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Modeling Accessibility to Emergency Obstetric Care in Mountain Region on Adonara Island, Eastern Indonesia

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Abstract

The geographical conditions of an area influence accessibility problems. This study aims to model the travel time to the PONED-*Pelayanan Obstetric Neonatal Emergensi Dasar* (Basic Emergency Obstetric and Neonatal Care-BEmONC) in a mountain region. The difficulties in access to PONED could cause maternal mortality in mountain regions. This study was done on the island of Adonara in the Flores Timur district. Adonara Island has a high maternal mortality rate. Modelling accessibility used a raster-based model to model travel time. We used Landsat 8 imagery, Digital Elevation Model (DEM), and road network data to obtain a land cover layer. The Saga GIS travel time calculation tool is used to calculate the accumulated cost of travel time. The cost is based on the speed of travel through each land cover pixel to the location of the Puskesmas Waiwerang (PONED 1) and Puskesmas Waiwadan (PONED 2). The results of the travel time modelling show that five sub-districts reach the two PONED locations in ≥ 1 hour. The longest time for people to travel to PONED is ≥ 6 hours from Ile Boleng sub-district because there is a mountain in the Ile Boleng sub-district. The scenario of adding one PONED shows that only two sub-districts reach the PONED in ≥ 1 hour. This scenario shows that adding new PONED can decrease travel time to PONED. The spatial modelling of travel time can be used by local governments in eastern Indonesia to improve access to basic obstetric emergency health centres in mountain areas.

Keywords: remote sensing, travel time, GIS, health

1. Introduction

Travel time has been used to model accessibility to health services in Indonesia. Travel time can be modeled using raster analysis for areas with limited road infrastructure. Some studies have modeled travel time to health facilities using raster analysis. For example, in Nusa Tenggara Timur province, there were study to model travel time to Emergency Obstetric Care (EmOC) in South Central Timor (TTS) district (Myers, Fisher, Nelson, & Belton, 2015) and model travel time to EmOC in Kupang district (Rambu Ngana & Eka Karyawati, 2021). Another study in Kupang district model travel time to Covid-19 referral services (Rambu Ngana, 2021). In Southwest Sulawesi Province, there was study to model travel time to medical facilities in Muna Barat district (Sula, Tosepu, & Mandaya, 2017). One study in DI Yogyakarta province to model travel time to Puskesmas (clinics) and hospital in Gunung Kidul district (Sri Andriani Permatasari & Lazuardi, 2019). Those studies show that travel time model based on raster analysis has been used for modeling accessibility to health services in Indonesia.

In health, travel time is related to saving a life. Suppose travel time is used as one of the criteria for the location of the Basic Emergency Obstetric and Neonatal Care (BEmONC) called PONED (*Pelayanan Obstetri Neonatal Emergensi Dasar*) in Indonesia (Kementerian Kesehatan RI, 2013). According to the guidelines for the implementation of PONED, the location of PONED must be reachable in less than 1 hour by public transportation from resident locations and non-PONED Puskesmas (clinic) locations

(DINKES PPKB, 2022; Kementerian Kesehatan RI, 2013).

Difficulties topographic caused high maternal deaths at remote areas in Indonesia. Byrne, Hodge, Jimenez-Soto, and Morgan (2014) reviewed maternal mortality strategies to address barriers to obstetric care in mountain regions such as Indonesia. They mentioned that difficulties in access to obstetric care could cause maternal mortality in mountain areas. According to them, the mountain region is above 1000 m. One cause of maternal death was delayed in reaching emergency obstetric care (Belton, Myers, & Ngana, 2014). Sri Andriani Permatasari and Lazuardi (2019) also mentioned that difficulties in access to health facilities cause maternal mortality. Therefore, modeling accessibility to PONED is important to analyze maternal mortality in a mountain region.

This study aims to model travel time to PONED as Emergency Obstetric Care (EMOC) in a mountain region. As a case study, we modeled travel time to PONED (on Adonara Island, Flores Timur (Flotim) district in Nusa Tenggara Timur province. On Adonara Island there is Mount Ile Boleng. It is 1659 m above sea level (Pemerintah Kabupaten Flores Timur, 2020). Adonara Island is one of the largest islands in the Flotim district, with a high maternal mortality rate. Figure 1 shows the number of maternal deaths over five years on Adonara Island. The highest number of maternal deaths is in the Adonara Timur sub-district.

