PEMETAAN AKSESIBILITAS FASILITAS KESEHATAN: PENDEKATAN *ISOCHRONE* DAN ANALISIS JARINGAN

Healthcare Accessibility Mapping: An Integrated Isochrone and Network Analysis Approach

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ABSTRAK

Setiap individu berhak atas taraf hidup yang menjamin kesehatan, kesejahteraan diri, dan keluarga. Salah satu pilar penting untuk menjaga kualitas hidup dan kesejahteraan masyarakat adalah melalui pelayanan kesehatan. Aksesibilitas terhadap fasilitas kesehatan menunjukkan bagaimana pelayanan kesehatan dapat dijangkau dari aspek geografis. Kabupaten Nias Selatan dipilih menjadi wilayah studi dalam penelitian ini dikarenakan kabupaten ini memiliki Indeks Pembangunan Kesehatan Masyarakat (IPKM) kedua terendah di Provinsi Sumatera Utara. Model *isochrone* dan *network analysis* berbasis sistem informasi geografis (GIS) digunakan untuk melihat bagaimana keterjangkauan fasilitas kesehatan di khususnya di kabupaten tertinggal seperti Nias Selatan. Hasil penelitian menunjukkan bahwa aksesibilitas fasilitas kesehatan di Nias Selatan dipengaruhi oleh jarak terhadap pusat pemerintahan yaitu di bagian selatan kabupaten. Semakin jauh dari pusat pemerintahan, aksesibilitas terhadap fasilitas kesehatan semakin rendah dikarenakan tidak tersedianya fasilitas kesehatan yang dekat dengan keberadaan penduduk. Moda transportasi dan jaringan jalan juga mempengaruhi aksesibiltas, dimana moda *driving car* menjadi alternatif dalam memperluas jangkauan aksesibilitas dari segi waktu dan moda *cycling road* lebih efektif untuk dapat menjangkau fasilitas kesehatan yang ada dari sisi jarak tempuh. Oleh karena itu, pemerataan jumlah fasilitas kesehatan perlu diperhatikan bagi wilayah bagian tengah dan utara Kabupaten Nias Selatan, serta pengembangan infrastruktur jaringan jalan dapat ditingkatkan untuk menjangkau fasilitas kesehatan yang tersedia.

Kata kunci: Fasilitas Kesehatan, Aksesibilitas, Nias Selatan, Peta *Isochrone*, Analisis Jaringan

ABSTRACT

Every individual has the right to a standard of living that ensures health and welfare for individuals and family. One of the important pillars to maintain the quality of life and community welfare is through health services. Accessibility to health facilities shows how health services can be reached from a geographical aspect. Nias Selatan Regency was chosen as the study area in this research because it has the second lowest Community Health Development Index (CHI) in Sumatera Utara Province. Geographic information system (GIS)-based isochrone and network analysis models were used to see how the accessibility of health facilities in underdeveloped districts such as Nias Selatan. The results show that the accessibility of health facilities in Nias Selatan is influenced by the distance to the center of government, which is in the southern part of the district. The further away from the government center, the lower the accessibility of health facilities due to the unavailability of health facilities close to the local residence. The mode of transportation and road network also affect accessibility, where the driving car mode is an alternative in expanding the range of accessibility in terms of time and the cycling road mode is more effective to reach existing health facilities in terms of distance. Therefore, equal distribution of the number of health facilities needs to be considered for the central and northern parts of Nias Selatan Regency, while the development of road network infrastructure can be improved to reach available health facilities

Keywords: Health Facilities, Accessibility, Nias Selatan, Isochrone Map, Network Analysis

I. INTRODUCTION

Every individual has the right to a standard of living that ensures the health, welfare of self and family (UN, 2024). One of the important pillars to maintain the quality of life and community welfare is through health services. Health services are measured through three aspects, namely social, economic and geographical aspects. The social aspect is viewed in terms of satisfaction with health services. The economic aspect is viewed from the community's ability from the financial side to access health services. While the geographical aspect emphasizes the ease of access to health services as measured by distance, travel time, transportation and road infrastructure (Maulany et al., 2021). Accessibility is becoming an increasingly important issue in health services. Accessibility relates to how health services from a geographical aspect (Laksono et al., 2016). The higher the population in an area, the need for health facilities will increase (Yati et al., 2017). In addition, realizing universal access to health facilities and services is a top priority that requires the active role of the community and government. This is in line with the third goal of the 2030 Sustainable Development Goals (SDGs) in target 3.8. The goal of achieving universal health coverage is through access to good health services, including access to health facilities (Bappenas, 2024).

