Multi-criteria overlay analysis to determine road management priorities based on regional economic condition indicators

by Turnitin Indonesia

Submission date: 27-Mar-2025 02:09PM (UTC-0700)
Submission ID: 2627192280
File name: 04_Proc_2412_Multi-criteria_overlay_analysis.pdf (1.11M)
Word count: 3881
Character count: 22577

IOP Conference Series:
Earth and
Environmental Science

PAPER · OPEN ACCESS

Multi-criteria overlay analysis to determine road management priorities based on regional economic condition indicators

To cite this article: Nindyo Cahyo Kresnanto *et al* 2024 *IOP Conf. Ser.: Earth Environ. Sci.* **1412** 012021

Multi-criteria overlay analysis to determine road management priorities based on regional economic condition indicators

Nindyo Cahyo Kresnanto[1*], Wika Harisa Putri[2] and Murti Ayu Hapsari[3]

[1] Master of Civil Engineering Department, Janabadra University
[2] Green and Sustainability Research Group, Janabadra University
[3] Law Department, Janabadra University

*E-mail: nindyo_ck@janabadra.ac.id

Abstract. Road construction has a positive impact on the growth of economic businesses and people's income; although it is not felt quantitatively by the community, from a macro perspective, it increases Gross Regional Domestic Product (GRDP) significantly. So, ideally, the entire road network in an area must be managed well and evenly. However, the regional government's budget will only be able to fund some maintenance or improvements to existing roads. Conditions like this require prioritization of road management based on regional conditions. This research aims to prioritize road management with a case study in Purwodadi Regency, Central Java Province, Indonesia. Prioritization uses a spatial analysis approach with several spatial indicator variables of economic conditions: the accessibility index, the ratio of road length to regional area, the independent village index, and the disadvantaged village index. The method used to analyze is multi-criteria overlay analysis (MCOA). MCOA allocates/prioritizes spatial objects (road networks) to suit certain purposes based on various attributes the selected spatial objects must have. The research results can show the road management priorities at the research location based on attribute/spatial variable influences (thematic map). Road networks in areas with a low economic index are a top management priority.

1. Introduction

The road network is a transportation infrastructure with a very high role in economic growth [1], [2]. It enhances regional accessibility [3], connect regions, support supply chains [4], and promotes tourism [5], [6]. Importantly, it also plays a significant role in poverty reduction [7]. Therefore, improving the quality of road network services is not just necessary, but a compassionate step towards supporting regional development.

The difficulty at the stakeholder level (especially local governments) in managing the road network is the limited budget for construction, rehabilitation, and maintenance [8]. Local governments must be able to prioritize managing the road network. Prioritization is needed to determine the order based on the level of importance, which is the road network that must be managed first. Thus, a limited budget managing the road network can provide optimum benefits for the road network to the community and improve the economy [9].

Determining road management priorities must be based on regional economic conditions and the characteristics of the existing road network. [10]. Economic conditions are a significant factor in determining priorities. Areas with poor economic conditions must be a top priority compared to areas with good economic conditions. Apart from that, equal distribution of the road network can also be a variable, especially for constructing new road networks. The priority for road management is a balance between economic reality, social justice and infrastructure efficiency. By considering regional contexts,

existing networks, and equitable distribution, we can build resilient road systems that drive sustainable economic growth

The most appropriate tool for prioritizing is spatial analysis. Spatial analysis can help determine these priorities because all factors determining road management priorities can be modelled in spatial information [11]. Thus, this research aims to assess road treatment priorities using a spatial analysis approach by considering various regional economic variables and the distribution of the road network. The case study for this research is in Grobogan Regency, Central Java Province, Indonesia.

Grobogan Regency was chosen as a research case study because it has an area of 1,975.86 km and is the second largest district in Central Java Province [12]. This district's economic growth tends to fluctuate between 4-6 per cent during 2013-2017, with the poverty rate still relatively high, reaching 13.27% in 2017. However, it is predicted to fall to 11.74% in 2021 [13] and this prediction will be achieved in 2023, namely 11.72% [14]. The highest growth was achieved in 2015 at 5.96%, while the lowest economic growth occurred in 2014 at 4.07%, and in 2022, growth reached 5.98% [15], but this is still the most underdeveloped growth among the surrounding districts [16].

