Travel Time-Based Analysis of Hospital Access in Dapa and General Luna, Siargao Island: A Comparative Study Using AccessMod vs. ArcGIS Pro

Shaira V. Gicale[1], Almira L. Zulueta[1], Alexis Richard C. Claridades[1]

[1]Department of Geodetic Engineering, University of the Philippines Diliman, Quezon City, Philippines - {svgicale, alzulueta, acclaridades)@up.edu.ph

Keywords: Healthcare Accessibility, AccessMod, ArcGIS Pro, Isotropic, Anisotropic, Siargao Island

Abstract

Access to timely and adequate healthcare remains a persistent challenge in many rural and island communities in the Philippines, where geographic and infrastructural barriers often limit service delivery. Spatial analysis using Geographic Information Systems (GIS) has emerged as a powerful method for assessing disparities in healthcare accessibility and informing evidence-based planning and decision-making. This study presents a comparative spatial analysis of hospital accessibility in the municipalities of Dapa and General Luna, Siargao Island, using two GIS tools: AccessMod and ArcGIS Pro. By employing cost-distance and network-based travel time modeling, the research identifies geographic disparities in access to healthcare services across barangays. Both tools successfully revealed consistent patterns of inaccessibility, with remote areas such as Libertad, Cambas-ac, and Cabitoonan showing the longest average travel times to existing hospitals. In contrast, central barangays like Brgy. 2, Brgy. 6, and Brgy. 7 in Dapa had the shortest travel times. The results demonstrate that despite differences in computational approach and input data structure, both models reinforce the same spatial inequities in health service delivery. These findings are crucial for local health planners and decision-makers seeking to enhance equity in healthcare access through infrastructure upgrades or facility placement. The integration of spatial tools in public health planning offers a valuable lens for identifying underserved communities and guiding targeted interventions.

1. Introduction

Healthcare access remains a pressing issue in the Philippines, especially in remote and geographically isolated areas such as Siargao Island. While tourism and population growth continue to accelerate in municipalities like General Luna, medical infrastructure has not kept pace. A 2022 report by the Department of Health (DOH) that over 40% of households in General Luna report travel times exceeding 45 minutes to reach the nearest functional health facility. These travel delays result in inequitable access to both primary and emergency care, placing vulnerable populations—especially the elderly, pregnant women, and children—at heightened risk.

This study explores and compares the capabilities of two GIS-based tools—AccessMod and ArcGIS Pro—in modeling travel time-based healthcare accessibility in Dapa and General Luna, Siargao. Both platforms utilize cost-distance algorithms to simulate access, but they differ in functionality, user experience, and data compatibility. Additionally, ArcGIS Pro was used to perform network analysis based on the existing road network as an alternative approach to assess accessibility.

AccessMod, developed by the World Health Organization (WHO), is tailored for healthcare planning in low-resource contexts. It allows users to model access to care based on physical terrain, road conditions, and land cover. Its open-source nature makes it attractive for use in developing countries but poses limitations in terms of data input flexibility and technical customization (World Health Organization, 2018). In contrast, ArcGIS Pro is a commercial GIS platform that supports complex spatial analysis and more refined outputs. Though not healthcare-specific, it offers greater control over modeling parameters and visualization, making it suitable for detailed spatial planning (Esri, 2023).

This research is both timely and relevant, given the increasing reliance on geospatial tools for evidence-based public health planning. In underserved and rapidly developing areas like Siargao Island, the ability to identify healthcare service gaps using spatial modeling can directly inform infrastructure development and policy decisions. By comparing two widely used yet fundamentally different GIS tools, this study contributes to the growing body of literature on data-driven healthcare solutions. It provides practical guidance for their application in resource-limited contexts.

Through this comparison, the study aims to demonstrate the application of GIS-based travel time modeling methods in assessing healthcare access. It further seeks to compare the two GIS tools in terms of their outputs, data input requirements, usability, and overall suitability for healthcare planning, particularly in resource-limited settings. Additionally, the study seeks to identify and analyze underserved areas in Dapa and General Luna on Siargao Island, Surigao del Norte, based on the modeled travel time results generated from both platforms.

The scope of this study focuses on land-based travel to hospitals within Dapa and General Luna. Spatial analysis is limited to identifying underserved areas through travel time surfaces derived from both AccessMod and ArcGIS Pro. The comparison centers on the effectiveness, ease of use, and data requirements of the two platforms in simulating healthcare accessibility.

Several limitations are acknowledged. First, the analysis excludes boat travel, which could be a relevant mode of transport in island contexts. Second, generalized travel speeds are used, as real-time traffic and detailed road condition data were unavailable. Lastly, AccessMod's limited data compatibility poses constraints on the complexity of the input and customization. Despite these limitations, this study provides valuable insights into the practical application of GIS tools in healthcare planning and highlights the importance of spatial approaches in achieving health equity.

https://doi.org/10.5194/isprs-annals-X-5-W4-2025-277-2026

2. Related Studies

Improving equitable access to healthcare services is a priority in many countries, including the Philippines, where island geographies such as Siargao pose unique challenges due to fragmented terrain, limited infrastructure, and natural barriers. To support health planning, spatial analysis using GIS has become essential for quantifying physical accessibility and informing resource allocation (Tanser et al., 2006; Ebener et al., 2015).

