Priority Areas for Public Infrastructure Development to Support National Equity, Case Study: East Nusa Tenggara, Indonesia

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ABSTRACT:
Equitable public infrastructure development has benefits both locally and nationally as it can improve the economy and the welfare of local population. However, achieving equitable infrastructure development remains challenging due to various obstacles, such as financial issues, environmental concerns like land clearing, and planning difficulties. To address these challenges, this study aims to develop a spatial model for public infrastructure planning in Indonesia, with a case study in Indonesia in East Nusa Tenggara (ENT) Province. The infrastructure includes transportation (roads) and basic services (health and education facilities). The research considers aspects of accessibility, socio-economic factors, and disasters using the Analytical Hierarchy Process (AHP) and Geographical Information Science (GIS) methods to determine development priorities. ENT was chosen because it has a low Human Development Index (HDI) and a high poverty rate in Indonesia. The results of this study indicate that priority areas for public infrastructure development in East Nusa Tenggara are dominated by the moderate class, covering 34.48% of the area, followed by the high class at 30.46%, the low class at 22.89%, and the very high class at 12.17%. The districts/cities with the highest area percentages in ENT are East Sumba, West Sumba, and Southwest Sumba. It is hoped that the results of this study can serve as a basis for policymakers in determining priority areas for public infrastructure development efficiently and effectively.

1. INTRODUCTION

The global target for 2030 is outlined in the SDGs 2030, one of which aims to reduce inequality within and among countries, as stated in Goal 10(United Nation, 2022). Not only globally, but issues related to equitable development are also included in Indonesia's national targets. One of the pillars of Indonesia's development for 2045 is equitable development, which consists of accelerating poverty eradication, equalizing business and income opportunities, equalizing regional development, and building integrated and equitable infrastructure (Bappenas, 2019).

Equitable public infrastructure development has several benefits both locally and nationally (Jatayu et al., 2024). Infrastructure development can enhance economic and social welfare (Azam, 2019). Infrastructure development can stimulate the economy by increasing new business potentials, improving labour productivity, enhancing human resources, and bringing positive impacts in the fields of health and education (Palei, 2015; Setiawan & Sulandrianingrum, 2020). Research by Wang (Wang et al., 2020) also explains the positive relationship between economic growth and public infrastructure development, particularly transportation infrastructure.

Infrastructure development planning certainly faces several challenges. The general challenges of infrastructure development are financial and investment issues (Darques, 2024). In Indonesia, the main challenge hindering infrastructure development is land acquisition, which accounts for about 30% of the total infrastructure development issues (Utomo, 2017). The challenges of equitable infrastructure and urban development in Indonesia include natural disasters such as floods and land subsidence, environmental and ecological issues, suboptimal public transportation services and integration, and poverty and social inequality between regions (Dimas Nu'man Fadhil et al., 2024) .To improve the efficiency and effectiveness of public infrastructure development in Indonesia, strategic spatial planning is needed to determine the priority of public development.

This research aims to develop a spatial model for public infrastructure planning in Indonesia with a case study in the East Nusa Tenggara (ENT) region. The public infrastructure in this research will focus on transportation infrastructure such as roads and basic service infrastructure such as health and education facilities (BPS, 2020). This research reviews three aspects in determining priority locations for infrastructure development, namely accessibility, socio-economic aspects, and disaster aspects. The integration of these three aspects will use the Analytical Hierarchy Process (AHP) and Geographical Information Science (GIS) methods. The results of this research are expected to increase the efficiency and effectiveness of infrastructure development planning by determining priority development areas.