2. Literature review

2.1. Road in economic growth role

The road network has a crucial role in regional economic growth. An excellent and well-connected road network improves connectivity between regions. This condition allows the movement of goods, services and people more efficiently, increasing the flow of trade and investment between regions. A good road network facilitates the distribution of goods from producers to consumers. This situation helps companies to reach a broader market and meet consumer demands more effectively [17].

From an employment perspective, the road network is a game-changer. It enables workers to travel between regions, quickly increasing labour market flexibility. This, in turn, allows companies to access a wider pool of human resources. The road network's role in regional growth is further underscored by its influence on investors' location decisions. A good transport infrastructure, with its accessibility, is a catalyst for economic activity, driving regional growth [18].

The development of the tourism sector also requires the support of a good road network, which allows tourists to access tourist attractions more easily. Infrastructure support can increase the tourism industry's income and create regional jobs [19]. Gaps between regions can also be solved by providing an even road network—the area where previously marginalized areas can connect better to more significant markets and resources [20].

2.2. Priority based on spatial analysis

Spatial analysis, a crucial tool, extracts or creates new information from spatial data. Its six types, including queries and reasoning, measurements, transformations, descriptive summaries, optimization, and hypothesis testing, play a significant role in decision-making. For instance, it can determine priorities for conservation areas [21], prioritize areas prone to dengue fever outbreaks [11], and even decide the priority of investment in the medical system in certain areas [22]. These facts underscore the importance of spatial analysis in various fields.

Using overlay operations to determine priorities is the basic principle of spatial analysis. Overlay analysis is one of the spatial GIS (Geographic Information System) operations. It integrates spatial data with attribute data (attributes are information about each map feature). Overlay analysis combines information from one GIS layer with another to derive or infer an attribute for one of the layers [23].

2.3. Economic and road network in Grobogan Regency as research location

The scope of the area in this research is the Grobogan Regency area (Figure 1), which is to the east of the capital of Central Java Province and is located between the two Kendeng Mountains stretching from west to east. Geographically, Grobogan Regency is located between 110°15' East Longitude - 111°25' East Longitude and 7° - 7°30' South Latitude [24].

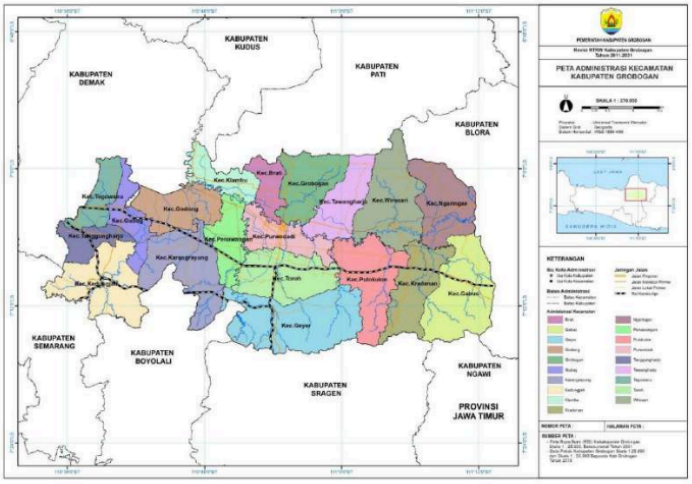

Figure 1. Grobogan Regency administrative area map.

The Grobogan Regency has 19 sub-districts, 280 villages/sub-districts, and an area of 2,022.25 km2. Several villages in the Regency are still underdeveloped based on the Village Development Index (IDM). The IDM can later be used to determine the progress status of a village. IDM is an important indicator for measuring the success of a village in carrying out its development [25]. Village status, referred to as village classification based on IDM, is explained in Permendesa PDT Trans No 2 of 2016, which classifies villages into five statuses, namely: 1) independent villages, 2) advanced villages, 3) developing villages, 4) disadvantaged/underdeveloped villages, and 5) very underdeveloped villages. Figure 2 shows the IDM status of Grobogan Regency 2020 based on village spatial boundaries.