Indonesia is an archipelago with many regions separated by water (Sunaryo, 2019). This is one of the reasons why access to health facilities is uneven in all regions. Difficult geographical conditions in some areas, especially in underdeveloped, frontier, and outermost areas, cause differences in travel time and greater costs to obtain health services (Su'udi et al., 2024). In addition, in the 2020-2024 Action Plan, the Directorate of Health Service Facilities targets 300 health centers to be built according to standards in Disadvantaged Areas, Borders, Islands (DTPK) to improve access to basic health facilities for DTPK communities (Direktorat Fasilitas Pelayanan Kesehatan, 2020). In achieving this target, strategic steps are needed from the geographical aspect to find out how the affordability of health facilities in DTPK areas. Therefore, this study aims to map the accessibility of health facilities in hard-to-reach areas such as disadvantaged areas. Accessibility is the ease of reaching an object or area by using certain modes of transportation. Accessibility is determined by two factors, namely land use and transportation (Kolcsár & Szilassi, n.d.). Land use means considering the proximity of health facilities, while transportation factors represent the level of public transportation provision in the region. Jones measures the accessibility of health services, one of which is in terms of supply factors, namely the number of health facilities available in an area (Jones, 2012). In addition, the accessibility of health services is also measured in terms of the physical reachability of health facilities (Gulliford et al., 2002). This shows that the number of health facilities in an area affects the level of fulfillment of community needs for health services.

In this study, the accessibility of health facilities is measured in terms of land use associated with spatial aspects to show the location of health facilities to the surrounding conditions. Geographic Information System (GIS) with isochrone map model approach and network analysis is used to support the research automatically and integrated. Isochrone has been widely used in transportation system planning. Isochron is used to compare the urban access range with different modes of transportation at different time limits (Dovey et al., 2017). In addition, in a study in Pakistan, an isochron-based accessibility model was used to visualize the time required to reach a travel destination considering the mode of travel (Bhellar et al., 2023).

On the other hand, the use of Geographic Information System (GIS) and big data sources as supporting data in analyzing spatial data infrastructure is a promising solution compared to traditional approaches. Nias Selatan Regency was chosen as the study area in this research because it is one of the underdeveloped regencies in Sumatera Utara Province. Based on data from the Ministry of Health, Nias Selatan Regency is ranked second lowest based on the 2018 Public Health Development Index in Sumatera Utara Province. In addition, based on the value of the Health Services sub-index in the 2018 IPKM, Nias Selatan Regency has decreased from 0.258 to 0.225 points (Kementerian Kesehatan, 2019). By knowing the access to health facilities in Nias Selatan Regency, this study will make a significant contribution to policy formulation by the government, especially by the Nias Selatan local government.

II. LITERATURE REVIEW

2.1 Isochrone Map in Accessibility Mapping

Accessibility is a measure of the ease with which a person can reach a particular location by considering spatially distributed activities and the desires of travelers. Accessibility measurements have been widely developed by considering individual activities and travel variations. Geurs and Van (2004) measure accessibility into 4 types, namely infrastructure, people, utility, and location-based measurements. The isochrone map is the most popular approach to measure accessibility without specifying a destination, where the isochrone measures the reachability of a location that can be reached from a fixed starting point with a specified mode of transportation and time. In previous research, the isochrone model was used to evaluate the effect of accessibility on commuting modes, accessibility measures with space-time constraints, and the relationship between accessibility and land use. In this study, isochrone maps were drawn using Geographic Information System (GIS) in combination with other spatial datasets. Accessibility studies are used to determine whether or not a particular health facility point can be reached by a particular time and mode.

2.2 Research Framework

Based on the theoretical basis and previous research, the framework developed by the

researcher is as follows.

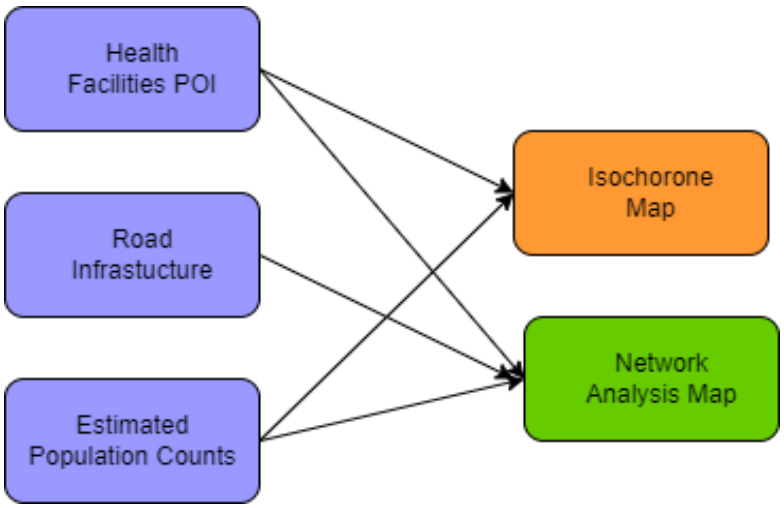

Figure 1. Research Framework

Based on Figure 1, it can be explained that in depicting the isochrone map with GIS, the POI variable of health facilities in Nias Selatan Regency and estimated population counts are used to see the distribution of population in certain areas. While the network analysis map uses road network variables to consider road conditions in measuring accessibility.

