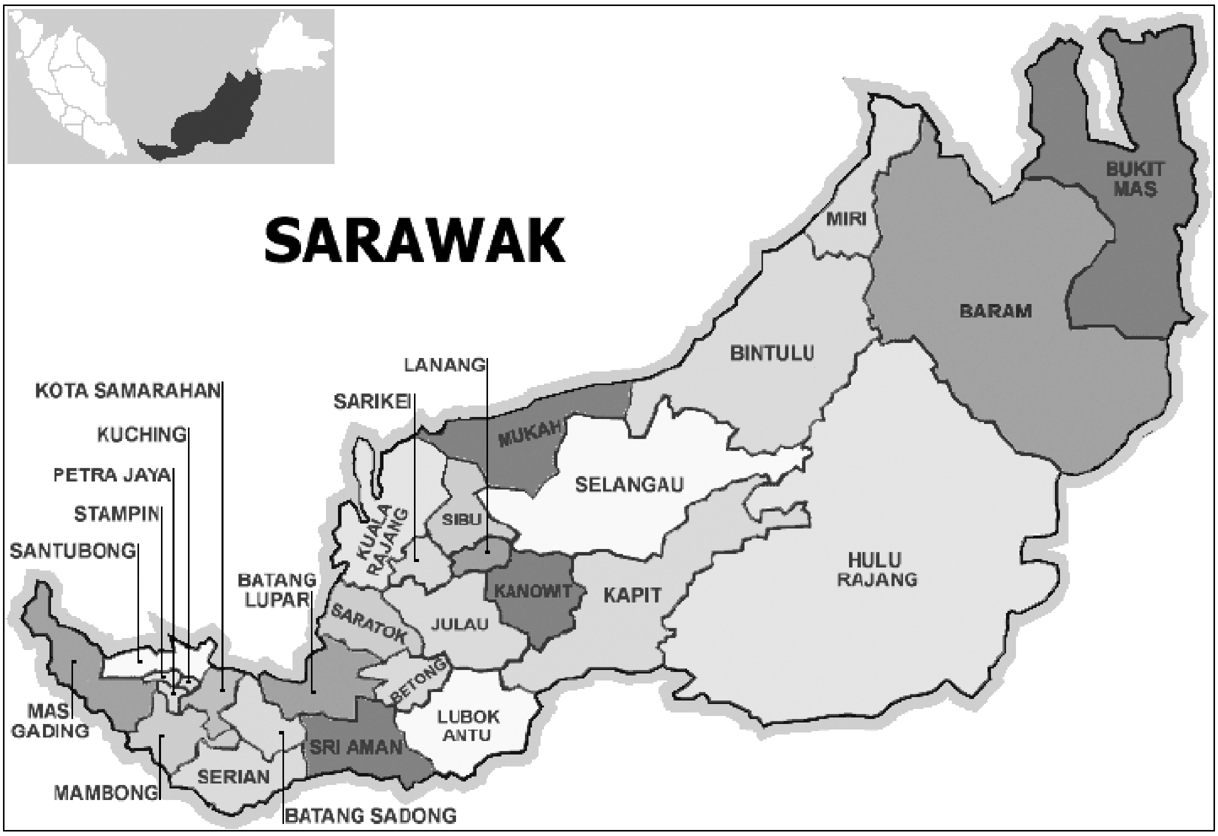


**Fig 1:** Sarawak state

**Data Source**

Data related to healthcare facilities were gathered from the Health Information Center, Ministry of Health Malaysia. Three indicators were used to characterize hospital capacity: the number of hospital beds, the number of staff, and the number of medical doctors. The latitude and longitude of the hospital locations were geocoded using the hospital names and addresses.

Road networks are used to compute the shortest travel times from the residents' locations to hospitals. The road network and administrative boundaries data were gathered from the Malaysian Centre for Geospatial Data Infrastructure (MACGDI) under Ministry of National Resources Environment (NRE).