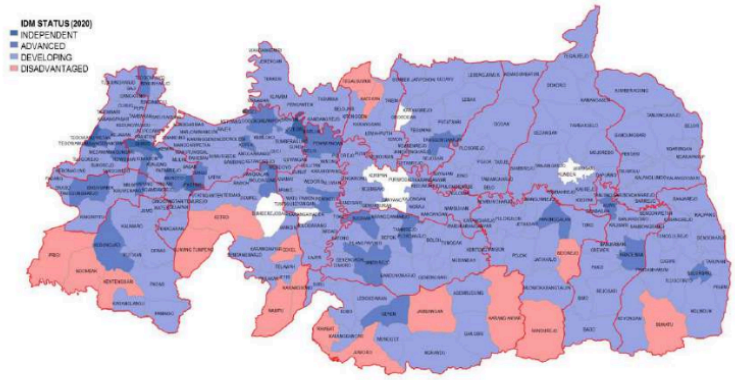

Figure 2. IDM status map of Grobogan Regency 2020.

The road network supporting connectivity in Grobogan Regency consists of roads with Provincial Roads, Regency Roads and Village Roads. There are 11 Provincial Road sections with a total length of 225.27 KM. Roads with Regency Road status are 250 sections with a total length of 917.77 KM. The remainder are village roads comprising 16,266 segments and a total length of 3,863.28 KM. The spatial distribution of the road network in Grobogan Regency can be seen in Figure 3.

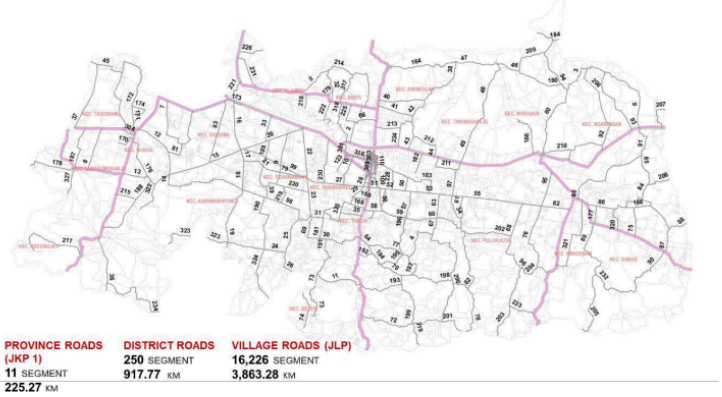

Figure 3. Road network in Grobogan Regency.

According to their function, roads in Purwodadi City are divided into collector, local and environmental roads. The primary collector road connects the city of Purwodadi with the cities of Semarang, Solo, Blora and Pati/Kudus. The total length of road space in Purwodadi Regency is 917.77 KM without Primary Arterial Roads (JAP) and Secondary Arterial Roads (JAS), with details according to their function as follows (Table 1):

Table 1. Length of road based on function.

SEGMENT LENGHT	JKP 4	JLP	JLing-P	JAS	JKS	JLS	Jling-S
917.77 KM	87.22 KM	755.01 KM	24.97 KM	0.00 KM	13.08 KM	22.13 KM	15.36 KM

Description: JKP (Primary Collector Road), JLP (Primary Local Road), JKS (Secondary Collector Road), JLS (Secondary Local Road), Jling-S (Secondary Neighborhood Road).

The spatial distribution of the road network in Grobogan Regency based on its function can be seen in Figure 4.

Figure 4. Spatial distribution of road hierarchy in Grobogan Regency.

3. Method

Determining the road hierarchy is greatly influenced by several factors, mainly the activity system that will be implemented. This activity system is contained in the national-level Spatial Plan and the district/city level. The road hierarchy is also determined by whether the road hierarchy system is included in the primary or secondary system. Furthermore, it is necessary to design a draft hierarchy before assessing the suitability of existing road conditions to determine definite function/status classification. The methodological approach for determining road hierarchy can be seen in Figure 5.