III. METHOD

3.1 Study Area

In this study, Nias Selatan Regency was chosen as the study area to see how the affordability of health facilities in the region. Based on its administrative area, Nias Selatan Regency is located in Sumatera Utara Province, precisely on the island of Nias, where Nias Selatan Regency consists of 35 sub-districts, 2 villages, and 459 villages. According to BPS population projection data in 2023, the population of Nias Selatan Regency amounted to 382.54 thousand people with an area of 2487.99 km2 (BPS Kabupaten Nias Selatan, 2024). Based on Presidential Regulation Number 63 of 2020 concerning the Determination of Disadvantaged Regions for 2020-2024, Nias Selatan Regency is designated as one of the disadvantaged regions in Sumatera Utara (Badan Pemeriksa Keuangan, 2020). This shows that the policy of accelerating the development of underdeveloped regions in this district has not been implemented properly. In addition, the condition of the region, which is located on two different islands, namely Nias Island and Batu Island, makes equitable development, especially in the affordability of health facilities a challenge. The results of this study will look at the accessibility of health facilities in Nias Selatan Regency on the island of Nias. Such accessibility includes which health facilities can be reached within a certain time and distance by various modes. In addition, a network analysis will

be conducted by considering the existing road network in this district.

3.2 Data Source

In mapping the accessibility of health facilities in Nias Selatan, geospatial big data is used in this study, namely points of interest (POI) derived from GoogleMaps. POI data contains a number of points of health facilities located in Nias Selatan to describe the accessibility of the area. The research data is systematically written in Table 1. In addition, road infrastructure data in Nias Selatan was used with the OSMnx package extracted from OpenStreetMap (OSM). Population estimation data from Worldpop was also used in this study to see the distribution of people in Nias Selatan who have access to health facilities**.**

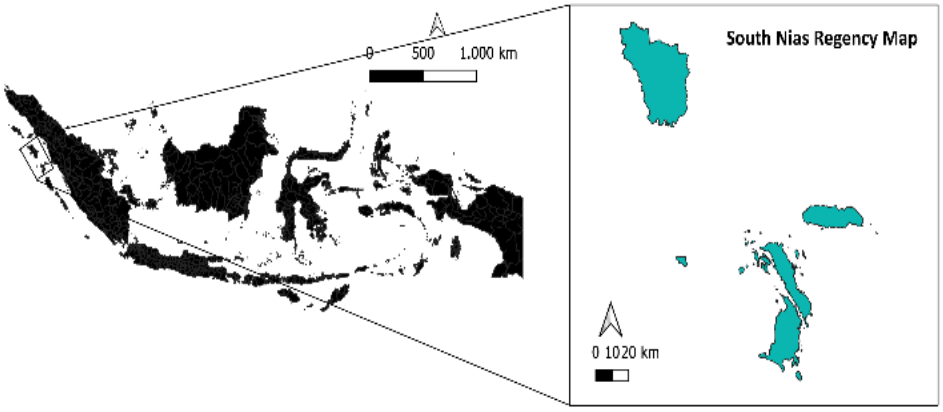

Figure 2. Map of the study area

3.3 Data Collection and Preprocessing

POI data from Google Maps was collected based on the names of health facilities registered with the Ministry of Health (Faskes BPJS, 2023). These facilities include hospitals, puksesmas, and posyandu located in Nias Selatan. Furthermore, data preprocessing was carried out by eliminating data that was not included in health facilities. In addition, POIs of health facilities in Nias Selatan Regency that are separated by sea, namely on Batu Islands, were not included as units of analysis to facilitate distance-based analysis. Road network data was extracted using the python-based OSMnx package on google colab. The road network was filtered based on the administrative coordinates of Nias Selatan Regency and then extracted in shp form. Population estimation data was taken from Worldpop for all regions of Indonesia in 2020. The population tif data was taken at the 100 x 100 m level with a constrained model, for a more accurate estimation because it considers the population based on the condition of the geographical area.