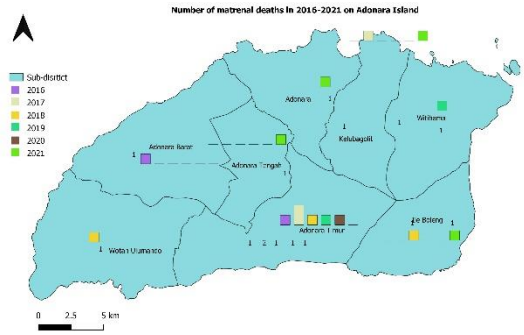

Figure 1. The number of maternal deaths each sub-district in Adonara Island in 2016-2021 (Dinas Kesehatan Flotim, 2022)

The Flotim district has a high Maternal Mortality Rate (MMR), where MMR in this district has fluctuated for four years (Pemerintah Kabupaten Flores Timur, 2020). The MMR is between 71 to 221 per 100000 live births. The area of Flotim district is an archipelago with hilly and mountainous conditions. Flotim district has an area of 5,983.38 km^2. The Flotim district consists of 3 large islands and 27 small islands and an ocean area of 4,170.53 km^2 (Pemerintah Kabupaten Flores Timur, 2020). Geographical conditions cause accessibility problems to health services in the Flotim district. The travel time model to the PONED on Adonara Island will be useful for analyzing the geographic accessibility of the PONED location on maternal mortality on Adonara Island, Flores Timur district.

2. Methods

This research was conducted on Adonara Island, Flores Timur district, Nusa Tenggara Timur Province, in 2021. The area of Adonara Island is 529.75 Km^2 (Figure 2).

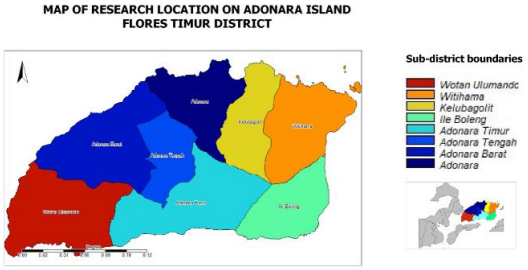

Figure 2. Map of research location

Raster-based travel time is used in the modeling based on the geographical conditions of an area. Travel time is calculated based on travel speed through various forms of land cover.

In this study, we created travel time model in SAGA GIS using inputs such as landcover map, GPS coordinate of PONED, land cover (LC) speed table, and Travel Time zone table (TT Zone). The LC speed table shows the travel time for each land cover type. The travel time of each pixel of land cover is calculated based on equation (1). The travel time value is the cost moving on each land cover class. Each class has a different travel time cost, it is calculated in seconds for each 30-meter pixel (1). The cost of these pixels is then accumulated for all areas. In this study, the image resolution (meters) for Landsat 8 is 30 meters. We measured travel speeds through each type of landcover using GPS and a speedometer motorcycle. Based on the travel speeds, we calculated travel time (TT) of each pixel of each landcover class using the equation below (Rambu Ngana & Eka Karyawati, 2021).

$$TT = \frac{resolusi\ citra}{(Travel\ speed \times 1000/3600)} \qquad (1)$$

TT: Travel Time in seconds; Travel speed in km/hour. 1 km=1000 meters. 1 hour = 3600 seconds.

We used travel time calculation tool in Saga GIS to calculate travel time to PONED (EMOC). Figure 3 shows flowchart of travel time modelling process in Saga GIS.

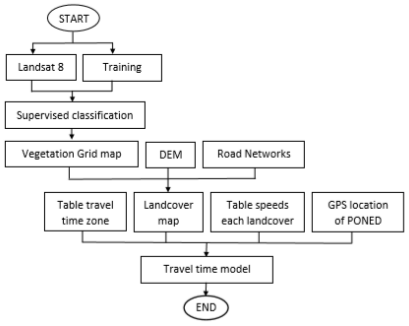

Figure 3. Flowchart of travel time modelling process

We used GPS to collect coordinate data for the location of two PONED (EMOC), those are the Puskesmas Waiwerang in Adonara Timur Sub-district (Figure 4) and Puskesmas Waiwadan in Adonara Barat Sub-district (Figure 5).