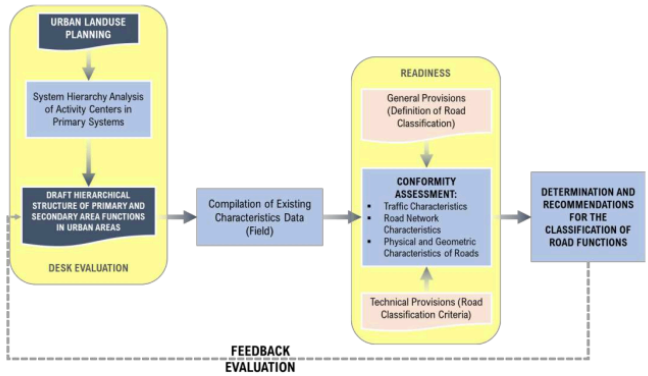

Figure 5. General approach to determining road hierarchy.

The data required in this research is activity system data in the form of Regency/City Spatial Planning, Existing Road Network System Hierarchy, and data on regional socio-economic conditions. The data used in the research is spatial data, which will be processed using GIS tools (Table 2).

Table 2. Data for road hierarchy system analysis.

Data Type	Sources	Needs	Data Format	Spatial Unit
Urban/Rural Land Use Planning	District/City	Activity Systems Analysis	Shp file	Regency
Road Network System	Provincial/Regency/ City Transportation Department	Network System Analysis	Shp file	-
Social Economic Data in the form of the Village Development Index (IDM)	Regency/City Regional Planning Agency (Bappeda)	Analysis of Economic Conditions	Shp file	Village
Admnistration Boundary Data	Regency/City Regional Planning Agency (Bappeda) and Geospatial Information Agency (https://tanahair.indonesia.go.id/portal-web)	Regional Analysis	Shp file	District and Village

This study analyzed the road network system by referring to the Regional Spatial Plan and considering connectivity between regions and within urban and rural areas. The study was carried out spatially using GIS to plot the activity system. The method used in this research can be seen in Figure 6.

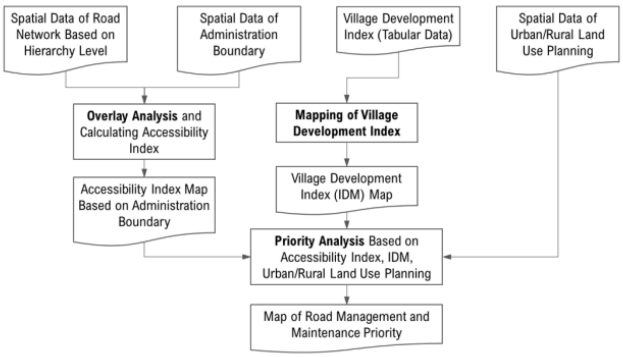

Figure 6. Methodology.

This research takes a case study in Grobogan Regency, Central Java Province, Indonesia. The district was used as a case study location because it is one of the districts with a poor population percentage of more than 11%; the average percentage of poor people in districts in Central Java Province is 10%. In fact, this district is very close to the capital of Central Java Province, namely Semarang. The location of the districts in Central Java Province can be seen in Figure 7.

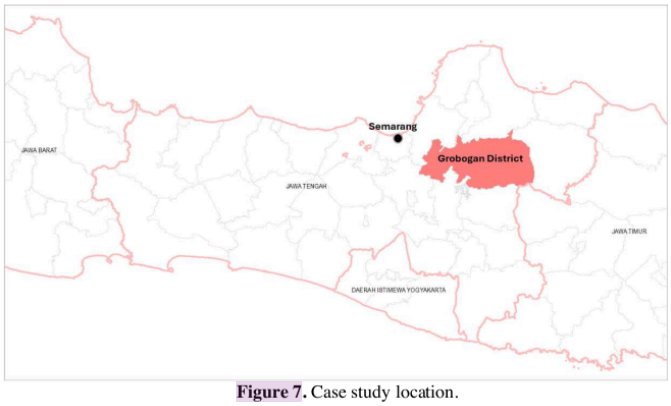

Figure 7. Case study location.

4. Result and discussion

4.1. Secondary network system analysis (connectivity, network voidness and accessibility index)

Currently, connectivity to sub-district capitals throughout Grobogan Regency is connected to Primary Collector Road 1 (JKP 1), except for Pulokulon District, which is connected to Primary Collector Road 4 (JKP 4). So, in general, all sub-district capitals that can be hierarchically connected to Primary Local Roads (JLP) according to Ministerial Regulation 3/Prt/M2012 (Guidelines for Determining Function and Status) are connected to a higher road hierarchy. Figure 8 shows the overlay between the road hierarchy and the location of the sub-district capital.