2. METHODOLOGY

2.1 Study Area

The study area of this research is the Nusa Tenggara Islands, specifically located in the Province of East Nusa Tenggara (ENT), as shown in Figure 1. ENT was chosen because it has a relatively low human development index (HDI) in Indonesia(BPS, 2015, 2024a). In 2022, the HDI value of ENT Province was 67.63 (the 3rd lowest in Indonesia) (BPS, 2024b). Additionally, according to data from BPS (BPS, 2024b), ENT also has a high poverty rate, with the poverty percentage in ENT Province reaching 19.48% in 2024 (the 3rd highest in Indonesia). However, geographically, ENT is very close to Java Island, which is the primary development centre in Indonesia. Moreover, ENT is a province that directly borders the neighbouring country, Timor Leste. Therefore, this research will spatially model the areas in ENT that are priority areas for public infrastructure development to enhance national development equity.

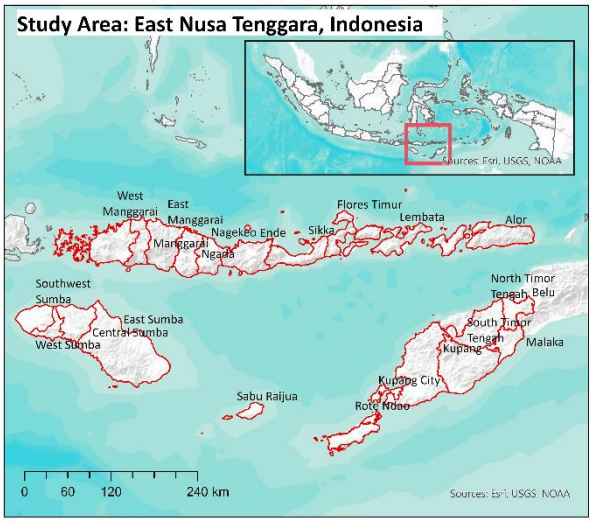

Figure 1. Study area

2.2 Data

The data used in this study can be seen in Table 1.

No	Data	Reference
1	Frontiers areas	Presidential Regulation Number 63 of 2020
2	Road	(BIG, 2020)
3	River	(BIG, 2020)
4	Built-Up Area	(BIG, 2020)
5	Education Building	(BIG, 2020)
6	Hospital	(BIG, 2020)
8	Government Office	(BIG, 2020)
9	DEM	(Hawker et al., 2022)
10	Gross Regional Domestic Product (GRDP)	(BPS DKI JAKARTA, 2024)
11	Boundaries	(BIG, 2020)
12	Disaster Map	(BNPB, 2020)
13	Population	WorldPop (2020)

Table 1. Data

2.3 Methods

The general flowchart of this research can be seen in Figure 2. Generally, this research is divided into four stages: modelling the accessibility aspect, the socio-economic aspect, the disaster aspect, and integrating these three aspects using the AHP and GIS methods. The more detailed explanation of each stage can be found in the paragraph below.

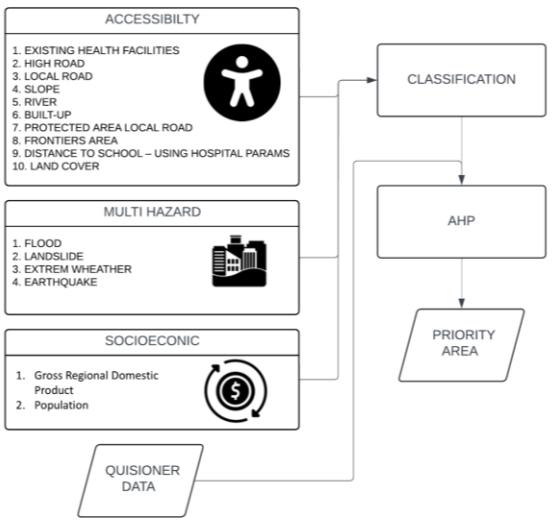

Figure 2. General methodology

2.3.1 Accessibility Aspect

The public facilities in this research focus on three objects: basic service facilities such as health, education facilities and transportation facilities such as roads. According to the regulation of the Minister of Regulation Public works and Public Housing No. 32 of 2006, the maximum radius for health facilities from the residential area is approximately 1.5-2 km (Minister of Public Works Regulation Number: 32/PRT/M/2006, 2006). This research also only uses one type of health facility, which is hospitals. In this research, education facilities are not differentiated and are assumed to be the same across primary schools, junior high schools, senior high schools, and universities. The location of education facilities is also recommended to be near residential areas (Minister of Public Works Regulation Number: 32/PRT/M/2006, 2006). The further away from health and education facilities, the higher the priority for development in that area, as it is underserved by basic service

infrastructure. Furthermore, Indonesia's education system follows a zoning system (Wisnubroto, 2024). Research by Halder et al. (2020) also explains that basic service locations should ideally be near residential areas.