Table 1. Summary of Data Sources

Data Source	Variable	Year	Level
GoogleMaps	POI health facilities	2020	regency
OSM	Road infrastructure	2020	regency
Worldpop	Populations Count Constrained	2020	100 x 100 m

3.4 Isochrone Map

Isochrone Map consists of two parts, namely lines and areas. Isochrone lines connect points with the same travel time from a certain location while isochrone areas show points within the isochrone area that can be reached by a certain time and mode. The accessibility analysis equation with the isochrone map is as follows.

$$A_i = \sum_j \quad O_j f(C_{ij})$$

where f is a step function, and t is time (in this case, cost). Therefore, only those opportunities that can be reached from j in time t are included in the accessibility calculation (O'Sullivan et al., 2000). The isochrone map accessibility model is used to display a visualization of the time required to reach an available health facility considering the chosen mode of travel. In addition, isochrone lines are carried out to see the shortest distance and fastest distance with various modes chosen to reach certain health facilities.

3.5 Network Analysis

Network analysis in this study is conducted to analyze advanced networks that are more complex than isochrone area analysis. In accessibility analysis with network analysis, the road network is used as a consideration of the cost required to reach a certain destination. How the neighborhoods and turns of the roads are used as layers in mapping the accessibility of a place. In QNEAT3 network analysis, the Iso-Area as Pointcloud algorithm (from layer) is used to calculate costs within a specified range of road network points. The selection of this algorithm is based on previous research which states that point-based Iso-Area is better than polygon-based (Van den Berg, 2017).The parameters used in network analysis can be seen in Table 2.

Table 2. Network Analysis Parameters

Parameter	Type	Research Use
Network Layer	Vektor	Road Network of Nias Selatan District
Startpoint Layer	Vektor	Health Facilities POI
Unique Point ID	Field	Health Facilities name
Size of Iso-Area	User Input	2500 meters
Optimization Criterion	-	Shortest

The point vector layer obtained was interpolated using Inverse Distance Weighted (IDW) where during interpolation the sample points were weighted to reduce the relative influence of one point to another. Furthermore, the interpolated layers were clipped according to the administrative boundaries of Nias Selatan Regency.

IV. RESULTS

4.1 Shortest and Fastest Route

In conducting isochrone-based mapping, the shortest route is measured based on distance priority while the fastest route is measured based on time priority. The fastest route map can be seen in Figure 3 and the shortest route map in Figure 4. Based on the fastest route seen from time, driving car is the fastest mode to access health facilities in Nias Selatan. Meanwhile, based on the shortest route passed, the modes of transportation by driving car, cycling road, and foot walking have the same path with the shortest distance traveled is by foot walking. The distance traveled by cycling road and foot walking is almost the same, but it is necessary to consider the more efficient time is by cycling road. A comparison of the duration and distance of these two routes can be seen in Table 3.

Table 3. Shortest and Fastest Route Cost

Dimension	Modes	Duration (hours)	Distance (Km)
Fastest Route	Foot Walking	134,15	670,751
	Driving Car	11,851	656,909
	Cycling Road	30,481	590,549
Shortest Route	Foot Walking	115,883	579,414
	Driving Car	13,802	617,436
	Cycling Road	33,977	579,984