Among specialized tools, AccessMod (Ray et al., 2008) has gained widespread adoption for modeling travel time to health facilities by integrating multiple geographic factors, including topography, road networks, and land cover. Recent peer-reviewed studies illustrate AccessMod's versatility. Hierink et al. (2023) applied it to assess primary healthcare accessibility in Ethiopia, Oliphant et al. (2022) optimized the deployment of community health workers in Mali, and Ochoa et al. (2023) examined vulnerability and healthcare access in Nepal. Similarly, Schmitz et al. (2019) and Joseph et al. (2020) demonstrated how AccessMod-derived travel time metrics can be used to evaluate access to emergency obstetric care and childhood immunization services in Tanzania, Uganda, and Kenya. These studies highlight AccessMod's capacity to generate detailed, standardized accessibility indicators aligned with global health initiatives, such as the WHO's Universal Health Coverage framework (WHO, 2019).

In contrast, ArcGIS Pro offers a flexible platform for healthcare accessibility modeling, featuring tools such as Network Analyst and raster-based cost surface analysis. Studies utilizing ArcGIS Pro demonstrate its utility for customized spatial accessibility assessments in varied contexts. For example, Schuurman et al. (2010) used ArcGIS network analysis to evaluate trauma center accessibility in Canada, while Delamater et al. (2012) compared raster and network models of healthcare provider access in Michigan, USA. Although not health-specific, ArcGIS Pro's advanced spatial analysis functions enable scenario-based modeling and integration of local data, which is particularly valuable for complex terrains and infrastructure networks typical of island settings.

Despite the rich literature using both AccessMod and ArcGIS Pro, there is limited research applying these tools in Philippine Island contexts, particularly Siargao. The municipalities of Dapa and General Luna face distinct accessibility challenges influenced by their road networks, terrain, and population distribution. Furthermore, direct comparative analyses between AccessMod and ArcGIS Pro remain rare, especially in low-resource island environments where data availability and infrastructure vary considerably.

3. Materials and Methods

3.1 Study Area and Dataset

This study centers on the municipalities of Dapa and General Luna on Siargao Island, Surigao del Norte. Siargao is a rapidly developing island, distinguished by its booming tourism industry and vibrant local communities (Philippine Statistics Authority, 2020). General Luna, a tourism hotspot on the island, experiences significant seasonal increases in population, which in turn intensifies demand for healthcare services during peak periods. Conversely, Dapa functions as the island's healthcare hub, hosting the Siargao Island Medical Center and key administrative health offices (Department of Health, 2020).

The distinct roles of these municipalities—General Luna as a tourism-driven service area and Dapa as the central medical provider of medical facilities—make them ideal for examining healthcare accessibility. Their diverse geographic features, including rugged terrain and dispersed settlements, combined with limited road infrastructure, present challenges to timely access to healthcare for both locals and tourists (Salvacion, 2022). Focusing on these two locations allows this study to address healthcare needs arising from both local populations and transient tourists. The resulting spatial analysis aims to provide targeted insights to improve health service coverage and inform planning decisions tailored to Siargao's unique social and geographic landscape.

To support this analysis, spatial datasets relevant to modeling travel time to healthcare facilities were first collected. All datasets were sourced from official Philippine government portals to ensure geographic accuracy and alignment with national standards. The administrative boundaries and land cover data for General Luna and Dapa were obtained from the Philippine Geoportal, which served to delineate the study area. Elevation data from the Copernicus Programme were used to generate slope layers and estimate walking difficulty, which are critical inputs for modeling terrain-related travel impedance. Land cover data were used to classify surface types, including built-up areas, low-density vegetation, and dense vegetation. These classifications informed travel speed assignments and the identification of potential barriers to movement in both modeling platforms. Road features were also extracted from the land cover dataset and played a key role in defining travel routes. The location of the primary healthcare facility within the study area—the Siargao District Hospital—was derived from the same land cover dataset and served as the central destination for the accessibility analysis.

This study did not incorporate real-time traffic and road condition data because such datasets were unavailable for Siargao Island from local government units (LGUs), national agencies, or open-access platforms. Although there are ongoing efforts in the Philippines to develop intelligent transportation systems, enhance road monitoring, and integrate geospatial data infrastructures, these initiatives have yet to yield publicly accessible, high-resolution datasets for remote and rural islands such as Siargao. Future research on hospital accessibility could greatly benefit from integrating real-time traffic patterns, congestion dynamics, seasonal road accessibility, and variations in surface conditions into travel time models. Including these factors would improve the accuracy of travel time estimates by capturing road performance under different traffic loads, weather conditions, and times of day. Addressing this data gap would enable planners and policymakers to design adaptive healthcare systems, optimize hospital service areas, and ensure timely medical access for communities, even under rapidly changing conditions.

3.2 Data Processing

3.2.1 Land cover: Land cover categories were reclassified into three generalized types—built-up, low dense vegetation, and dense vegetation—to support spatial modeling and accessibility analysis using AccessMod. This simplified classification enables compatibility with the software's travel time computation, (barriers) and varying degrees of traversable land. This reclassification was based primarily on the European Space Agency (ESA, 2021) World Cover 10m 2020 dataset, which provides globally recognized land cover definitions. To adapt these global schemes to local conditions, Philippine-specific land use categories from the Housing and Land Use Regulatory Board Comprehensive Land Use Plan (CLUP) (HLURB, 2014) Guidebook were incorporated. This integration ensured the classification reflected local land use realities while maintaining consistency with global standards. Moreover, adjustments were made to align with AccessMod's modeling requirements, which demand clear distinctions between impassable barriers and varying levels of traversable land to ensure accurate travel time calculations.