Figure 4. Puskesmas Waiwerang.

Figure 5. Puskesmas Waiwadan

Landsat 8 images with a 30-meter spatial resolution for the Adonara Island region were downloaded from the USGS (https://earthexplorer.usgs.gov/). These images were cut based on administration map of Flores Timur district. The map was taken from: https://tanahair.indonesia.co.id

Then the Landsat images were projected onto WGS 84 UTM Zone 51S. The Landsat 8 images were used to create a vegetation map using the Supervised Classification method. GPS location coordinates of settlements, prairie, rice fields, forests, mountains, farm, bare land, and water bodies were used as training areas for land cover (Figure 6). We took also GPS location of the Mount Ile Boleng.

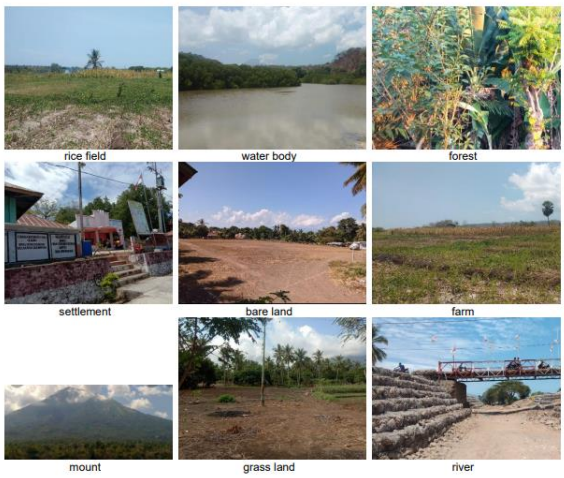

Figure 6. Landcover types in Adonara Island

Digital Elevation Model (DEM) image of the Flores Timur district was used for river networks map (DAS-*Daerah Aliran Sungai*). It was downloaded from the website: https://tanahair.indonesia.co.id.

The road network map on Adonara Island was taken from road network data from the Regional Development Planning Agency (Bappeda) of Flores Timur district, Nusa Tenggara Timur province. While the administrative map in the form of a *.shp file for the Flores Timur district was downloaded from the website: https://tanahair.indonesia.co.id.

Land cover map was created using the land cover scenario offset tool in Saga GIS with inputs of vegetation map, DEM map, and road network map (Figure 7).

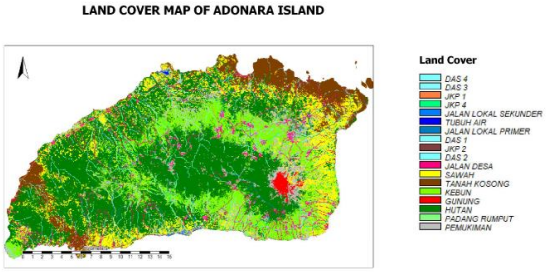

Figure 7. Landcover map of Adonara island

The travel time through each pixel in the land cover image can be calculated by the travel time equation (1). The travel time (TT) through each land cover class is shown in table 1. The travel time model was created using the travel time calculation tool on Saga GIS.

Table 1..Travel speed and travel time (TT) through each land cover class

ID	Cover class	km/h	TT
1	Farm	5	21.6
2	Grass land	10	10.8
3	Settlement	8	13.5
4	Forest	2	54
5	Mount	0	9999
6	Rice field	7	15.43
7	Bare land	10	10.8
8	Water Body	0	9999
201	Road Jalan desa	10	10.8
202	Road Jalan lokal Primer	11	9.82
203	Road jalan lokal sekunder	9	12
204	Road JKP 1	15	7.2
205	Road JKP 2	12	9
206	Road JKP 4	20	5.4
101	River network (DAS 1)	0	9999
102	River network (DAS 2)	3	36
103	River network (DAS 3)	0	9999
104	River newtwork (DAS 4)	2	54

Landcover types on Table 1 consist of farm, grass land, settlement, forest, mount, rice field, bare land, water body, roads networks and river networks.

The travel time tool uses four inputs. These are a landcover map, PONED points locations, a table of

travel time for land cover type, and a time zone classes table (Table 2).