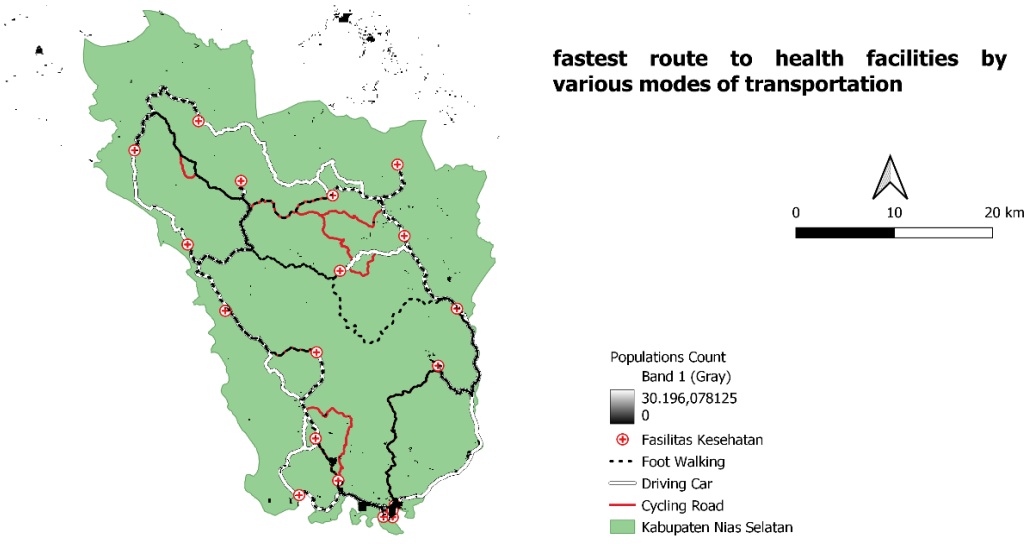

Figure 3. Fastest route to health facilities

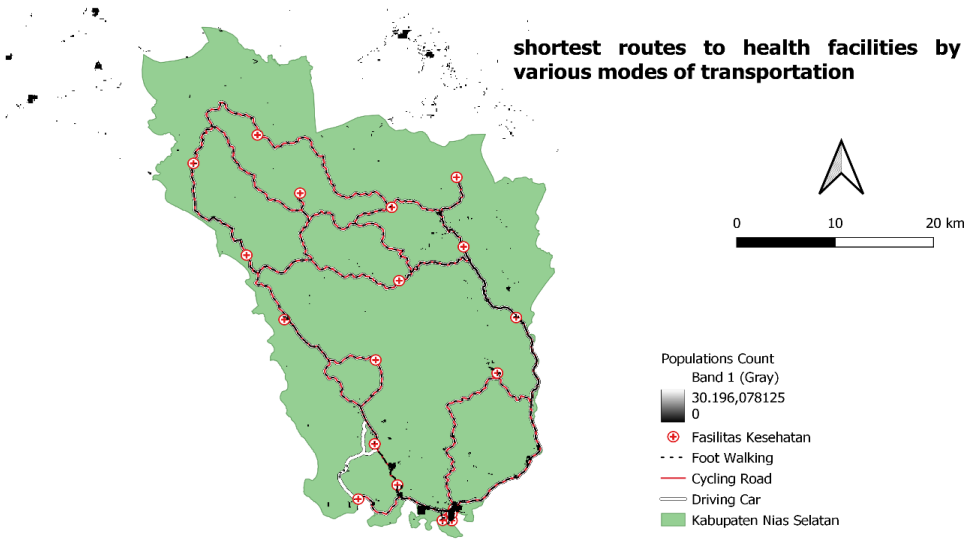

Figure 4. Shortest route to health facilities

4.2 Isochrone Maps and Accessibility Analysis

Accessibility analysis with the isochrone map was carried out using the cycling road transportation mode. This is because measuring accessibility based on distance is more optimal than time. Therefore, the cycling road transportation mode was chosen to map health accessibility because it has the shortest route range of the other three modes. The isochrone map can be seen in Figure 5 with time dimensions of 30, 60, and 90 minutes, and distance dimensions in the range of 1 km, 5 km, and 10 km. Based on the isochrone coverage area in Figure 6, in the northern part of Nias Selatan Regency, Huruna and Lolomatua sub-districts have access to facilities that can be reached within 1 hour with access to health facilities available at distances exceeding 10 km. Other sub-districts in northern Nias Selatan, such as Hilisahawaae, Lolowau, Oou, Hilimegael, have access within 10 km and can be reached within 30-60 minutes.