In the analysis, impassable features such as water bodies, swamps, quarries, and reclaimed areas were treated as barriers and excluded from the final land cover classification. The three land cover categories used in Table 1—, built-up, low dense vegetation, and dense vegetation—were applied to the travel time modeling. Built-up refers to surfaces dominated by man-made infrastructure, including residential zones, commercial areas, transport terminals, institutional uses, and tourism facilities. Low dense vegetation encompasses lands with scattered vegetation or agricultural use—such as agroforestry, orchards, and crop areas—that typically offer moderate traversability. Lastly, dense vegetation refers to areas with high vegetation density, such as forests and mangroves, which are often protected and less accessible. This categorization facilitates more accurate modeling of travel impedance based on land cover characteristics, allowing for context-specific interpretation in both urban and rural Philippine settings.

3.2.2 Road Network: The road network layer was extracted from land cover data and reclassified into three hierarchical categories—main, secondary, and tertiary roads—to support spatial data standardization and facilitate consistent integration across analysis platforms. This classification follows functional typologies commonly used in Philippine transport planning and GIS-based modeling, consistent with guidelines from the Department of Public Works and Highways (DPWH, 2018) and standard practices in regional land use datasets. Main roads refer to major transport corridors such as highways and arterial roads, built for high-capacity, long-distance travel, typically paved and connecting major settlements. Secondary roads are intermediate connections linking municipalities or barangays to the main road network, supporting moderate traffic with varying surface conditions. Tertiary roads are local access routes within barangays or residential areas, often narrow, informal, or unpaved, and primarily serve low-volume traffic.

Notably, residential areas initially classified as part of the road network were reclassified as built-up due to their informal, narrow, and often unpaved nature, which is common in General Luna and Dapa. These areas are typically accessed by foot or low-speed vehicles and do not function as formal roads. This reclassification aligns with accessibility studies, which assign slower travel modes to dense residential zones rather than incorporating them into road networks (Tanser et al., 2006; Huerta Munoz et al., 2012; World Health Organization, 2018).

3.3 Methodology

Figure 1 summarizes the methodology for this study. The workflow illustrates the methodological framework comparing AccessMod and ArcGIS Pro for accessibility analysis. AccessMod directly prepares for accessibility analysis through distance accumulation techniques, whereas ArcGIS Pro involves more detailed preprocessing steps, the creation of a network dataset, and preparation for both distance and network analysis. The outputs from each pathway are then subjected to a comparative analysis, which informs the study's conclusion regarding the strengths, limitations, and applicability of the two approaches.

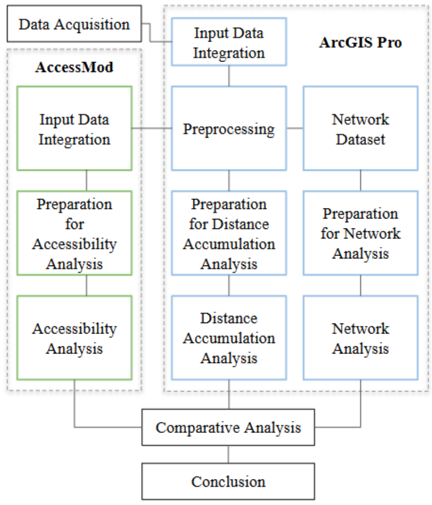

Figure 1. Overview of the Methodological Framework

3.3.1 Accessibility Analysis: AccessMod requires a combination of raster and vector data formats. Hence, it needs to undergo preprocessing, as shown in Figure 1, to start the analysis. Raster datasets are used for the digital elevation model (DEM), land cover, and barriers, while vector layers are employed for roads and hospital locations. In addition, tabular data is needed to classify land cover types and to define travel scenarios by assigning specific speeds to each land cover class and mode of transportation (e.g., walking, bicycling, or motorized). Before data integration, AccessMod also requires that all input datasets be projected in the WGS 1984 UTM Zone 51N coordinate system to ensure spatial consistency. Furthermore, all raster datasets must have the same pixel resolution and alignment to avoid errors during analysis.

All preprocessing of raster datasets was conducted externally in ArcGIS Pro, as AccessMod does not offer tools for reclassification, defining a consistent spatial extent for raster, or performing topological corrections and attribute validation on road network data. These preprocessing procedures were essential to ensure data uniformity, spatial alignment, and the accuracy of the resulting friction surface.

The land cover was reclassified using numeric codes to simplify the assignment of travel costs, summarized in Table 1. Because the original land cover dataset was in vector format, it was converted to a raster format with a spatial resolution of 1 meter per pixel to ensure compatibility with other raster inputs used in the accessibility model.

Class	Label
1	Built Area
2	Low Dense Vegetation
3	Dense Vegetation

Table 1. Land cover table.

The DEM was standardized to match the study area's extent, ensuring uniformity across all raster inputs. To ensure proper alignment with other datasets, the DEM was resampled to a spatial resolution of one meter per pixel, matching the resolution of the land cover raster.

The road network was cleaned to remove disconnected segments, correct digitization errors, and ensure that all features were properly connected, thereby ensuring accurate travel time modeling. This process helped eliminate gaps or overlaps that could disrupt the generation of a continuous and navigable travel surface. Furthermore, the road network data was classified into three categories, as mentioned above, based on road hierarchy and functional classification. This classification allowed for the assignment of different travel speeds to each road type during the creation of the friction surface, reflecting varying levels of accessibility and travel efficiency across the transportation network.