Besides basic facilities, the public facilities that need more attention are transportation facilities, specifically roads. This research focuses on collector roads and local roads (Halder et al., 2020). The further away from local and collector roads, the higher the priority for the improvement of access to public service facilities in underprivileged areas. This research will also prioritize the development of public facilities in frontier areas of Indonesia, particularly in ENT. According to Presidential Regulation No. 63 of 2020 (Presidential Regulation of the Republic of Indonesia No. 63 of 2020, 2020), there are 62 cities/regencies classified as such areas, and in the ENT Province, there are thirteen cities/regencies in this category. These remote, outermost, and frontier areas require high priority for public facility development to boost the local economy. These thirteen areas include West Sumba, Kupang, East Sumba, South Timor Tengah, Belu, Alor, Lembata, Rote Ndao, Southwest Sumba, Central Sumba, East Manggarai, Sabu Raijua, and Malaka (Presidential Regulation of the Republic of Indonesia No. 63 of 2020, 2020).

The development of public facilities needs to consider the geographical elements. The ideal slope for public facility construction is a low or gentle slope, and conversely, the steeper the slope, the lower the priority for public facility development (Nsaif et al., 2020). The recommended land cover for public facility construction, in order, is open land, built-up area/residential, and agriculture/savanna/grassland (Halder et al., 2020). On the other hand, land cover needs to be avoided includes vegetation and water bodies to preserve environmental sustainability and avoid polluting water ecosystems and causing deforestation (Halder et al., 2020). Therefore, the further away from water bodies such as rivers, the more recommended it is for public facility development (Ajaj et al., 2019). Public facility development should also avoid and be distant from protected areas in order to preserve these areas and cultural heritage sites, making areas closer to protected areas less recommended for development (Halder et al., 2020).

2.3.2 Socio-Economic Aspect

Socio-economic aspects refer to social and economic factors that influence the living conditions of an individual, family, or community (Wardhana, 2023). These aspects, occurring in specific regions, can indicate the socio-economic strength of that area. The economic aspect is represented by the GRDP (Gross Regional Domestic Product), where the GRDP at advertised costs is the total of net value-added emerging from all financial divisions in a locale. Esteem included is the combination of generation variables and crude materials within the generation handle. The calculation of esteem included is the generation esteem (yield) short middle costs (BPS, accessed on July 14, 2024). Classification of GRDP in this research is based on BNPB regulation no 12 in 2012.

Another factor is population density. It is a crucial factor in the impact of infrastructure development in Semarang. The result of population growth is an increase in the number of people in the outskirts of Semarang, which impacts infrastructure development in that area (Arsadi et al., 2020)a. Therefore, considering the infrastructure development in densely populated areas are necessary to support the community's economy. Classification population density using table below

2.3.3 Multi-Disaster Aspect

Indonesia is a country with many regions that have a high hazard of natural disasters, including flash flood, tidal flood, floods, severe weather, earthquakes, and tsunamis. Concurring to the Worldwide Hazard Record in 2019, Indonesia positioned 37th out of 180 nations most defenseless to characteristic fiascos. As of May 18, 2020, the number of recorded natural disasters was 1,296 cases, with damage including 331 educational facilities, 396 places of worship, 32 health facilities, 58 institutions, and 181 bridges (Retnowati, 2020). Therefore, infrastructure development must consider minimizing the occurrence of natural disasters in these areas to reduce losses caused by natural disasters. The Director of State Assets Management explained that the average annual loss due to disasters from 2000-2016 was IDR 22.8 trillion.