**Spatial Analysis**

Spatial coverage for each hospital with the specified amount of time to access was determined by calculating the service areas and applied together with its network analysis in the GIS environment. Network analysis tool was used to create a network dataset and determine the new route and closest facility.

The shortest network distance and shortest travel time has been chosen to measure the proximity between the hospital and the user of those facilities because shortest network distance and shortest travel time both provides the most realistic distance measures. A simplified network analysis setting has been established in the ArcGIS Network Analyst tools to measure the travel distance and travel time between the hospitals.

The network setting allows U-turn at intersections and stops at any point.[7] Traffic lights are not considered by assuming that health care service users are able to travel to a health care facility at the specified location without any disruption. In reality, such assumptions may not hold true and hence may increase the travel time of the users.

The measurement of travel distance, measurements of car based travel time along the road network between health care facilities locations and all centroids have been undertaken using road length and travel speed.[8] Travel time has been derived using the following equation:

$$T_{ij} = \sum_{k=n}^{h} \left(\frac{l_k}{v_k}\right)$$

Where $T_{ij}$ is travel time between a centroid i and its closest health care facility location *j* specified by a road network distance of $\sum_{k=n}^{h} l_k$, where lk is the length of the road segment *k* and $v_k$ is the speed limits on road segment *k*.[9]

The road network dataset created for measuring the travel distance was also used to measure car based service area. Generalized polygons were created for each health care facility. Service areas based on car travel time measured with break time values of 15m, 30m, ad and 60m were also generated for each type of facility.[10]

**Results**

Analysis shows that most hospitals in Sarawak are accessible especially located in the urban area (Kuching, Betong, Sarikei, Sibu, Mukah, Miri and Limbang). Hospitals that present low accessibility are usually located on the eastern and rural areas (Kapit, Belaga, Song and Long Lama) which are categorized by a lower density of the public transportation network. The difference across the urban area in terms of access to hospitals indicate that a high number of communities are connected to the transport infrastructure (federal road and highway).