This condition is based on the regional planning concept that the city hierarchy must be connected to the appropriate road hierarchy. This will streamline the movement and function of the road. The compatibility between the city and road hierarchies significantly increases regional efficiency and helps economic growth [26], [27].

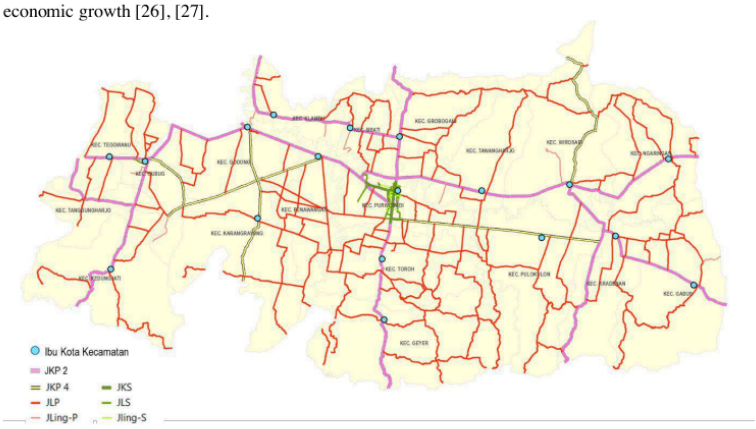

Figure 8. Overlay of road hierarchy with sub-district capitals (ibu kota kecamatan).

Connectivity to regional growth centres (Local Activity Center (PKL); Regional Service Center (PPK); Local Service Center (PPL); Promotional et al. Center (PKLp)) in Grobogan Regency has also been fulfilled with an adequate hierarchical structure (Figure 9). All strategic areas in the Grobogan Regency are connected via a primary network with an appropriate hierarchy. Each secondary system is also well-connected.

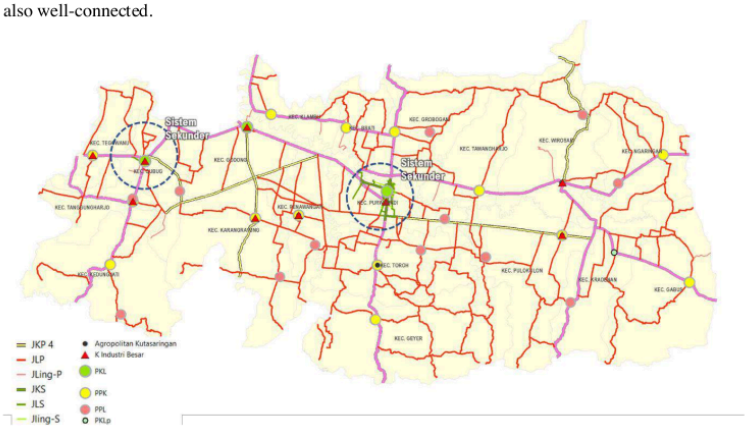

Figure 9. Road network overlay (connectivity) with local growth centers.

4.2. Road network development needs and priority

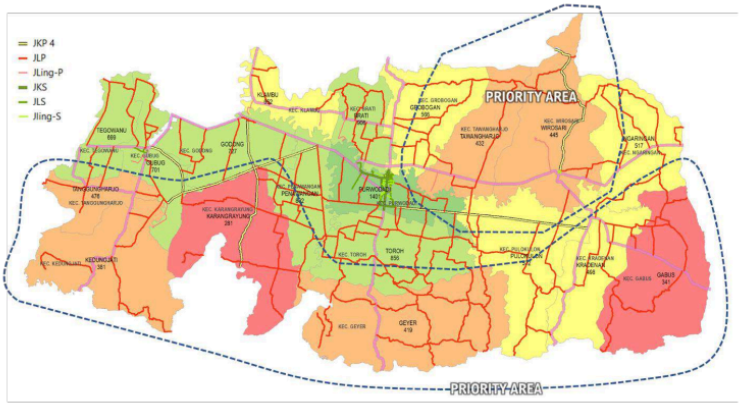

Figure 10. Priority based on accessibility index.