According to statistical data from the Central Statistics Agency (BPS), the most frequent natural disasters in East Nusa Tenggara in 2023 were tornadoes with 50 incidents, floods with 29 incidents, forest fires with 14 incidents, landslides with 10 incidents, earthquakes with 5 incidents, tidal waves with 4 incidents, droughts with 2 incidents, and volcanic eruptions with 2 incidents. In 2022, the most frequent were floods with 31 incidents, tornadoes with 8 incidents, and landslides with 3 incidents. Therefore, the most frequent disasters in East Nusa Tenggara are tornadoes, landslides, floods, and earthquakes.

According to BNPB regulation no. 2 In 2012, there is a classification of weights for creating a multi-hazard map weights for all disasters are visible, but since the focus of the research only uses 4 disasters, there needs to be a modification of the weights as done by Pratiwi(Pratiwi et al., 2016).

2.3.4 Public Infrastructure Priority Area

The Analytic Hierarchy Process (AHP) could be a choice back strategy created by Thomas L. Saaty (Saaty, T. L.,1993). This decision support model breaks down complex multi-factor or multi-criteria problems into a hierarchy. According to Saaty (Saaty, 1980), hierarchy is characterized as a representation of a multifaceted issue in a layered structure, where the primary level is the objective, taken after by variables, criteria, sub-criteria, and so on until the ultimate level of choices.

AHP is designed to gather the opinions of people closely related to a specific goal/problem through a process designed to

determine the importance level among different variables. The AHP method is based on the idea that the value of individual experience and knowledge in decision-making is less than the data used in the decision-making process. By incorporating human judgement into decision-making, in essence, AHP helps unravel complex issues by organising a chain of command of criteria, which are subjectively evaluated by partners, and after that drawing different contemplations to create weights or needs (conclusions). The main tool of AHP may be a utilitarian chain of command with human recognition as its essential input. The pecking order permits complex or unstructured issues to be broken down into sub-problems, which are at that point organised into a progressive frame (Kusrini, 2007). The development of weights for AHP is based on a survey of sources from various scientific fields resulted in the following weight assessments in Table 2

Table 2 weight of AHP

No	Type	Weight
1	Accessibility Aspect	0.493
2	Socio-Economic Aspect	0.139
3	Multi-Disaster Aspect	0.368

3. RESULT AND DISCUSSION

3.1 Accessibility Aspect

Figure 3 shows the prioritization modelling of public infrastructure development based on the accessibility aspects. Around 44.21% of the area in East Nusa Tenggara (ENT) falls into the "very low" class in terms of accessibility. This is because these areas consist of forests, bodies of water, and protected areas. Meanwhile, the rest are categorized into the "low," "moderate," "high," and "very high" classes, with respective area percentages of 14.18%, 15.04%, 16.64%, and 9.93%.

Figure 4 shows statistical percentage of the area designated as a priority for public infrastructure development based on accessibility aspects. Areas with "high" and "very high" accessibility should be prioritized in terms of accessibility. This means that these areas currently lack of public infrastructure (healthcare and educational facilities). However, these areas have the potential for public infrastructure development due to favourable topography and location, such as being far from protected areas, not a part of forests or bodies of water, having relatively flat slopes, and being close to residential areas. Proximity to residential areas should be considered to ensure that the infrastructure built remains accessible to the community. Additionally, areas classified as "high" and "very high" are often part of the disadvantaged, outermost, and frontier regions, which should be prioritized for public infrastructure development in terms of accessibility. Areas such as South West Sumba, Malaka, West Sumba, South Central Timor, and Central Sumba have the highest priority, with the "High" and "Very High" classes making up 55.48%, 53.11%, 51.84%, 51.17%, and 47.16% of their areas, respectively. Based on this aspect, it is proved that these areas have limited support for additional public facilities that are adequate for further public infrastructure development.