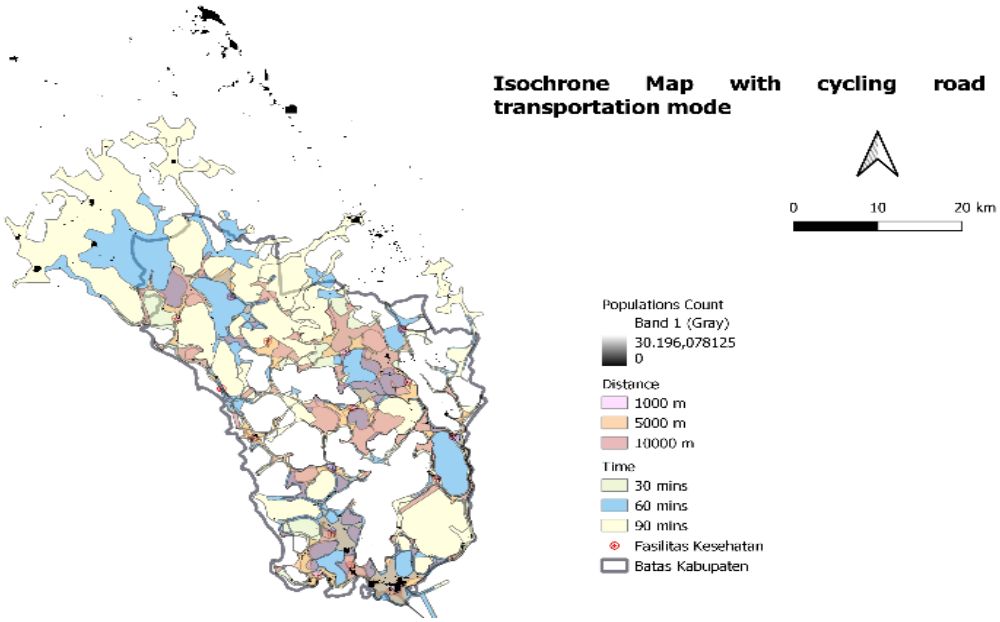

Figure 5. Isochrone Map with Cycling Road

In the central part of Nias Selatan, which consists of Mazo, Aramo, Goma, and Susua sub-districts, access to health facilities can be reached within 30 minutes with a distance of 10 km. Meanwhile, the sub-districts of Siduaori, Somambawa, Oou, Hilimegael are outside the access distance and time indicating that health facilities are reached beyond a distance of 10 km and a time of 1.5 hours using the cycling road mode. In the southern part of Nias Island, access to health facilities is better than in other areas of Nias Selatan Regency. This can be seen from the distribution of health facilities that are concentrated in this area. In Kecamatan Fanayama and Luahagundre Maniamolo, access to health facilities is at a distance of 5 km within 1 hour using the cycling road. Meanwhile, Teluk Dalam sub-district is outside the scope of accessibility but there is no population distribution in the area. The Isochrone map can be seen in Figure 6.

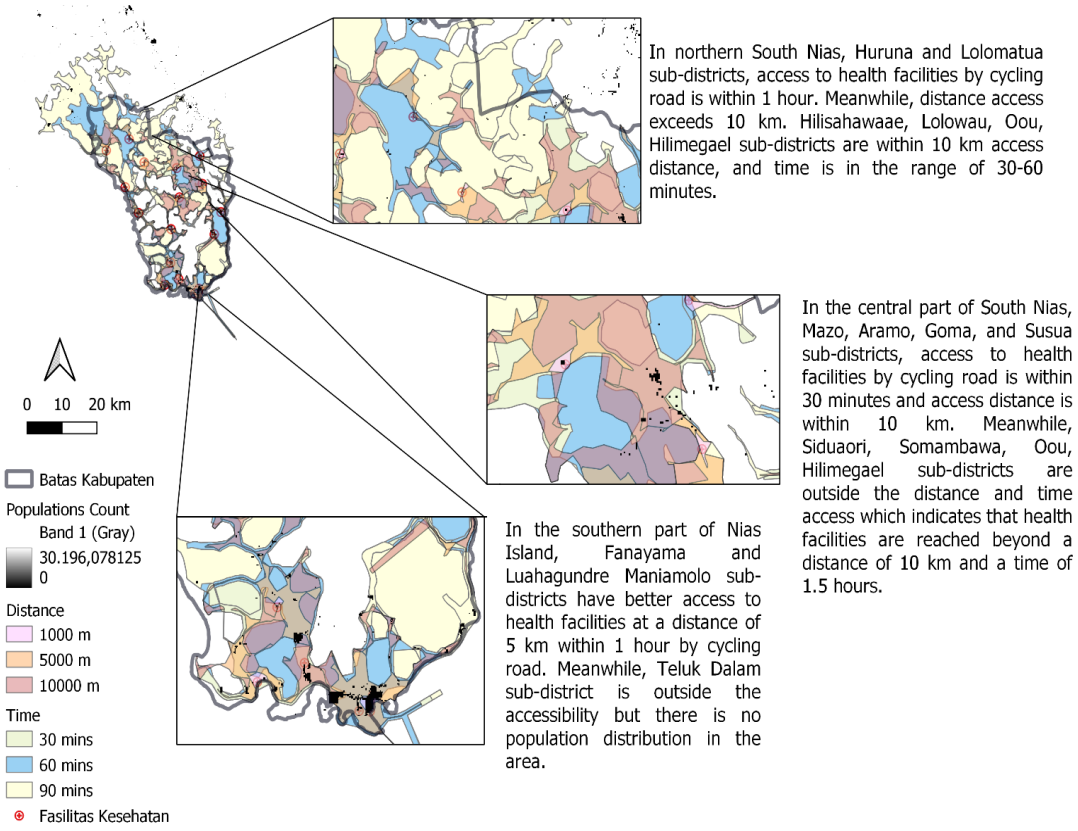

Figure 6. Isochrone Map Analysis

V. Network Analysis Map

Network analysis was conducted to see the accessibility of health facilities based on road network conditions. This is because the road network will affect the measurement of accessibility in an area. The road network is represented as a vector of points that are measured in distance to an existing health facility. The point vectors will be interpolated to form an iso-area with a size of 2.5 km. Based on the figure, it can be seen that within a range of 2.5 km the majority of health

facility accessibility is in the far category. This is indicated by the distribution of the population in the far and very far categories. With the isochrone map, Fanayama and Luahagundre Maniamolo sub-districts have health facilities within 5 km. With network analysis that considers the road network, these areas are in the distant accessibility category. Meanwhile, in Kecamatan Lahusa, health facilities are in the close-to-reach category. The network analysis map can be seen in Figure 7.