The use of the accessibility index as a variable to assess economic conditions has also been carried out in various studies. The accessibility index can be considered a suitable tool to provide more complete insights into economic investigations and resilience measurements [28], [29]. Other studies have proven that accessibility significantly impacts economic growth [30], [31] (Figure 10).

Meanwhile, the overlay results between the road network and poor sub-districts show that the southern region of Grobogan Regency has the most poor sub-districts. So, road management priorities (improvement and rehabilitation) must be focused on this region (Figure 11). This result strengthens the accessibility index analysis, stating that areas with low accessibility indices are also the cause of areas not developing.

Figure 11. Priority based on poor villages.

5. Conclusions

In the Grobogan Regency, connectivity to regional growth centres is well-structured, featuring an adequate hierarchical system. All strategic areas are linked via a primary network, which includes well-connected secondary systems. The priority for improving the Primary Network System lies in the southern region, focusing on enhancing accessibility in underdeveloped areas and those with an accessibility index below 500. Additionally, attention is needed for several northern regions, including Tawangharjo and Wirosari, which still have low accessibility indices.

References

[1] Y. Zhang and L. Cheng, "The role of transport infrastructure in economic growth: Empirical evidence in the UK," *Transp Policy (Oxf)*, vol. 133, pp. 223–233, Mar. 2023, doi: 10.1016/J.TRANPOL.2023.01.017.

[2] M. N. Asimakopoulou and F. Kehagia, "Road network, CO2 emissions, linked to sustainable development: A European analysis," *E3S Web of Conferences*, vol. 436, Oct. 2023, doi: 10.1051/E3SCONF/202343611010.

[3] G. Gecchele, R. Ceccato, and M. Gastaldi, "Road Network Vulnerability Analysis: Case Study Considering Travel Demand and Accessibility Changes," *J Transp Eng A Syst*, vol. 145, no. 7, Jul. 2019, doi: 10.1061/JTEPBS.0000252.

[4] V. Eriksson, A. Dubois, and K. Hulthén, "Transport in supply networks," *International Journal of Logistics Management*, vol. 33, no. 5, pp. 85–106, 2022, doi: 10.1108/IJLM-06-2021-0350/FULL/PDF.

[5] J. Yu, B. Safarov, C. Wang, M. Buzrukova, and B. Janzakov, "The Effect of Transportation Networks on Heritage Tourism and New Urbanization-Empirical Research Based on Rich Heritage Sites in a Chinese Province," 2023, doi: 10.3390/heritage6120383.

[6] M. Talebi *et al*., "A GIS-MCDM-based road network planning for tourism development and management in Arasbaran forest, Iran," *Environ Monit Assess*, vol. 191, no. 11, pp. 1–15, 2019, doi: 10.1007/s10661-019-7831-3.

[7] N. C. Kresnanto, R. Raharti, E. Andari, W. H. Putri, M. Willdan, and R. I. Ramadhan, *Subsidi Transportasi untuk Masyarakat Berpenghasilan Rendah*. Yogyakarta: Amara Books, 2023.

Accessed: Mar. 01, 2024. [Online]. Available: https://katalog.amarabooks.com/katalog/subsidi-transportasi-untuk-masyarakat-berpenghasilan-rendah/

[8] J. Litzka and A. Weninger-Vycudil, "The Effect of Restricted Budgets for Road Maintenance," *Procedia Soc Behav Sci*, vol. 48, pp. 484–494, Jan. 2012, doi: 10.1016/J.SBSPRO.2012.06.1027.

[9] H. D. Baihaqi and C. A. Prastyanto, "Analysis of Determining Priority of Road Maintenance Program in The Region of Kediri Road And Bridge Management Department of Highways East Java Province Using Multi Criteria Analysis (MCA) Method," 2023.

[10] P. J. Gertler, M. Gonzalez-Navarro, T. Gracner, and A. D. Rothenberg, "The Role of Road Quality Investments on Economic Activity and Welfare: Evidence from Indonesia's Highways *," 2014.