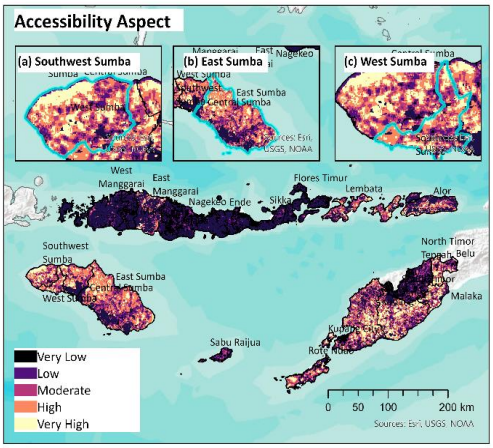

Figure 3. Accessibility Aspect Spatially

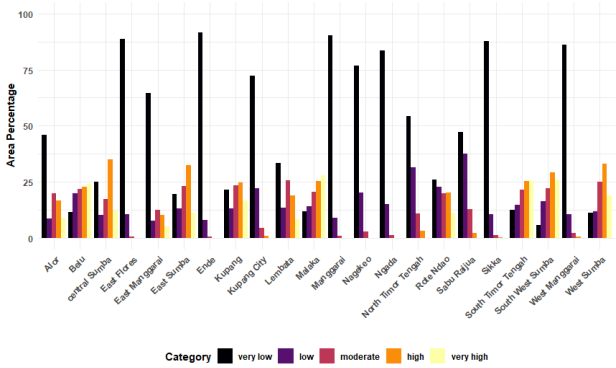

Figure 4. Accessibility Aspect Statistically

3.2 Socio-Economic Aspect

The socio-economic aspect describes the condition of a region based on economic and human factors. In the province of East Nusa Tenggara (ENT), the economic condition ranges from low to moderate. However, to ensure equitable development, priority should be given to areas with low economic levels but high population density, targeting the improvement of their economies.

In the ENT region, most areas fall into moderate classification, account for 72.72%, while the low classification accounts for 27.27%. This is due to the limited population distribution, with most people clustered around the district capitals. According to BNPB regulations, ENT falls into the low category in terms of regional income, resulting in the majority areas being classified as moderate. In the socio-economic aspect, areas categorized as "low priority" are usually those with relatively high economic levels and low population densities. Therefore, to ensure equity, areas with low economic growth and high population densities would be given higher priority to promote regional equity and economic growth.