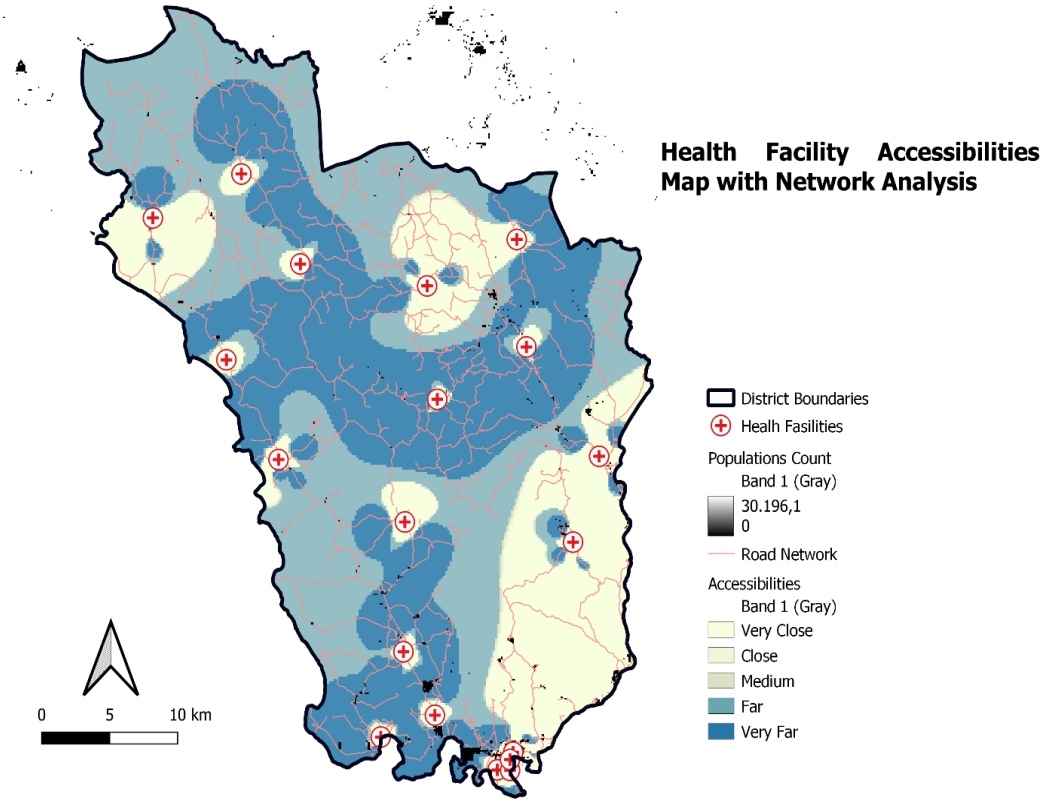

Figure 7. Network Analysis Map

VI. CONCLUSION

Community accessibility to health services is multidimensional. Accessibility is not only influenced by the availability of health workers and adequate facilities, but also how these facilities can be reached by the community. In Nias Selatan Regency, the accessibility of health facilities is influenced by the distance to the center of government, which is in the southern part of the kabupaten. This is evident from the number of health facilities clustered in this area. In addition, accessibility in the government center area is in the good category. Meanwhile, the accessibility of health facilities is further away from the center of government, namely in the northern part of Nias Selatan Regency, including Kecamatan Huruna and Lolomatua, where access to health facilities is very difficult to reach, which is more than 10 km and takes 1 hour.

Several sub-districts in Nias Selatan Regency also have very low accessibility due to the

unavailability of health facilities close to the population. The accessibility of health facilities is also influenced by the mode of transportation and the available road network. The driving car mode expands the range of accessibility in a short time while in terms of distance, the cycling road mode is more effective in reaching health facilities in Nias Selatan. Therefore, equal distribution of the number of health facilities needs to be considered for the central and northern parts of Nias Selatan Regency, and the development of road network infrastructure can be improved to reach available health facilities.

