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Community dynamics towards the existence of toll roads in Indonesia: a literature and spatial study

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Infrastructure is the backbone of the development of a region. However, infrastructure must also be designed with sustainability in mind including toll road construction. This study investigates the societal dynamics and impacts of toll roads in Indonesia from 2019 to 2023. Through a literature review of 92 relevant articles obtained from scientific journals, books, and reports using keywords "toll" and "community," trends and perceptions regarding toll roads were analyzed. The evaluative descriptive method, guided by Neuman was employed to assess the trends rationally. Findings reveal a declining growth rate (−5.43%) in articles related to tolls and society, averaging 18 scientific articles per year. Economic and social aspects were most discussed, followed by legal and environmental considerations. Regionally, toll roads' impacts varied: positive economic effects were noted in urban and toll gate adjacent areas, while negative impacts were observed in rural regions reliant on passing vehicle trade and agriculture. Socially, industrial zones, dense population centers, and potential tourism spots benefited, but issues like land scarcity and social disparities widened. Environmental risks included damage to sensitive ecosystems, water sources, air quality, and agricultural land, particularly in disaster-prone regions. The study emphasizes the need for comprehensive planning and mitigation strategies to address toll roads' multifaceted impacts on society, economy, and the environment. By understanding these dynamics, policymakers and planners can develop sustainable infrastructure solutions that benefit all stakeholders. This research contributes valuable insights to transportation infrastructure development and management in Indonesia, aiding policymakers and urban planners in making informed decisions.

KEYWORDS

community dynamics, toll roads, economic impact, environmental impact, policy planning, "toll" and "community"

1 Introduction

Infrastructure is the backbone of the development of a region (Sembiring, 2022). Whether it is highways, bridges, airports, ports, transportation systems, energy, clean water, sanitation, or communication, infrastructure plays a crucial role in determining the level of economic growth, social welfare, and progress of a region. Its urgency lies in its ability to open up accessibility, facilitate trade, enhance mobility, support investment, and improve the quality of life for residents (Afriyana et al., 2023).

The economic growth of a region is closely linked to its infrastructure. For instance, a well-maintained highway reduces the transportation costs of goods and enhances market accessibility, thereby encouraging investment and industrial growth (Verdania, 2023). According to Funk and Hain, (2023) every dollar invested in transportation infrastructure can generate a return of $4 in economic growth in the long term.

Additionally, infrastructure also plays a vital role in reducing the economic disparity between urban and rural areas (Suraji and Cakrawala, 2023; Aryanti et al., 2022). The development of infrastructure in remote or marginalized areas can open up access to markets, healthcare, and education that were previously difficult to reach, thereby enabling the communities in those regions to improve their standard of living (Zakaria, 2023).

In a global context, countries with reliable infrastructure can more easily connect to global supply chains, thereby enhancing their competitiveness in international trade (Muhtar, 2021; Daniswara and Ikhsan, 2022). Additionally, infrastructure is also a crucial part of the global Sustainable Development Goals (SDGs) agenda, which emphasizes the importance of inclusive, resilient, and sustainable infrastructure. This is exemplified by the development of the Port of Rotterdam in the Netherlands, which is one of the busiest ports in the world and a key driver of the country's economy.

However, infrastructure must also be designed with sustainability in mind. Environmentally unfriendly infrastructure development can have long-term detrimental impacts on the environment and society. Therefore, it is crucial to consider factors such as energy efficiency, waste management, and environmental impact mitigation in the planning and construction of infrastructure (Mambiravana, 2023).

The construction of toll roads is one of the most important forms of infrastructure in regional development. Toll roads not only enhance connectivity between cities and regions but also speed up the mobility of goods and people, thereby supporting overall economic growth (Faradilla, 2022). For example, the Trans-Sumatra highway project in Indonesia has opened up better accessibility between the western and eastern islands of Sumatra, allowing trade and investment to expand faster in the region.