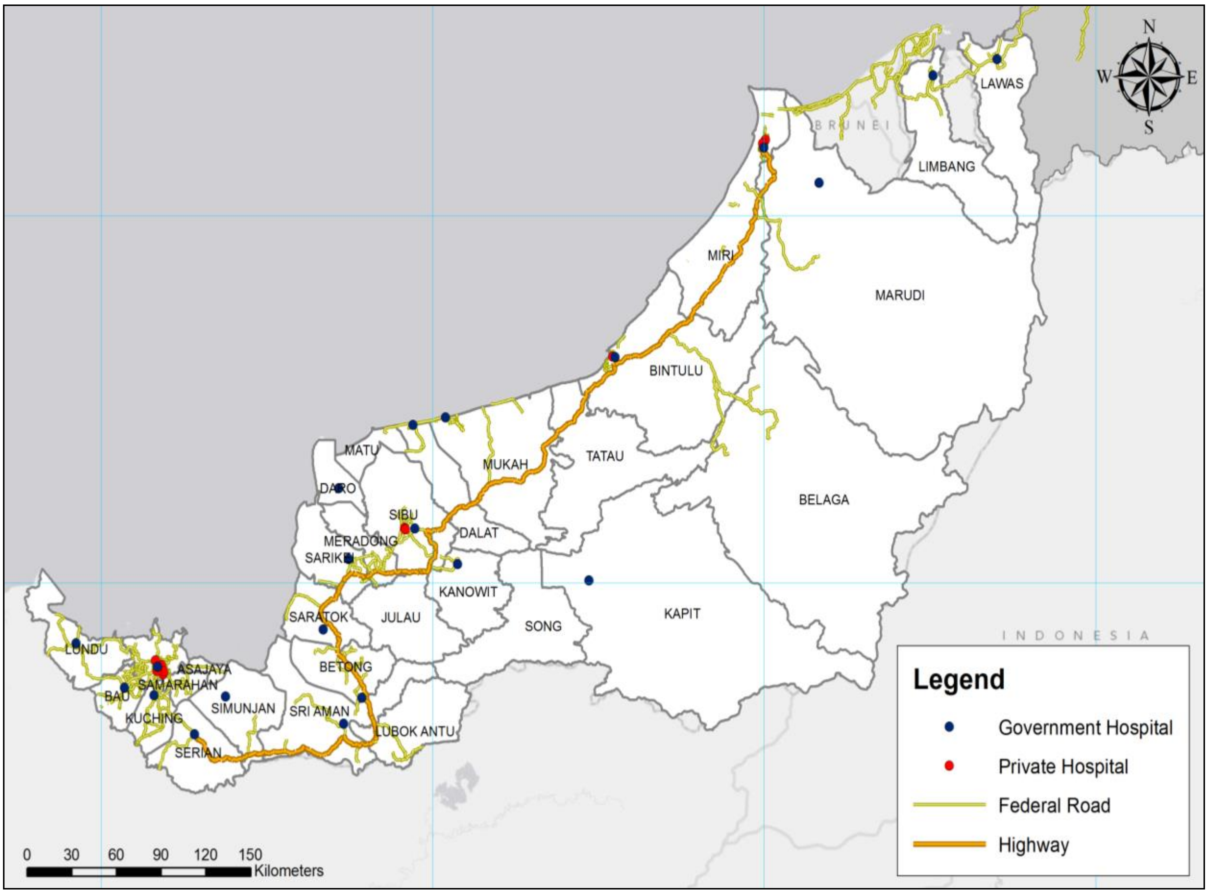


**Fig 2:** Distribution of Public and Private Hospital in Sarawak

Based on analysis, the travel time to the nearest hospital is mapped with an interval of 15 min into Fig. 3, which reveals a significant spatial variation across the district. Urban areas have much shorter travel time than rural areas.

The result shows 6.4% of Sarawakians could reach a public hospital within 15 minutes by driving, 12.3% and 39.6% within 30 and 60 minutes respectively. Meanwhile, 9.1% of Sarawakians could reach a private hospital within 15 minutes, 27.1% and 38.8% within 30 and 60 minutes respectively. 14.5% of Sarawakians could reach any hospital in Sarawak within 15 minutes, 32.0% and 46.1% within 30 and 60 minutes respectively.