The hospital locations, required in vector format for the analysis, were extracted as point features from the land cover dataset. Further, the travel time scenario table, summarized in Table 2, was also prepared to detail the assigned travel speeds and transportation modes for each land cover and road classification used in the modeling. It specifies how different terrain types and road classes correspond to realistic movement modes—such as walking, bicycling, or motorized transport—and their respective speeds, reflecting local conditions. This table served as a key input for AccessMod to simulate multimodal travel and generate travel time surfaces.

Class	Label	Speed (km/h)	Mode
1	Built Area	15	Bicycling
2	Low Dense Vegetation	6	Walking
3	Dense Vegetation	5	Walking
1001	Main Road	80	Motorized
1002	Secondary Road	60	Motorized
1003	Tertiary Road	40	Motorized

Table 2. Scenario table using multimodal transportation.

Once preprocessing was complete, the prepared dataset was integrated into the software. AccessMod combines the land cover and road network data to create a friction surface—a raster layer where each cell value represents the time required to traverse that cell. This surface accounts for the varying travel speeds across different terrains and infrastructures.

Using the friction surface and DEM-derived slope data, AccessMod then performs cost-distance analyses to calculate travel times from each cell to the nearest health facility. It employs algorithms that consider both isotropic (uniform in all directions) and anisotropic (direction-dependent) travel conditions. The result is a raster output depicting travel time surfaces across the study area.

3.3.2 Distance Accumulation: For the Distance Accumulation approach, the land cover and road rasters were reclassified so that each cell value represented travel time in minutes, derived from assigned travel speeds for each land cover class and travel mode (walking, bicycling, motorized). These speeds were converted into time-based cost values corresponding to the raster resolution of 1 meter per cell. A DEM was used to calculate the slope between each cell and its neighbors. This enabled anisotropic modeling, where movement costs depend on travel direction rather than being uniform in all directions.

Walking speeds were adjusted using Tobler's hiking function, which modifies speed based on slope gradient (Tobler, 1993), while bicycling speeds were corrected using a physical model that accounts for air resistance, gravity, and rolling friction, with downhill speed limited to twice the flat surface speed. Using these inputs, the cumulative travel time surface reflects both land cover impedance and topographic variation, consistent with the anisotropic approach used in AccessMod 5 (World Health Organization, 2021).

In modeling bicycle-based travel within the accessibility analysis, AccessMod's built-in physical bicycling model was used to correct travel speeds according to terrain slope. This model incorporates the effects of air resistance, gravity, and rolling friction, providing a more realistic estimation of cycling speed over varying terrain.

After the friction surface was prepared, preprocessing for the Distance Accumulation analysis was conducted. This stage integrated three key raster inputs: the friction surface, the digital elevation model (DEM), and the locations of health facilities. The output of this process is a travel time raster, where each cell value represents the cumulative travel time, in minutes, from that location to the nearest health facility. This output provides a spatial representation of accessibility across the study area.

3.3.3 Network Analysis: For the network-based analysis, a routable network dataset was derived from the existing road network layer. This involved transforming the road features into a network dataset structure in ArcGIS Pro that supports routing functionality. Key attributes—including road classification, speed limits, and travel directionality—were incorporated to enable the calculation of travel time impedance, representing the time it takes to traverse each road segment based on mode-specific speeds (Esri, 2023a).

The network dataset was further enhanced by incorporating real-world traffic restrictions, such as one-way streets, turn prohibitions, and restricted access roads, to improve routing accuracy. Connectivity rules were validated to ensure that the network reflects actual vehicular flow and connectivity, minimizing routing errors and unrealistic paths.

Incident locations were identified as potential destinations or demand points for healthcare access. These were determined by extracting land cover classes and zoning features indicative of high population density and human activity—such as commercial areas, general institutional zones, informal settlements, residential neighborhoods, and socialized housing. This selection process involved a combination of attribute queries and spatial selection techniques within GIS.

Once the facilities and incident locations were defined, the route algorithm was used to calculate the optimal routes based on the shortest travel time. The routing analysis considered both impedance values (derived from speed and segment length) and network constraints, ensuring that calculated routes were both efficient and realistic. The resulting output includes a set of route lines showing the fastest paths from each origin to corresponding incident locations, as well as tabular data summarizing travel times, distances, and path attributes for each route (Esri, 2023b).

4. Results

The comparison between isotropic and anisotropic travel time analyses highlights the role of terrain in shaping healthcare accessibility across Siargao Island. Both AccessMod and ArcGIS Pro were used to generate travel time surfaces, taking into account land cover types and travel speed settings. The resulting maps help visualize how different modeling methods capture spatial accessibility patterns.