Study of Oktafiani (2023), found that toll road development has a socio-economic impact on the community. Socio-economic changes in the community occur in the form of an increase or decrease in income so that it also changes the social status of the community and changes in livelihoods. Further research by Rahmayanti, (2020) explained that the existence of the Trans-Java toll road had a negative impact on the economic and social welfare of the Kaligangsa Kulon community, namely, a decrease in income, an increase in criminal acts, and reduced environmental soil fertility. In contrast, research of Qodariyah, (2021) In contrast, Qodariyah's research (2021) found that there were socio-economic changes that were getting better after the construction of toll roads in the farming community of Clarak Village, Probolinggo Regency.

The economic impact of toll roads on the regional economy is diverse and varies in different contexts. Toll roads are generally seen as a catalyst for economic growth, the effects of which can be uneven, especially between urban and rural areas. For example, toll roads have been shown to increase economic growth in both local and neighboring areas, with the most pronounced effects in geographically close areas and areas with similar levels of economic development (Yin et al., 2024). However, in rural areas, the impact can be more complex. In Heyuan, a rural area in China, access to toll roads has been found to promote entrepreneurial activity in local towns while suppressing it in neighboring towns, leading to a concentration of firms in more economically developed areas and creating regional economic imbalances (Xie et al., 2024). This shows that toll roads can increase economic efficiency, but they can also exacerbate regional disparities. In addition, the construction of toll roads has been linked to poverty reduction in economically underdeveloped regions, such as western China, but this effect is not uniform across all regions (Tian et al., 2023).

The social dynamics of toll roads reveal complex interactions between accessibility, community displacement, and social inequality, with different impacts on urban and rural areas. In urban environments, toll roads often increase mobility and economic opportunities, attract highly skilled workers and increase the share of high-income taxpayers, as seen in studies of the Swiss highway network, which leads to urban sprawl and shifts in income distribution (Fretz et al., 2021). However, in rural areas, the effects can be more nuanced and sometimes detrimental. For example, in rural China, access to toll roads has been shown to promote entrepreneurial activity in economically developed cities while suppressing it in adjacent and less developed areas, thus exacerbating regional economic imbalances (Xie et al., 2024). Similarly, in South Africa's Eastern Cape, inadequate road infrastructure perpetuates social exclusion and economic marginalization, highlighting the need for equality-driven infrastructure policies (Fobosi and Malima, 2025). Some of the literature underlines that toll roads can increase connectivity and economic growth, but also risk deepening social inequality, especially in rural areas, unless they are carefully managed with inclusive policies.

The environmental consequences of toll roads vary, impacting ecosystems, air quality, and agricultural land, with significant variations depending on the geographical and construction context. Research has shown that the construction of freeways can cause substantial ecological stress, especially in sensitive areas. For example, the Linghua Expressway in China shows a decrease in agricultural land and forest land, with an increase in grasslands and road areas, although ecological resilience has increased over time due to protective measures (Wang et al., 2024; Wen et al., 2025). In contrast, the Chanliu Expressway suffered continuous environmental damage due to inadequate protective measures during its construction (Wang et al., 2024). In mountainous and highland areas, such as those surrounding the Du-Ku Highway, environmental changes are exacerbated by global warming, affecting surface water, ground surface temperature, and vegetation indices, posing a risk to infrastructure safety (Mu et al., 2024). The Qinghai-Tibet Highway has been shown to reduce plant community function and biodiversity, with the most significant impact occurring closest to the road (Tan et al., 2024).

The development and existence of toll roads poses various challenges, including land acquisition, environmental preservation, and community financial sustainability. The land acquisition process for toll road construction often involves evicting local residents or businesses that live or operate along the planned route. This can lead to social conflicts and justice issues, and requires considerable time and cost to resolve. In addition, environmental maintenance is also a serious challenge. Toll road construction can have adverse impacts

on the environment, such as deforestation, land degradation, or water and air pollution. Therefore, it is important to conduct a comprehensive environmental impact evaluation before starting construction, as well as implement necessary mitigation measures to protect and sustain the surrounding environment. Another challenge is the financial sustainability of the community. While toll roads can provide long-term economic benefits, there is still the question of how to ensure the long-term financial sustainability of the project for the community.