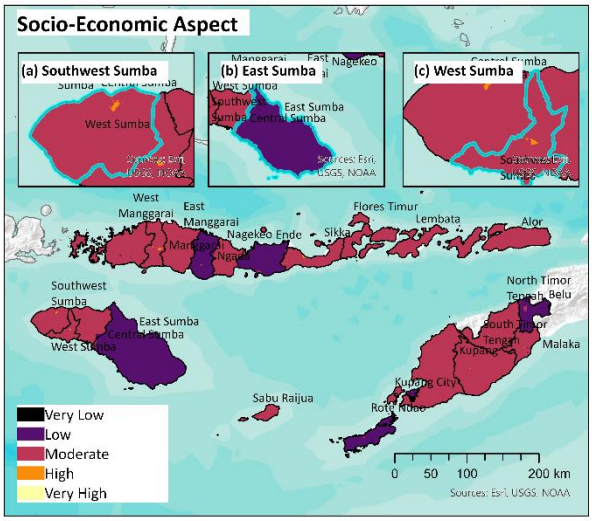

Figure 5. Socio-Economic Aspect Spatially

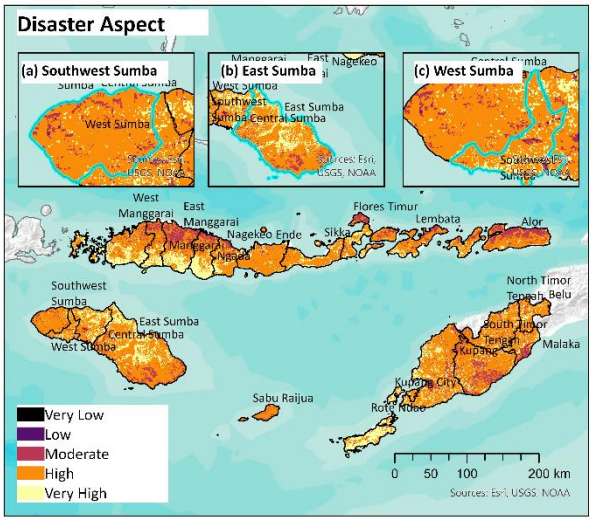

Figure 6. Multi-Disaster Aspect Spatially

3.3 Multi-Disaster Aspect

In the disaster aspect, the results can be seen in Figures 6 and 7. Figure 6 shows that East Nusa Tenggara (ENT) has low disaster and is relatively safer for infrastructure development. This is indicated by a large portion of the area having "high" and "very high" priority categories for infrastructure development when viewed from a disaster perspective. The disaster aspects considered include flood hazards, landslides, extreme weather, and earthquakes, as these disasters frequently occur in the ENT province. The overall percentage distribution for priority areas based on multi-disaster of "Very High," "High," "Moderate," and "Low" hazard areas are 0.22%, 13.17%, 63.39%, and 23.27%, respectively.

Figure 7 shows the multi-disaster aspect values for each city/regency in ENT. The results indicate that Rote Ndao, West Manggarai, Ngada, Central Sumba, and Manggarai are the locations with the highest priority when considered from the disaster aspect. Respectively, the total percentage of "Very High" and "High" categories in Rote Ndao, West Manggarai, Ngada, Central Sumba, and Manggarai are 73.74%, 39.66%, 38.93%, 33.91%, and 28.42%. These five regions have high priority in the disaster aspect because they potentially have low disaster hazard. In areas with low disaster, economic growth is more likely because investors have greater confidence due to the lower likelihood of disasters. This reduces the potential costs associated with disaster-related maintenance, thereby minimizing the hazard and encouraging investment.

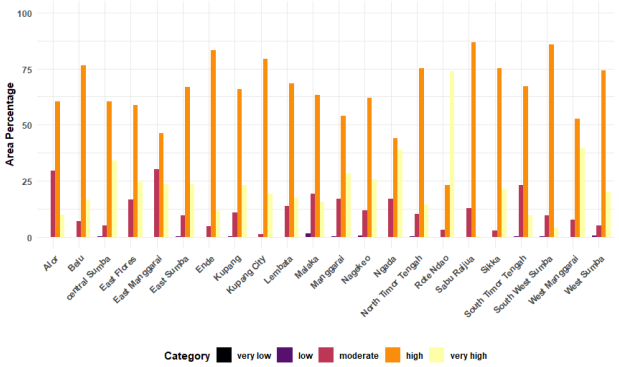

Figure 7. Multi-Disaster Aspect Statistically

3.4 Priority Areas

The priority areas for public infrastructure development can be seen in Figure 8. Figure 8 is dominated by the "moderate" class, covering 34.48% of the area, followed by the "high" class at 30.46%, the "low" class at 22.89%, and the "very high" class at 12.17%. Additionally, Figure 9 shows the distribution in each city/regency across the different priority classes. The results indicate that the regencies of West Sumba, South West Sumba, Malaka, Belu, and East Sumba have the highest priority, with the total percentages of the "Very High" and "High" classes being 77.49%, 77.13%, 71.92%, 70.93%, and 68.58%, respectively.

High priority means these areas have limited accessibility, low disaster hazard, relatively high population, and low economic levels. These regions should be prioritized for infrastructure development to improve the well-being and economy, especially in education and healthcare for the local population.