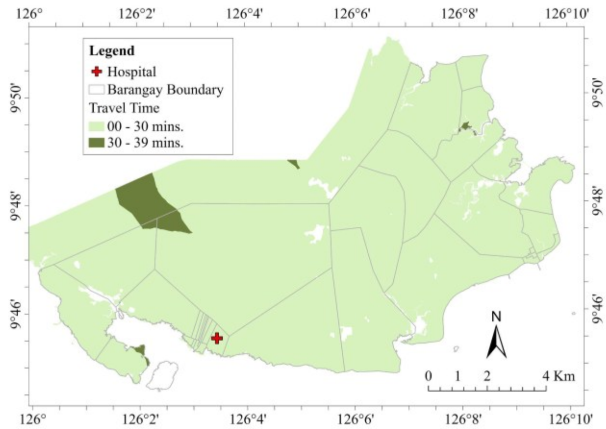

Figure 2. Isotropic Travel Time Map from AccessMod

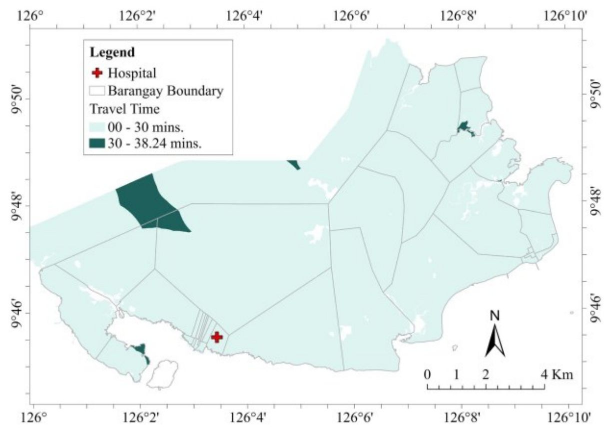

Figure 3. Isotropic Travel Time Map from ArcGIS Pro

Figures 2 and 3 show the results of isotropic modeling, where travel is simulated across a flat surface with constant movement speed. Because elevation is not factored in, the resulting catchment areas—particularly the 30-minute accessibility zones—appear broader and more continuous. Both AccessMod and ArcGIS Pro produced comparable outputs, with only a minimal difference in maximum travel time, suggesting consistency between the tools when terrain is not considered. However, this method may overestimate accessibility in areas with rugged topography.

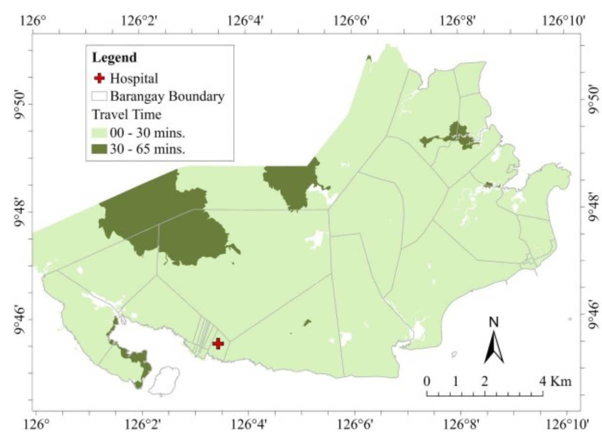

Figure 4. Anisotropic Travel Time Map from AccessMod

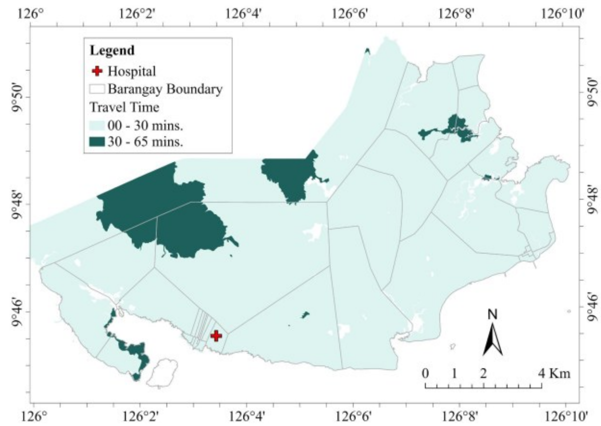

Figure 5. Anisotropic Travel Time Map from ArcGIS Pro

Figures 4 and 5 display anisotropic travel time models, which incorporate slope data to simulate the effect of uphill or downhill movement on travel speed. These maps show that many upland or slope-constrained areas fall outside the 30-minute catchment zone, particularly in barangays farther from the coast or along hilly terrain. Compared to isotropic outputs, the anisotropic models offer a more realistic depiction of accessibility by accounting for terrain-related travel delays. The maximum travel time remains consistent between tools, reinforcing the reliability of both models in simulating terrain-affected access.

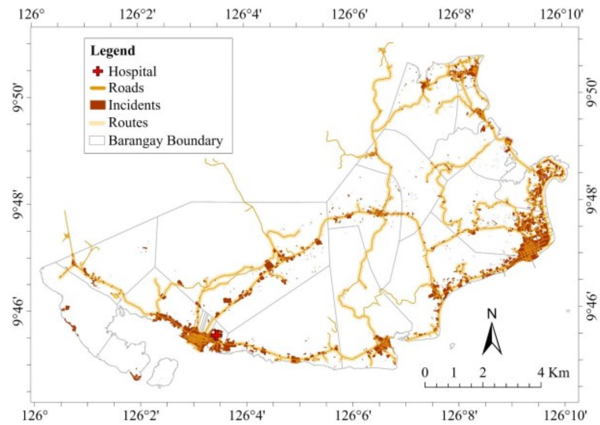

Figure 6. ArcGIS Pro Network-Based Route Map

Figure 6 presents the results of a network-based route map conducted using ArcGIS Pro. Unlike raster-based models, this method simulates movement along actual road infrastructure with assigned travel speeds, generating more practical service areas based on real routes. The analysis highlights differences in accessibility across barangays, particularly in areas close to the main municipal road networks, such as Brgy. 2 and Brgy. 7 in Dapa showed shorter average travel times, while more remote barangays like Cabitoonan and Libertad recorded the highest travel times. Table 3 summarizes these average values, allowing direct comparison of spatial disparities between communities.

To further evaluate travel time across administrative boundaries, zonal statistics were applied to raster travel time surfaces. The mean travel time was calculated per barangay to capture overall accessibility conditions. The analysis comparing AccessMod and ArcGIS Pro for modeling healthcare accessibility in Siargao Island demonstrates that both tools effectively generate travel time surfaces that integrate terrain, land cover, and road networks, producing comparable results that accurately reflect physical access to health facilities. This confirms the practical applicability of GIS-based travel time modeling in resource-limited island settings.