Since 1978 until mid-January 2024, the total length of toll roads in Indonesia has reached 2,816 km, divided into Java Island 1,782.47 km, Sumatra Island 865.43 km, Kalimantan Island 97.27 km, Sulawesi Island 61.64 km, and Bali Island 10.07 km (BPJT, 2024). Of course, the construction of the toll road has a number of dynamics and challenges in the community both during planning, process, and post-development. For example, what happened to the workshop market traders in Serdang Bedagai Regency who experienced a drastic decrease in income and laid off employees after the existence of the toll road (Arief, 2023). In addition, there are also changes in the social conditions of traders in terms of routine, reduction in wages and labor, and the need for new innovations in increasing sales (Dewi and Prakoso, 2019). Various community dynamics towards toll roads have been documented in a number of scientific works that are interesting to study. These various scientific works describe very diverse community dynamics towards the existence of toll roads. Therefore, this study was conducted with the aim of: 1) find trends in scientific papers on the dynamics of society towards the existence of toll roads based on the year, and the object of research 2) identify the dynamics that occur in society towards the existence of toll roads in Indonesia.

This study fills a critical gap in the literature by providing an integrative evaluation of toll road impacts, synthesizing both the positive and negative effects across various societal sectors. It expands the understanding of toll road dynamics beyond economic considerations, incorporating social and environmental dimensions. By examining the regional disparities in toll road impacts, this research highlights the need for tailored approaches in infrastructure development that consider local contexts, thereby addressing the limitations of one-size-fits-all policies.

Moreover, the study offers actionable insights for policymakers, urban planners, and infrastructure developers, enabling them to create more sustainable and inclusive toll road systems. It advocates for comprehensive planning and mitigation strategies that align with both national development goals and local needs, ultimately supporting informed decision-making in the field of transportation infrastructure management.

2 Methods

This research follows a literature review methodology, relying on secondary data sources such as scientific journal articles, books, and reports. The study primarily employs an evaluative descriptive method as outlined by Neuman (2014) which is designed to provide a rational, systematic assessment of the trends and issues under review.

The spatial analysis was conducted using Geographic Information Systems (GIS) tools, which are essential for analyzing the spatial distribution of toll roads and their impacts across different regions. Although the primary focus of the research is on geographical and environmental aspects, GIS is useful in visualizing and mapping the geographic variation in toll road impacts. The spatial distribution of toll roads' economic, social, and environmental effects was studied, especially how they differ between urban, rural, and industrial zones. ArcGIS Used for creating maps and analyzing spatial data, ArcGIS helped in visualizing the locations of toll roads and understanding regional differences in their impacts. In addition, the report of the Meteorological and Climatological Agency for Physics (BMKG) was also used to visualize the temperature map.

The Publish or Perish application was used to conduct an initial search, ensuring that the articles retrieved were from reputable journals and sources. The selection of the 92 articles was based on strict inclusion criteria to ensure relevance and quality: 1) Only articles published between 2019 and 2023 were included to ensure that the research reflects the latest trends and impacts related to toll roads, 2) Articles were retrieved using the keywords "toll" and "community", ensuring that the focus remained on studies discussing the effects of toll roads on different societal aspects. 3) The articles were sourced from the Crossref index, a reputable source for scholarly publications, ensuring that only peer-reviewed and credible sources were included, and 4) Articles were selected based on their focus on economic, social, environmental, or legal impacts of toll roads, with particular attention to studies that analyzed these aspects spatially.

The choice of the 2019–2023 period in this study is based on several important reasons. First, this period covers a major transformation phase in the development of toll road infrastructure in Indonesia, with major projects such as the Trans-Sumatra Toll Road expanding the transportation network. Second, this period also covers the economic and social transition period following the COVID-19 pandemic, where changes in mobility patterns and local economic activities are very visible, especially in areas around toll roads.

Once the articles were selected, the data was processed using Biblioshiny (an R tool for bibliometric analysis) and Microsoft Excel. Biblioshiny was used to analyze the bibliographic data of the selected articles, helping to identify trends in publication over time. Microsoft Excel was used for the content analysis, particularly to organize and categorize the articles based on the four primary aspects (economic, social, environmental, and legal), and track trends and gaps in the research.