Table 2. Travel time zone

NAME	DESCRIPTION	MIN	MAX
0-30 minutes	0-30 min	0	30
30-60 minutes	30-60 min	30	60
60-90 minutes	60-90 min	60	90
90-150 minutes	90-150 min	90	150
150+ minutes	150+ min	150	10000

The travel time calculation results are classified per travel time zone. The travel time model from Saga GIS is then exported to QGIS for map layout.

To understand the impact of adding a new PONED to travel time on Adonara Island, a travel time model scenario was modeled for adding one PONED in the Witihama sub-district.

We validated our travel time model by calculating travel time from the location of the residents' houses to PONED.

6. Results and Discussion

The model of travel time to PONED locations in two Puskesmas on Adonara Island is shown in Figure 8.

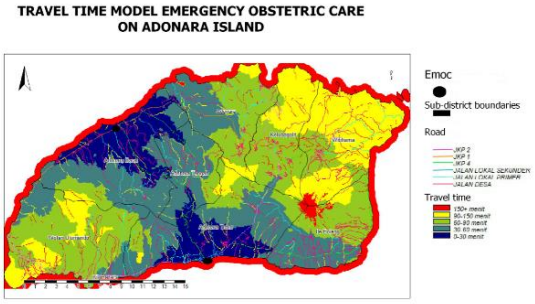

Figure 8. Travel time model to PONED location on Adonara Island

The model shows five sub-districts on the island of Adonara: Kelubagolit sub-district, Witihama sub-district, Ile Boleng sub-district, Adonara sub-district and Wotan Ulumado sub-district, reaching the PONED ≤1 hour. The longest travel time to the PONED is ≥ 6 hours in Ile Boleng sub-district, where there is Mount Ile Boleng at the location. Although there is already a PONED in the Adonara Timur sub-district, the number of maternal deaths is still high in the sub-district. This could be because the mother who died was a referral from outside the Puskesmas Waiwerang. The results of this study indicate that there is an influence of geographical accessibility on maternal mortality which has been mentioned at previous research from Belton, Myers, and Ngana (2014) in Eastern Indonesia that one of the causes of maternal death is the delay in handling by health workers. Also, it has been mentioned by Nadya (2021), that one of the causes of maternal death in the Flotim district is the delay in handling by health workers.

From the modelling results of scenario adding new the PONED, it shows that most areas on the Adonara Island can reach the PONED location ≤ 1 hour (Figure 9), and there are only two sub-districts that reach the PONED ≥ 1 hour, namely Wotan Ulumado sub-district and Adonara sub-district. Adding one PONED can increase the number of sub-districts reaching the PONED ≤ 1 hour. These results indicate that geographic accessibility needs to be improved on Adonara Island by adding more health facilities and improving infrastructure. This is in accordance with the recommendations from research Rambu Ngana (2021) on the need to improve infrastructure and add health facilities to overcome the problem of physical access to health services in locations with difficult geographical conditions.

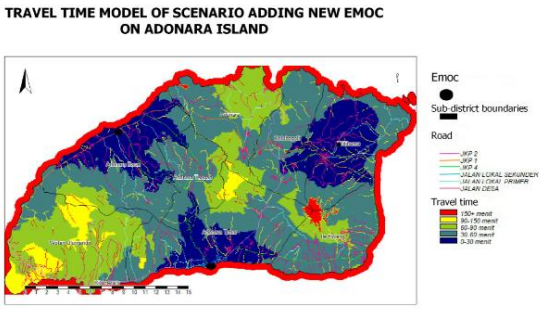

Figure 9. Scenario model of travel time for the addition of PONED on Adonara Island.

By using the travel time model to the PONED location,, the Flores Timur district government can see the problem of geographical accessibility to the PONED. Increasing access to PONED can be done by adding PONED in the five sub-districts. The difficulty of transportation to the hospital in the capital of Flores Timur district, Larantuka, also caused the death of the mother. Referrals for pregnant women from Adonara Island to Larantuka Hospital must cross the sea by boat.

This study has shown a travel time model for emergency obstetric services on Adonara Island in the dry season. In 2021, Adonara Island was attacked by Seroja tropical Cyclone disaster, which caused heavy rains, landslides, and flooding and damaged infrastructure there. Therefore, future research can model travel time in the rainy season, where the weather affects travel time in areas with difficult geographical conditions.