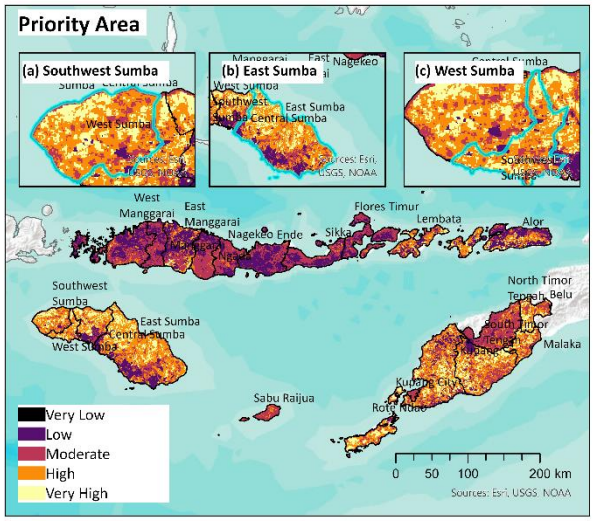

Figure 8. Priority Areas Spatially

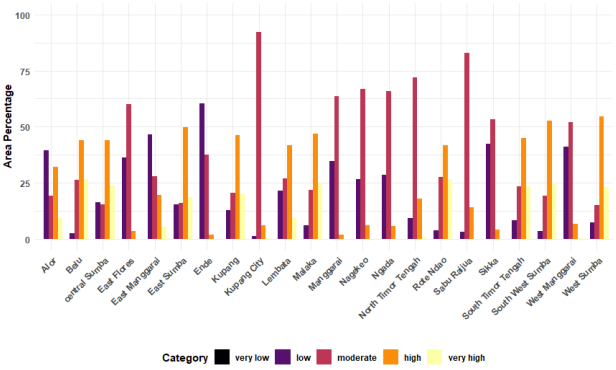

Figure 9. Priority Areas Statistically

3.5 Limitation and Future Study

This study has several limitations. First, in the terms of educational facilities, this research assumes that primary schools, junior high schools, senior high schools, and universities are the same. The lower the education level, the more critical it is for the facility to be accessible to residential areas, and vice versa. Ideally, education levels should be separated into categories, which can be further developed in future research.

Second, regarding healthcare facilities, this study only considers hospitals. Practically, there are many types of healthcare facilities in Indonesia, ranging from small, medium, to large scales. Future research can consider the various types of healthcare facilities available. The limitation of provided data posed a challenge in this study, necessitating assumptions for the parameters of healthcare and educational facilities.

Third, the assumption of public infrastructure facilities in this study focuses solely on transportation, healthcare, and educational facilities. Generally, public facilities refer to spaces accessible to the public for various activities, such as hospitals, public spaces, or even economic zones. Therefore, future research can consider other types of public facilities, such as economic facilities (banks, cooperatives, markets, and others).

4. CONCLUSION

The conclusion of this study highlights the priority locations for public infrastructure development. It aim at improving the quality of life for communities in terms of transportation, health, and education where there is still potential for regional economic growth. The first result focuses on the accessibility aspect, showing the distribution of accessibility values across the priority “very low”, "low," "moderate," "high," and "very high" classes, with respective area percentages of 14.18%, 15.04%, 16.64%, and 9.93%. The second result examines the socio-economic aspect, indicating that in East Nusa Tenggara (ENT), most of the area classify into the "moderate" priority class, with a total of 72.72%, and the "low" class accounts for 27.27%. The third result addresses the disaster aspect, where the "Very High," "High," "Moderate," and "Low" classes have percentages of 0.22%, 13.17%, 63.39%, and 23.27%, respectively. Lastly, the priority values for public infrastructure development are distributed across the "very high" class at 12.17%, the "high" class at 30.46%, the "moderate" class at 34.48%, and the "low" class at 22.89%. High-priority areas can serve as recommendations for the government in developing public facilities such as healthcare and education. This study is expected to help all regions can equally benefit from public facilities, particularly in transportation, education, and healthcare services.

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