To ensure the credibility of the findings, the following validation steps were taken: 1) the articles selected were cross-referenced with existing reviews and primary research to ensure that key studies were not missed and to confirm that the findings were consistent with established knowledge, 2) to enhance the validity, the preliminary findings were shared with experts in the field of toll road research and urban planning, whose feedback helped to refine the analysis and improve the reliability of the results, and 3) triangulation was employed by incorporating findings from various sources (journals, reports, books), which helped validate the consistency and comprehensiveness of the study's conclusions. For more details, the systematic process of research identification, screening, eligibility, and inclusion can be seen in Figure 1.

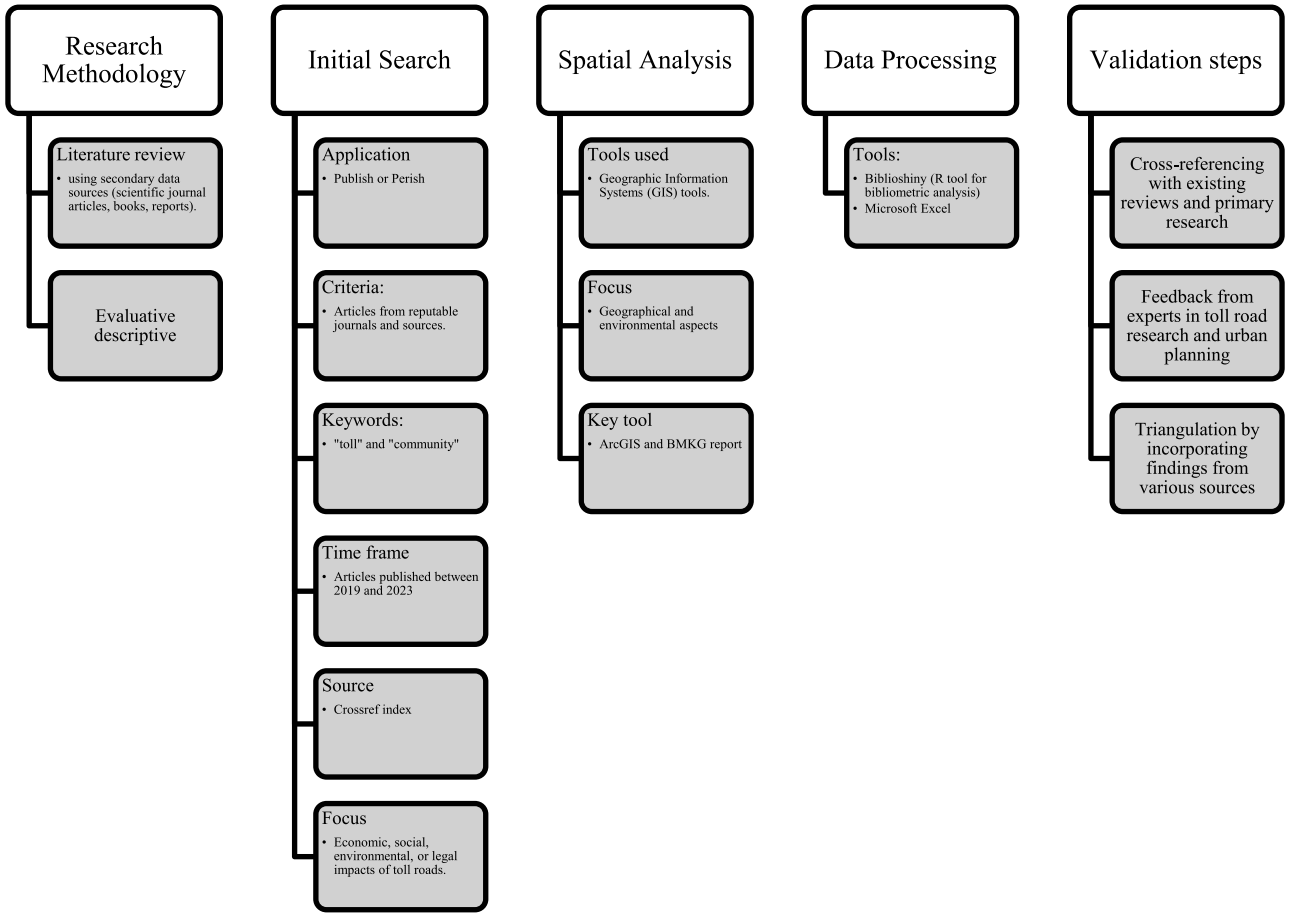

FIGURE 1
Prisma flow diagram of research.