AccessMod offers a streamlined, health-focused interface with straightforward data input requirements, making it accessible to users with limited GIS expertise, although it provides less flexibility in data handling. In contrast, ArcGIS Pro supports a broader range of data formats and enables advanced customization for detailed spatial analyses but requires greater technical skill and preprocessing effort.

Barangay	AccessMod		ArcGIS		
	Iso (mins)	Aniso (mins)	Iso (mins)	Aniso (mins)	Net (mins)
Dapa					
Pob. 1	1.95	2.41	1.46	1.90	1.57
Pob. 2	2.25	2.74	1.72	2.19	1.45
Pob. 3	2.90	3.80	2.58	3.46	1.49
Pob. 4	3.24	4.53	2.43	3.69	1.60
Pob. 5	3.72	5.19	2.89	4.34	1.63
Pob. 6	2.55	2.56	2.08	2.07	2.04
Pob. 7	2.00	2.00	1.75	1.73	1.68
Pob. 8	4.05	5.14	3.58	4.65	1.68
Pob. 9	2.55	2.56	2.06	2.05	1.95
Pob. 10	4.03	4.34	3.55	3.85	2.53
Pob. 11	2.75	2.76	2.28	2.27	2.24
Pob. 12	7.01	8.48	6.51	7.96	2.79
Pob. 13	2.89	2.90	2.34	2.33	2.47
Cambas-ac	26.42	28.43	18.16	20.11	3.22
Don Paulino	11.11	14.79	10.67	14.33	4.01
Jubang	16.14	17.76	14.74	16.34	5.97
Osmeña	13.10	17.85	12.50	17.23	5.33
Santa Fe	15.20	18.47	14.36	17.61	5.34
Union	12.23	14.42	11.71	13.88	8.65
General Luna					
Cabitoonan	23.35	24.23	21.09	21.95	19.45
Catangnan	17.97	18.25	16.71	16.96	16.16
Consuelo	12.33	14.65	12.13	14.42	7.41
Corazon	15.17	16.99	15.03	16.83	11.17
Libertad	24.29	24.90	23.67	24.25	22.23
Magsaysay	22.04	23.68	21.06	22.67	18.02
Malinao	14.58	15.94	13.88	15.20	12.36
Pk. I	13.78	13.79	12.99	12.97	13.10
Pk. II	13.05	13.06	13.24	13.21	12.63
Pk. III	13.96	13.97	13.47	13.44	12.86
Pk. IV	13.10	13.10	13.16	13.14	12.59
Pk. V	14.39	14.43	14.22	14.23	13.52
Sta. Cruz	21.16	22.96	20.87	22.63	18.75
Sta. Fe	15.20	18.47	14.36	17.60	19.28
Tawin-tawin	16.00	17.00	15.27	16.24	12.89

Table 3. AccessMod Isotropic Average Time Travel Map

Both tools successfully identified underserved communities in Dapa and General Luna, offering valuable spatial insights for healthcare planners aiming to improve equitable access. Across all three methods, remote areas such as Libertad, Cambas-ac, and Cabitoonan consistently recorded the longest average travel, while central poblacion barangays like Brgy. 2, Brgy. 6, and Brgy. 7 in Dapa showed the shortest (see Table 3).

Although the estimated times varied between ArcGIS Pro and AccessMod's isotropic and anisotropic models, each method effectively captured the spatial distribution of healthcare accessibility. These findings underscore persistent geographic disparities and suggest that while all approaches are reliable for identifying underserved areas, certain methods may be less suitable for accurately estimating travel time due to differences in terrain handling and movement assumptions.

Overall, the complementary strengths of AccessMod and ArcGIS Pro make them valuable resources for evidence-based healthcare planning in remote island contexts such as Siargao Island, supporting efforts to enhance access and address healthcare disparities.

5. Discussion

The results of this study highlight spatial disparities in hospital accessibility between Dapa and General Luna, with certain barangays experiencing travel times exceeding the recommended 30-minute threshold for timely medical care. These findings can serve as an evidence base for prioritizing areas that require improved access, whether through the construction of new health facilities, upgrading of existing ones, or enhancing transportation infrastructure.

For the Department of Health (DOH) and local government units (LGUs), integrating spatial accessibility analysis into infrastructure planning could improve resource allocation efficiency. In practice, the modeled travel time surfaces can be overlaid with demographic and epidemiological data to identify high-need areas. This supports the principles of Republic Act No. 11223 (Universal Health Care Act) and the DOH's Philippine Health Facility Development Plan, which emphasize equitable access to essential health services. Accessibility modeling also aligns with disaster preparedness frameworks, such as the National Disaster Risk Reduction and Management Plan, by identifying communities likely to face delayed emergency response during hazard events.

Finally, the methodological comparison between AccessMod and ArcGIS Pro offers guidance for selecting appropriate tools based on institutional resources. Agencies with limited budgets may opt for AccessMod's open-source framework to generate rapid accessibility assessments, while those with existing ArcGIS Pro infrastructure can leverage its advanced customization for integrating multi-sectoral datasets. By institutionalizing such analyses within LGU and DOH planning workflows, decision-makers can shift from reactive to proactive health facility planning, ensuring that geographic accessibility is a central criterion in service delivery strategies.