[11] Efriza and T. Eryando, "Spatial Analysis for the Identification of Priority Areas Dengue in West Sumatera Province, Indonesia," *International Journal of Innovative Research and Development*, vol. 11, no. 1, Jan. 2022, doi: 10.24940/IJIRD/2022/V11/I1/JAN22045.

[12] "Letak Geografis dan Sumber Daya Alam Kabupaten Grobogan," Bappeda Kabupaten Grobogan. Accessed: Mar. 08, 2024. [Online]. Available: https://bappeda.grobogan.go.id/dokumen/data-statistik/35-letak-geografis-dan-sumber-daya-alam-kabupaten-grobogan

[13] Pemda Kabupaten Grobogan, "Angka Kemiskinan Kabupaten Grobogan," Pemda Kabupaten Grobogan. Accessed: Mar. 08, 2024. [Online]. Available: https://pojokperekonomian.grobogan.go.id/info-ekonomi/ekonomi-regional-grobogan/230-angka-kemiskinan-kabupaten-grobogan

[14] Saiful Anwar, "Ini Angka Kemiskinan di Grobogan dari Tahun ke Tahun - Murianews.com." Accessed: Jun. 29, 2024. [Online]. Available: https://berita.murianews.com/saiful-anwar/412629/ini-angka-kemiskinan-di-grobogan-dari-tahun-ke-tahun

[15] Tya Wedya, "Tahun 2022 Pertumbuhan Ekonomi Grobogan Naik Jadi 5,98 Persen." Accessed: Mar. 08, 2024. [Online]. Available: https://suarabaru.id/2023/05/24/tahun-2022-pertumbuhan-ekonomi-grobogan-naik-jadi-598-persen

[16] Dzikri Ainun Faza, Dwi Susilowati, and Zainal Arifin, "Analisis Ketimpangan, Pola Pertumbuhan Ekonomi dan Sektor Unggulan di Kawasan Kedungsepur Provinsi Jawa Tengah," *Jurnal Ilmu Ekonomi (JIE)*, vol. 7, no. 2, pp. 180–194, 2023.

[17] Md. R. I. slam, Md. E. I. Monjur, T. Akon, Md. R. I. slam, Md. E. I. Monjur, and T. Akon, "Supply Chain Management and Logistics: How Important Interconnection Is for Business Success," *Open Journal of Business and Management*, vol. 11, no. 5, pp. 2505–2524, Aug. 2023, doi: 10.4236/OJBM.2023.115139.

[18] N. T. T. Dung, N. Q. Toan, and V. P. L. Trang, "Solutions to Promote Diversification of Investment Capital For Road Transport Development in Vietnam," *International Journal of Economics and Finance Studies*, vol. 13, no. 2, pp. 108–130, 2021, doi: 10.34109/IJEFS.20212006.

[19] S. Kanwal, M. I. Rasheed, A. H. Pitafi, A. Pitafi, and M. Ren, "Road and transport infrastructure development and community support for tourism: The role of perceived benefits, and community satisfaction," *Tour Manag*, vol. 77, p. 104014, Apr. 2020, doi: 10.1016/J.TOURMAN.2019.104014.

[20] P. J. Gertler, M. Gonzalez-Navarro, T. Gracner, and A. D. Rothenberg, "The Role of Road Quality Investments on Economic Activity and Welfare: Evidence from Indonesia's Highways *," 2014.

[21] A. E. Izquierdo and M. L. Clark, "Spatial Analysis of Conservation Priorities Based on Ecosystem Services in the Atlantic Forest Region of Misiones, Argentina," *Forests 2012, Vol. 3, Pages 764-786*, vol. 3, no. 3, pp. 764–786, Aug. 2012, doi: 10.3390/F3030764.

[22] A. M. Buda *et al*., "Use of geospatial analysis for priority setting in surgical system investment in Guatemala," *The Lancet Regional Health - Americas*, vol. 7, p. 100145, Mar. 2022, doi: 10.1016/J.LANA.2021.100145.

[23] D. Tiede, "A new geospatial overlay method for the analysis and visualization of spatial change patterns using object-oriented data modeling concepts," *Cartogr Geogr Inf Sci*, vol. 41, no. 3, pp. 227–234, May 2014, doi: 10.1080/15230406.2014.901900.