3 Result and discussion

3.1 Number of annual publications

Based on the results obtained through the Biblioshiny application, it is known that the publication of articles related to toll and society during the 2019–2023 period has a growth rate of −5.43% with an average of 18 scientific articles per year. Visually, the number of article publications is shown in Figure 2 where the curve line tends to decrease every year.

The decline in academic publications is due to several factors. First, the shift in the focus of research towards urgent issues such as the COVID-19 pandemic, which has diverted academics' attention from the topic of transportation infrastructure. In addition, technological developments such as autonomous vehicles and intelligent transportation systems may be attracting more attention from researchers, reducing interest in the social and economic impacts of highway construction. Second, although toll road construction is increasing, existing research may already be considered in-depth, while more attention is focused on new issues such as climate change and green infrastructure.

The negative value in the growth rate of article publications indicates a significant change in research interest related to the topic of tolls and society. Nevertheless, the average of 18 scientific articles per year shows that the topic remains the focus of a number of researchers. The high level of infrastructure development programs in Indonesia such as bridges and the relocation of the

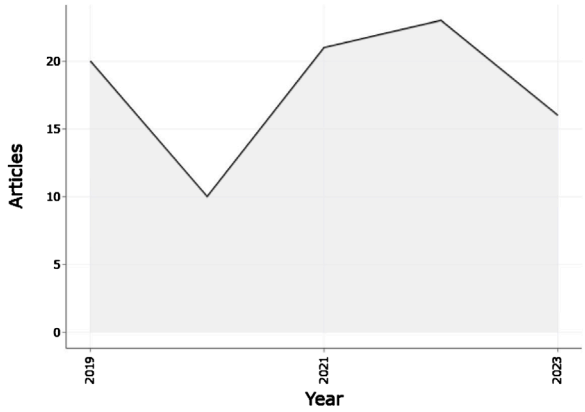

FIGURE 2
Annual article production.

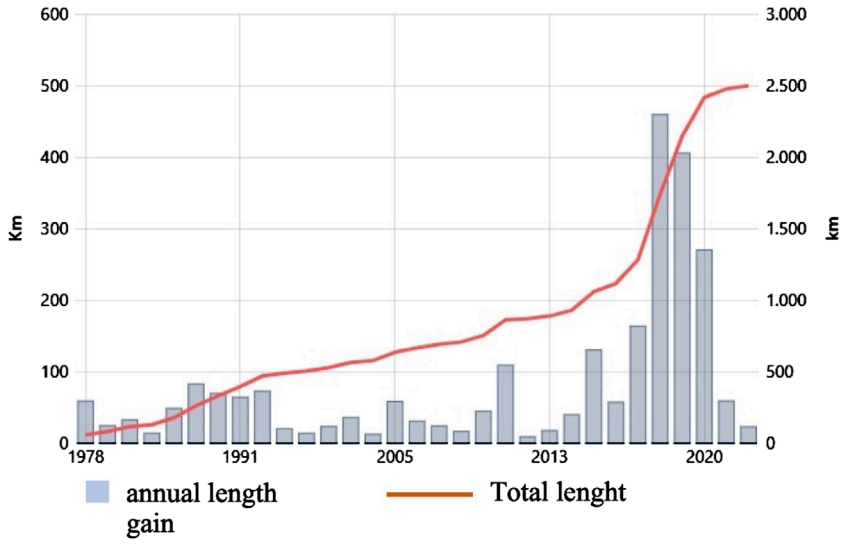

FIGURE 3
Toll road growth in Indonesia(Source: databoks, 2022).

capital city have become another focus of studies on society and infrastructure.