These distinctions highlight that while ArcGIS Pro may be preferable for agencies with established GIS infrastructure and advanced analytical needs, AccessMod remains a practical choice for health-focused accessibility assessments, especially in resource-limited settings. Finally, ArcGIS Pro offers advanced customization and integration with diverse spatial datasets but requires paid licensing, specialized training, and higher computational resources. AccessMod is open-source and optimized for health accessibility modeling, making it more accessible to low-resource settings, but it offers less flexibility in customizing algorithms, limited cartographic options, and fewer data integration capabilities. Table 4 summarizes these comparisons.

Criteria	ArcGIS Pro	AccessMod
Pros	Highly customizable; supports diverse datasets; advanced cartographic outputs	Free, open-source; health-focused; simple travel time computation
Cons	Paid license; high hardware needs; steep learning curve	Limited customization; less flexible for non-health uses
Data Requirements	Handles many formats; supports large/complex datasets	Needs specific layers (DEM, land cover, roads, facilities) in set formats
Skills Needed	Advanced GIS skills for analysis & integration	Moderate GIS skills; basic health accessibility concepts

Table 4. Comparison of ArcGIS Pro and AccessMod

6. Conclusions

This study demonstrated the effective application of geospatial tools—AccessMod and ArcGIS Pro—in modeling healthcare accessibility through travel time analysis in Dapa and General Luna, Siargao Island. Both platforms successfully generated travel time surfaces and identified underserved areas, confirming the value of GIS-based approaches in supporting healthcare planning, particularly in remote and resource-constrained settings.

AccessMod is a user-friendly tool specifically designed for healthcare accessibility analysis, enabling the effective calculation of travel time in both isotropic and anisotropic conditions. However, it lacks data preprocessing functionalities, requiring users to prepare all necessary datasets beforehand. ArcGIS Pro, on the other hand, is a comprehensive GIS software that includes detailed data preprocessing, visualization, and advanced modeling capabilities but requires intermediate GIS skills for effective use. Results prove that AccessMod is ideal for focused accessibility analysis with minimal technical barriers once data is ready. At the same time, ArcGIS Pro offers complete control and customization throughout the entire workflow, from raw data to final analysis and visualization.

The cost-distance method, particularly in anisotropic modeling, provides a comprehensive view of physical accessibility in areas with uneven terrain and limited infrastructure. The network-based approach is more accurate in structured environments with reliable road data. The choice between the two should be based on the geographic context and the nature of the accessibility challenges being studied.

Recent national and local initiatives highlight the urgency of improving equitable healthcare access. The Department of Health's Philippine Health Facility Development Plan (2020–2040) prioritizes the strategic location of facilities to minimize geographic and socioeconomic barriers, while several LGUs, including those in Siargao, have initiated health investment programs aimed at expanding rural health infrastructure. The results of this study can directly support these efforts by identifying priority areas where travel times to hospitals exceed recommended thresholds. Decision-makers can operationalize these findings by integrating travel time analysis into their facility siting processes, prioritizing road network improvements in underserved barangays, and deploying mobile health units to communities with persistent access gaps. Such evidence-based planning can help ensure that infrastructure investments yield maximum public health benefits, particularly in rural island contexts where resources are limited and transportation networks are constrained.

Several limitations must be acknowledged. While the travel time maps were generated using validated datasets and established modeling approaches, the outputs were not field-validated due to logistical constraints and the unavailability of up-to-date, location-specific travel time data from local agencies. Future work could incorporate GPS-based travel surveys or crowd-sourced mobility datasets to verify modeled travel times. The study focused solely on land-based travel, excluding boat transportation, which is particularly critical for residents of outlying islands. Generalized travel speeds were used due to the lack of real-time traffic and road condition data, and AccessMod's limited data compatibility constrained certain aspects of the modeling process.

The study did not include cross-regional comparisons due to the unavailability of standardized datasets from other locations within the project timeframe. Moreover, there are currently no publicly available datasets documenting actual emergency response records, such as ambulance dispatch times, travel durations, or patient transfer logs, which could validate and enrich accessibility models. Additionally, ensuring methodological consistency across different regions would require harmonizing spatial resolution, road network accuracy, and health facility datasets, which was beyond the scope of this research. Future studies could replicate this analysis in other island municipalities or rural provinces to assess the generalizability of the findings and identify location-specific accessibility challenges.

Future research should incorporate maritime transport modes to capture a more comprehensive picture of accessibility in island contexts and expand the scope of analysis to cover the entire Siargao Island. This would provide a more complete understanding of healthcare disparities across the region and support more inclusive and equitable health infrastructure planning. Ultimately, this study underscores the crucial role of spatial modeling in addressing healthcare access challenges and highlights the need for flexible, data-informed approaches tailored to the unique geographical realities of island communities.

References

Delamater, P. L., Messina, J. P., Shortridge, A. M., & Grady, S. C., 2012. Measuring geographic access to health care: raster and network-based methods. *International Journal of Health Geographics*, 11(1), 15. doi.org/10.1186/1476-072X-11-15.

Department of Health, 2020. *Philippine Health Facility Development Plan 2020–2040*. Department of Health – Republic of the Philippines. doh.gov.ph/sites/default/files/publications/HFDP-2020-2040.pdf (20 April 2025).

Department of Public Works and Highways, 2022. *Philippine Highway Traffic Operations Manual*. dpwh.gov.ph (21 April 2025).

Ebener, S., Stenberg, K., Brun, M., Monet, J.-P., Ray, N., Sobel, H., & Tan-Torres Edejer, T., 2015. Proposing standardised geographical indicators of physical access to emergency obstetric and newborn care in low- and middle-income countries. *BMJ Global Health*, 4(1), e000778. doi.org/10.1136/bmjgh-2018-000778.