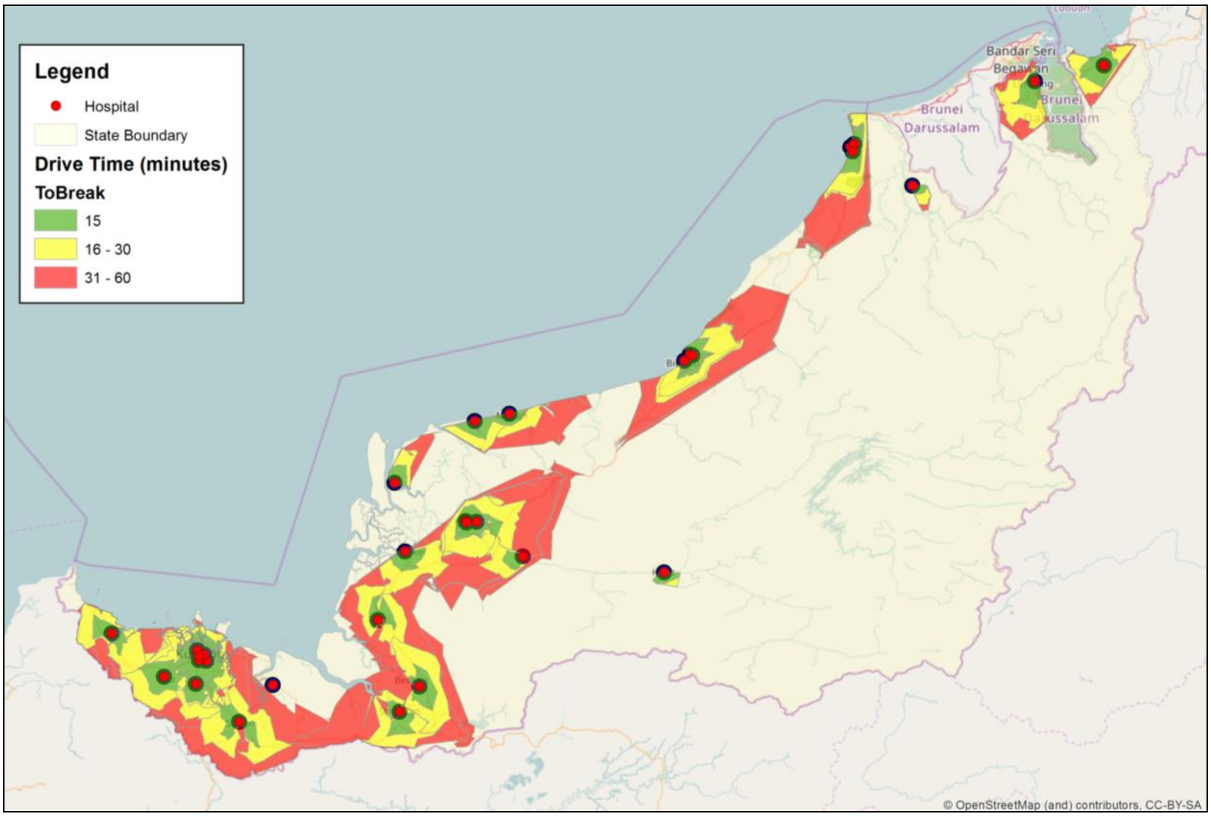


**Fig 3:** Drive Time to Hospital

## Discussion

The analyses mentioned above indicate a generally good access to hospital but it also exhibits a spatial accessibility between the urban and rural areas across the district. This spatial accessibility is dominantly caused by the imbalanced transportation network between the urban and rural areas. These findings are consistent with those of previous studies by Luis Rosero in Costa Rica.[11]

It is critically important to know the supply and demand of health services and to understand how these two factors converge in accessibility of health services for the population, in order to monitor and evaluate the impact of current reforms in the health sector. More equitable access to services is a central objective of reform; monitoring and evaluation of this factor requires rigorous measurement and analysis. [12] This study uses GIS techniques to perform these measurements, evaluate the impact of reform on equity of access, and provide guidelines for focused interventions.

Sarawak has with its wide distribution of hilly and low road density may cause longer travel time to health facilities compared to Peninsular Malaysia. Urban areas are more accessible to the nearest hospital to living quarters of population rather than rural area. Additional study should be conducted to identify the relationship between distance and actual time taken to travel to nearest health facilities.

The mappings of access to health services allow the identification of geographic inequities and to pinpoint specific communities in need. Decision making to correct inequities in access should make every effort to optimize the use of scarce resources. One way to do this is focusing interventions in areas identified by these maps, where impact would be greatest. However, it is not enough merely to identify needed locations, as consideration should also be given to the size of the population that would benefit.

Improvements of access in areas with little population density would have a lesser impact and would call for other strategies such as mobile units, small facilities, and perhaps the participation of volunteers in the community. In any case, the availability of data in a GIS platform, as the one developed in this study, makes possible the response to queries regarding the impact of alternative measures to alter the service supply environment and, in consequence, to optimize resource allocation.

## Conclusion

The analysis of accessibility to hospitals in the state of Sarawak was based on GIS with network analysis methods. The analysis is able to identify the best route and closest hospital to access during healthcare emergencies. Therefore, the findings of this study could assist healthcare policy makers and planners to understand the existing health care system of Sarawak and to identify medically underserved areas. This study has also shown the feasibility of using GIS technology for monitoring and evaluating the reform process and the degree of equitable access to services. With the use of a GIS platform as the one developed in this study, different scenarios could be evaluated for changing supply and, consequently, setting guidelines to optimize decisions on location allocation to make access more equitable.

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