Based on the results of data processing through Biblioshiny, it is known that the study of bridges and communities has a growth rate of −1.34% while the study of (Capital City of the Archipelago) IKN and communities has a constant growth rate (0%). Both figures are much greater than the growth rate of studies on toll roads and society which touched −5.43%. This means that the level of productivity of scientific papers discussing bridges, IKN, and communities is higher than tolls and communities throughout 2019–2023.

The Ministry of Public Works and Public Housing (PUPR) noted that the number of national bridges in Indonesia reached 18,990 units in 2022. This number increased by 0.34% compared to the previous year which amounted to 18,925 units. Meanwhile, the realization of IKN construction in August 2023 reached an average of 18.17% since 2021 (Satgas Pembangunan Infrastruktur IKN, 2023). This shifted the focus of the study to society and toll road infrastructure, which grew by only 0.09% in 2022 (Kusnanda, 2022).

The discussion of toll roads and society involves a deep understanding of economics, social, law, and the environment. Based on the recapitulation of 92 scientific papers, it was found that economy and social are the most discussed objects of study followed by law and environment with a fairly balanced amount. This condition explains that most articles discuss the economy and social simultaneously. However, there are also 10 articles that do not discuss the four aspects, such as discussing e-tolls, toll rates, land acquisition for toll construction, and public communication about tolls. As well as, 17 articles that could not be accessed thoroughly. More clearly, it is shown in Figure 3.

Economic and social study objects are widely discussed in toll road and community research because infrastructure development such as toll roads has direct and indirect impacts on the economic and social conditions of the community (Pratama, 2023; Butarbutar and Rahayu, 2023). Direct impacts include the acquisition of agricultural land, changes in land functions, and increases in commodity prices. Indirect impacts include community dissatisfaction with the land acquisition process, changes in living conditions for children, adults, families, and communities. Toll road development does not always have a positive side for the community, especially in terms of land acquisition, isolated areas, and transportation costs (Zultaqawa et al., 2010).

The object of study on the environment is also discussed in the study of toll roads and society because toll road construction can affect the social, economic and physical environment. Toll road development can cause land conversion, which can affect the welfare of the community and the environment (Pratama, 2023). On the environmental side, toll road construction may cause air and noise pollution, which may affect community conditions. In addition, toll road construction can lead to the use of building materials, which can affect waste management (Kusuma, 2022).

Not only economic, social, and environmental, the object of study of law is also quite widely discussed in toll road and community studies because toll road construction can cause legal problems, such as land acquisition for development, the legal basis for land conversion, and legal protection for people affected by land acquisition for toll road construction (Ryandika, 2022a; Putra and Maulana, 2023).

3.2 Community dynamics towards the existence of toll roads

The dynamics of society towards the existence of toll roads are very complex (Figure 5). Toll road construction can improve the socio-economic integration of communities between regions and open up isolation in areas that were previously difficult to reach while reducing the mobility of passing vehicles. However, toll road construction can also cause negative impacts, such as inefficient land use that can lead to legal problems (Ahmad, 2022). On the economic side, toll road construction can affect farmers' income due to the