REFERENCES

Bappenas. (n.d.). *Tujuan 3: Kehidupan sehat dan sejahtera*. SDGs Bappenas. Retrieved June 4, 2024, from https://sdgs.bappenas.go.id/17-goals/goal-3/

BPS Kabupaten Nias Selatan. (2024). *Kecamatan Nias Selatan dalam angka 2024* (Vol. 21). ISBN: 2656-2170.

Bhellar, M. G., Talpur, M. A. H., Khahro, S. H., Ali, T. H., & Javed, Y. (2023). Visualizing travel accessibility in a congested city center: A GIS-based isochrone model and trip rate analysis considering sustainable transportation solutions. *Sustainability, 15*(23), 16499. https://doi.org/10.3390/su152316499

Direktorat Fasilitas Pelayanan Kesehatan, Direktorat Jenderal Pelayanan Kesehatan, Kementerian Kesehatan. (2020, September). *Rencana Aksi 2020-2024*.

Dovey, K., Woodcock, I., & Pike, L. (2017). Isochrone mapping of urban transport: Car-dependency, mode-choice and design research. *Planning Practice & Research, 32*(4), 402–416. https://doi.org/10.1080/02697459.2017.1329487

E-Health Indonesia. (2023, August 17). Tantangan di balik layanan kesehatan hambatan dan solusi. *EHealth Indonesia Blog*. Retrieved April 26, 2024, from https://ehealth.co.id/blog/post/tantangan-di-balik-layanan-kesehatan-hambatan-dan-solusi/

Faskes BPJS. (2023, July). Alamat faskes dan kode BPJS Kabupaten Nias Selatan. *Faskes BPJS*. Retrieved April 7, 2024, from https://www.faskesbpjs.com/2023/07/faskes-nias-selatan.html

Gulliford, S., Figueroa-Munoz, C., Jackson, S., Khoshaba, A. K., McCormack, D. K. J. A. M. L. R. R. E., & van Eijk, P. T. R. M. (2002). What does 'access to health care' mean? *Journal of Health Services Research & Policy, 7*(3), 186–188.

Jones, S. G. (2012). Development of multi-dimensional health care access index. In *Proceedings of the ESRI Health Geographical Information System Conference*.

Kementerian Kesehatan. (2019). *Indeks Pembangunan Kesehatan Masyarakat (IPKM) 2018*. Kementerian Kesehatan.

Kolcsár, R. A., & Szilassi, P. (n.d.). Assessing accessibility of urban green spaces based on isochrone maps and street resolution population data through the example of Zalaegerszeg, Hungary. *University of Szeged, Faculty of Science and Informatics*.

Laksono, A. D., Mubasyiroh, R., Laksmiarti, T., Nurhotimah, E., Suharmiati, S., & Sukoco, N. E. (2016). *Aksesibilitas pelayanan kesehatan di Indonesia*. Yogyakarta, Indonesia: PT Kanisius.

Maulany, R. F., Dianingati, R. S., & Annisaa, E. (2021). Faktor-faktor yang mempengaruhi akses

kesehatan. *Indonesian Journal of Pharmacy and Natural Product, 4*(2), 142-149.

O'Sullivan, D., Morrison, A., & Shearer, J. (2000). Using desktop GIS for the investigation of accessibility by public transport: An isochrone approach. *International Journal of Geographical Information Science, 14*(1), 85–104.

Peraturan BPK. (2020, December 31). Peraturan Presiden (PERPRES) Nomor 63 Tahun 2020: Penetapan daerah tertinggal tahun 2020-2024. *Peraturan BPK*. Retrieved June 8, 2024, from https://peraturan.bpk.go.id/Details/136563/perpres-no-63-tahun-2020

Sunaryo, T. (2019). Indonesia sebagai negara kepulauan. *Jurnal Kajian Stratejik Ketahanan Nasional, 2*(2), 1-17. Retrieved from https://scholarhub.ui.ac.id/jkskn

Su'udi, A., Putranto, R. H., Harna, H., Irawan, A. M. A., & Fatmawati, I. (2024). Analisis kondisi geografis dan ketersediaan peralatan di puskesmas terpencil/sangat terpencil di Indonesia.

United Nations. (n.d.). *Universal Declaration of Human Rights - Indonesian*. United Nations. Retrieved April 26, 2024, from https://www.un.org/en/about-us/universal-declaration-of-human-rights

Van den Berg, J. (2017, March). Towards a dynamic isochrone map: Adding spatiotemporal traffic and population data. *International Journal of Geographical Information Science, 2017*(3), 1–15.

Yati, M. W., Deliar, A., & Virtriana, R. (2017). Pemodelan tingkat layanan kesehatan masyarakat berbasiskan sistem informasi geografis (Wilayah Studi: Kota Bandung). *ITB Indonesian Journal of Geospatial, 6*(1), 55-70.