7. Conclusion

Modelling travel time to the PONED on Adonara Island shows that there are five sub-districts that reach the PONED with a travel time ≥ 1 hour. Where the longest travel time, ≥ 6 hours, is on the Ile Boleng sub-district because there is a mountain. The scenario of adding 1 PONED can reduce the number of areas that reach PONED ≥1 hour where there are two sub-districts that reach PONED ≥ 1 hour. This spatial modelling of travel time shows that

geographical conditions on Adonara Island affect travel time to emergency obstetric care locations. The local government of the Flores Timur district needs to pay attention to the geographical conditions on Adonara Island in determining the location of the PONED using a travel time raster model.

Acknowledgments

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References

Belton, S., Myers, B., & Ngana, F. R. (2014). Maternal deaths in eastern Indonesia: 20 years and still walking: an ethnographic study. BMC Pregnancy Childbirth, 14(1), 39-39. doi:10.1186/1471-2393-14-39

Byrne, A., Hodge, A., Jimenez-Soto, E., & Morgan, A. (2014). What Works? Strategies to Increase Reproductive, Maternal and Child Health in Difficult to Access Mountainous Locations: A Systematic Literature Review. *PLOS ONE, 9*(2), e87683. doi:10.1371/journal.pone.0087683

Dinas Kesehatan Flotim. (2022). *Laporan Jumlah kematian ibu di Kabupaten Flores Timur tahun 2016-2021*.

DINKES PPKB, T. (2022). PUSKESMAS PONED (Pelayanan Obstetri Neonatal Emergency Dasar) DI KAB. TRENGGALEK http://dkkb.trenggalekkab.go.id/2015/artikel/puskesmas%20poned.pdf

Kementerian Kesehatan RI. (2013). *Pedoman penyelenggaraan Puskesmas mampu PONED*. Retrieved from https://kanalpengetahuan.fk.ugm.ac.id/kolaborasi-ponek-dan-poned-dalam-upaya-penurunan-aki/

Pemerintah Kabupaten Flores Timur. (2020). Peraturan Bupati Flores Timur No 22 tahun 2019. Rencana Kerja Pemerintah Daerah (RKPD) Kabupaten Flores Timur tahun 2020. Retrieved from Pemerintah Kabupaten Flores Timur website: https://florestimurkab.go.id/beranda/2019/09/30/rencana-kerja-pemerintah-daerah-kabupaten-flores-timur-tahun-2020/

Rambu Ngana, F. (2021). *Pemodelan waktu tempuh untuk mitigasi bencana Covid-19 di wilayah dengan kondisi geografis yang sulit.* Paper presented at the Seminar Nasional Ilmu Fisika dan Terapannya.

Rambu Ngana, F., & Eka Karyawati, A. A. I. N. (2021). Scenario modelling as planning evidence to improve access to emergency obstetric care in eastern Indonesia. *PloS one, 16*(6), e0251869-e0251869. doi:10.1371/journal.pone.0251869

Myers, B. A., Fisher, R. P., Nelson, N., & Belton, S. J. A. p. h. (2015). Defining remoteness from health care: integrated research on accessing emergency maternal care in Indonesia. *2*(3), 257.

Nadya. (2021). Tantangan Flores Timur: Angka Kematian Ibu & Bayi. Retrieved from https://centertropmed-ugm.org/tantangan-flores-timur-angka-kematian-ibu-bayi/

Pemerintah Kabupaten Flores Timur. (2020). *Peraturan Bupati Flores Timur Nomor 33 Tahun 2020. Rencana Kerja Pemerintah Daerah Kabupaten Flores Timur tahun 2021*. Retrieved from https://florestimurkab.go.id/beranda/wp-content/uploads/2020/10/RKPD-Kab-Flores-Timur-2021_c.pd

Sri Andriani Permatasari, D., & Lazuardi, L. (2019). *Aksesibilitas Kesehatan Maternal Dalam Upaya Penurunan Angka Kematian Ibu di Kabupaten Gunung Kidul (kajian dengan AccessMOD 5.0).* Universitas Gadjah Mada,

Sula, N., Tosepu, R., & Mandaya, I. (2017). *Geo-Spatial Modeling of Travel Time to Medical Facilities in Muna Barat District, Southeast Sulawesi Province, Indonesia.* Paper presented at the International Symposium on Geoinformatics (ISyG).