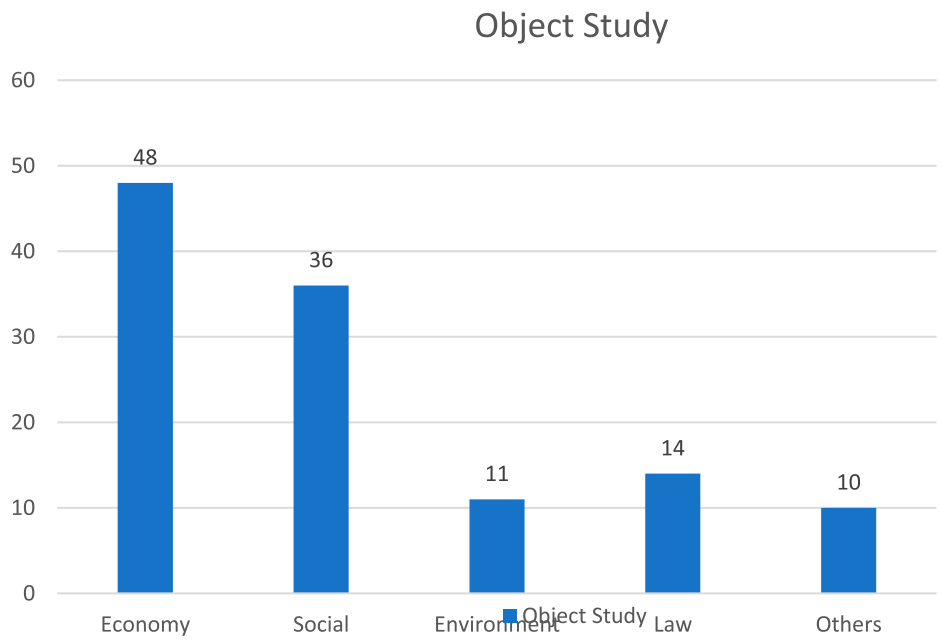

FIGURE 4
Study objects on society and toll roads.

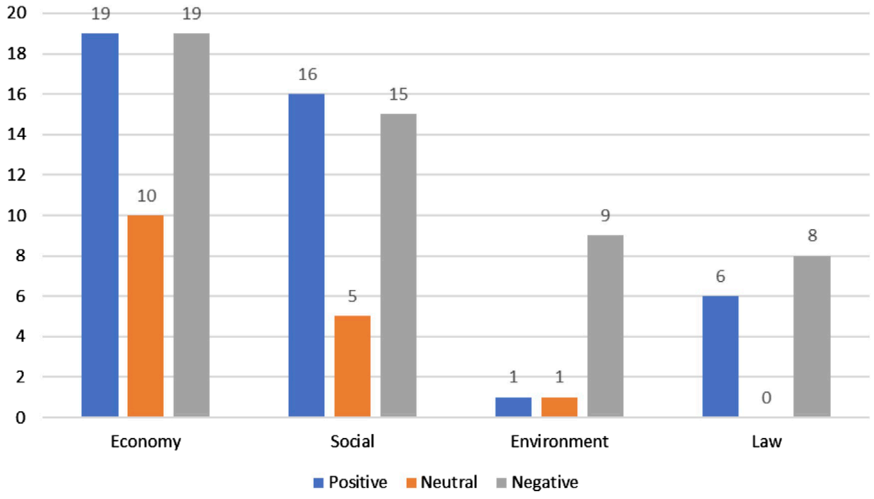

FIGURE 5
Community dynamics towards the existence of toll roads.

use of agricultural land. However, toll road construction can also make business activities busier, open up employment opportunities, and increase people's economic activities (Sumaryoto, 2010). The dynamics are more clearly shown in Figure 4.

Based on the literature study, the positive and negative impacts on the economic aspects of the toll road are balanced. Negative impacts occur in various areas, such as Koripan village (Diana et al., 2019), Kalisari village (A'la, 2019), Brebes district (Darwanto and Samadikun, 2019), Grati sub-district (Fitri, 2019), Kaligangsa Kulon village (Rahmayanti, 2020), Pangkalan urban village (Rahmawati, 2021), Buni Bakti village (Syahrahma, 2021), Dolok Maraja village (Faradilla, 2022), Sumedang district (Febrianty and Susilowati, 2022) and so on. Negative impacts occur in the form of decreased income, decreased demand, and layoffs. The decrease in the number of vehicles traveling on arterial roads as a result of toll roads is the main trigger for the negative economic impacts that occur in the community.