[24] Bappeda Kabupaten Grobogan, "Letak Geografis dan Sumber Daya Alam Kabupaten Grobogan." Accessed: Mar. 09, 2024. [Online]. Available: https://bappeda.grobogan.go.id/dokumen/data-statistik/35-letak-geografis-dan-sumber-daya-alam-kabupaten-grobogan
[25] Satu Data Indonesia, "Indeks Desa Membangun (IDM) Kabupaten Grobogan Tahun 2020." Accessed: Mar. 09, 2024. [Online]. Available: https://katalog.data.go.id/dataset/indeks-desa-membangun-idm-kabupaten-grobogan-tahun-2019/resource/d06f6e58-a339-4668-85e8-99e18be48425
[26] A. Goto and H. Nakamura, "Functionally Hierarchical Road Classification Considering the Area Characteristics for the Performance-oriented Road Planning," *Transportation Research Procedia*, vol. 15, pp. 732–748, Jan. 2016, doi: 10.1016/J.TRPRO.2016.06.061.
[27] S. Tsigdinos, Y. Paraskevopoulos, and E. Kourmpa, "Exploratory evaluation of road network hierarchy in small-sized cities: Evidence from 20 Greek cities," *Transportation Research Procedia*, vol. 60, pp. 480–487, Jan. 2022, doi: 10.1016/J.TRPRO.2021.12.062.
[28] J. Östh, A. Reggiani, and G. Galiazzo, "Spatial economic resilience and accessibility: A joint perspective," *Comput Environ Urban Syst*, vol. 49, pp. 148–159, Jan. 2015, doi: 10.1016/J.COMPENVURBSYS.2014.07.007.
[29] M. De Bok and F. Van Oort, "Agglomeration economies, accessibility and the spatial choice behavior of relocating firms," *J Transp Land Use*, vol. 4, no. 1, p. 5, May 2011, doi: 10.5198/JTLU.V4I1.144.
[30] O. Kotavaara *et al*., "Role of Accessibility and Socio-Economic Variables in Modelling Population Change at Varying Scale," *Journal of Geographic Information System*, vol. 6, no. 4, pp. 386–403, Aug. 2014, doi: 10.4236/JGIS.2014.64034.
[31] C. Buonocore *et al*., "Accessibility analysis in spatial planning: A case of special economic zones (SEZs) in Campania, Southern Italy," *Land use policy*, vol. 132, p. 106763, Sep. 2023, doi: 10.1016/J.LANDUSEPOL.2023.106763.

Multi-criteria overlay analysis to determine road management priorities based on regional economic condition indicators

ORIGINALITY REPORT

18%	11%	7%	11%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Curtin University of Technology Student Paper	4%
2	Submitted to University of California, Los Angeles Student Paper	2%
3	Submitted to Westcliff University Student Paper	2%
4	Submitted to Chulalongkorn University Student Paper	1%
5	Gofran Ali Hussein, Hamid Athab Al-Jameel, Ahmed Yahya. "Evaluation of Al-Najaf road networks connectivity and Spatial Pattern", Journal of Physics: Conference Series, 2021 Publication	1%
6	pertambangan.fst.uinjkt.ac.id Internet Source	1%
7	v2.bappeda.grobogan.go.id Internet Source	1%
8	knepublishing.com Internet Source	1%
9	N C Kresnanto. "Model of relationship between car ownership growth and economic	1%

growth in Java", IOP Conference Series: Materials Science and Engineering, 2019
Publication

10	Östh, John, Aura Reggiani, and Giacomo Galiazzo. "Spatial economic resilience and accessibility: A joint perspective", Computers Environment and Urban Systems, 2015. Publication	<1 %
11	dusk.geo.oregonstate.edu Internet Source	<1 %
12	Ardiantiono, Nicolas J. Deere, David J.I. Seaman, U. Mamat Rahmat et al. "Improved cost-effectiveness of species monitoring programs through data integration", Current Biology, 2025 Publication	<1 %
13	KAUSAR, Devi Roza Krisnandhi. "Socio-Economic Impacts of Tourism on a World Heritage Site : Case Study of Rural Borobudur, Indonesia", NAGOYA Repository (New oai_dc setup Aug 2014), 2010. Publication	<1 %

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	On		