Ebener, S., Ray, N., & Black, M., 2004. Using GIS to measure physical accessibility to health care. *International Journal of Health Geographics*, 3(1), 1–13. doi.org/10.1186/1476-072X-3-3.

ESA, 2021. *WorldCover 10m 2020 v100*. European Space Agency. worldcover2020.esa.int (19 April 2025).

Esri, 2023. *ArcGIS Pro: Geographic information system software*. esri.com/en-us/arcgis/products/arcgis-pro/overview (15 April 2025).

Esri, 2023a. What is Network Analyst? ArcGIS Pro Documentation. pro.arcgis.com/en/pro-app/latest/help/analysis/networks/what-is-network-analyst-.htm (25 April 2025).

Esri, 2023b. Network Dataset Properties. ArcGIS Pro Documentation. pro.arcgis.com/en/pro-app/latest/help/analysis/networks/network-dataset-properties.htm (25 April 2025).

Hierink, F., Oladeji, O., Robins, A., Muñiz, M., Ayalew, Y., & Ray, N., 2023. Implementing the primary healthcare roadmap in Ethiopia: a mixed geospatial analysis of accessibility and availability. *Communications Medicine*, 3, 140. doi.org/10.1038/s43856-023-00372-z.

Housing and Land Use Regulatory Board (HLURB), 2014. *Comprehensive Land Use Plan (CLUP) Guidebook Volume 3: Model Zoning Ordinance*. HLURB, Quezon City, Philippines. lcp.org.ph/UserFiles/League_of_Cities/file/HLURB_CLUP_Guidebook_Vol_3_11042015.pdf (15 April 2025).

Huerta Munoz, U., & Källestål, C., 2012. Geographical accessibility and spatial coverage modeling of the primary health care network in the Western Province of Rwanda. *International Journal of Health Geographics*, 11(1), 40. doi.org/10.1186/1476-072X-11-40.

Joseph, N. K., Macharia, P. M., Ouma, P. O., Mumo, J., Jalang'o, R., Wagacha, P. W., & Okiro, E. A., 2020. Spatial access inequities and childhood immunisation uptake in Kenya. *BMC Public Health*, 20, 1407. doi.org/10.1186/s12889-020-09486-8.

Knoblauch, R. L., Pietrucha, M. T., & Nitzburg, M., 1996. *Field Studies of Pedestrian Walking Speed and Start-Up Time*. Transportation Research Record, 1538, 27–38. doi.org/10.3141/1538-04.

Ochoa, C., Rai, M., Babo Martins, S., Alcoba, G., Bolon, I., Ruiz de Castañeda, R., & Ray, N., 2023. Vulnerability to snakebite envenoming and access to healthcare in the Terai region of Nepal: a geospatial analysis. *The Lancet Regional Health – Southeast Asia*, 9, 100103. doi.org/10.1016/j.lansea.2022.100103.

Oliphant, N. P., Sy, Z., Koné, B., Berthé, M., Beebe, M., Samake, M., & Doherty, T., 2022. Improving the efficiency of scale-up and deployment of community health workers in Mali: a geospatial analysis. *PLOS Global Public Health*, 2(10), e0000626. doi.org/10.1371/journal.pgph.0000626.

Ray, N., & Ebener, S., 2008. AccessMod 3.0: computing geographic coverage and accessibility to health care services using anisotropic movement of patients. *International Journal of Health Geographics*, 7, 63. doi.org/10.1186/1476-072X-7-63.

Schmitz, M. M., Serbanescu, F., Arnott, G. E., Dynes, M., Chaote, P., Msuya, A. A., & Chen, Y. N., 2019. Referral transit time between sending and first-line receiving health facilities: a geographical analysis in Tanzania. *BMJ Global Health*, 4(4), e001568. doi.org/10.1136/bmjgh-2019-001568.

World Health Organization, 2018. *Global Reference List of 100 Core Health Indicators*. who.int/healthinfo/indicators/2018/en (27 April 2025).

World Health Organization, 2019. *Primary Health Care on the Road to Universal Health Coverage*: 2019 Monitoring Report. World Health Organization, Geneva. who.int/publications/i/item/9789240029040 (15 April 2025).

World Health Organization, 2021. *AccessMod 5.8.0 User Manual: A tool for accessibility analysis and health service planning*. World Health Organization, Geneva. accessmod.org (25 April 2025).

Philippine Statistics Authority, 2020. *2020 Census of Population and Housing*. psa.gov.ph/content/2020-census-population-and-housing (27 April 2025).

Salvacion, A. R., 2022. Measuring spatial accessibility of healthcare facilities in Marinduque, Philippines. *ISPRS International Journal of Geo-Information, 11*(10), 516. doi.org/10.3390/ijgi11100516.

Schuurman, N., Fiedler, R. S., Grzybowski, S. C., & Grund, D., 2006. Defining rational hospital catchments for non-urban areas based on travel-time. *International Journal of Health Geographics*, 5, 43. doi.org/10.1186/1476-072X-5-43.

Tanser, F., Gijsbertsen, B., & Herbst, K., 2006. Modelling and understanding primary health care accessibility and utilization in rural South Africa: An exploration using a geographical information system. *Social Science & Medicine, 63(*3), 691–705. doi.org/10.1016/j.socscimed.2006.01.015.

Tobler, W., 1993. Three Presentations on Geographical Analysis and Modeling: Non-Isotropic Geographic Modeling; Speculations on the Geometry of Geography; and Global Spatial Analysis. NCGIA Technical Report 93-1. escholarship.org/uc/item/05r820mz (20 April 2025).