Meanwhile, positive impacts occurred in various areas, such as Wonorejo Village, Pettarani (Hilmi, 2021), Pekalongan (Saputri et al., 2022), Citali village (Ramdani, 2022), Manado-Bitung (Kandiyoh et al., 2022), Bagi village (Santoso, 2022), Pangkalan Jati urban village (Joesoef et al., 2021), Magelang city (Orbawati and

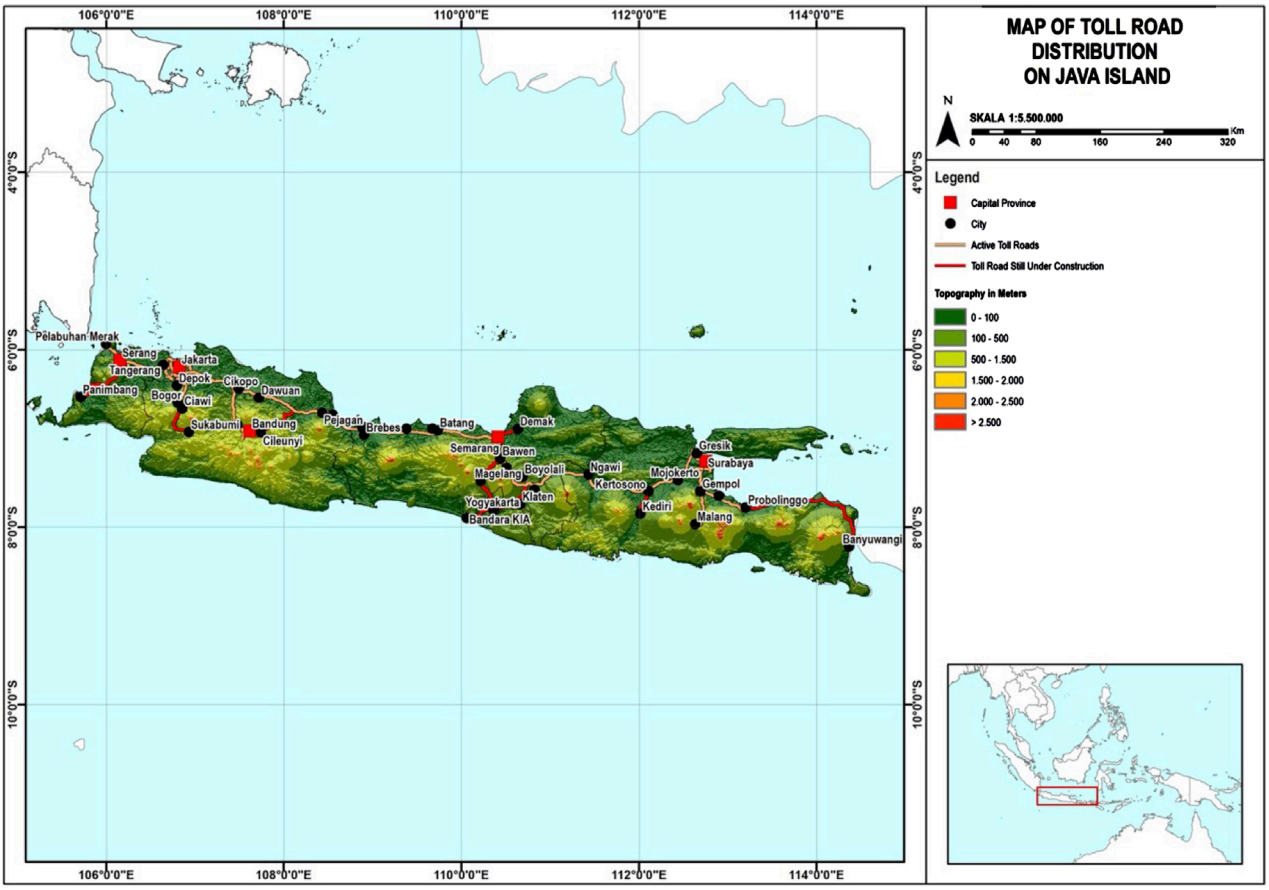

FIGURE 6
Java island toll road network map.

Rusdjijati, 2021), Cipali (Cahya, 2021), Medan Deli, Medan Helvetia, Medan Marelan, Sunggal dan Binjai Timur (Tarigan, 2021), and so on. Positive impacts occur in the form of increased income, increased land prices, changes in livelihoods, and at a macro level trigger economic growth. Increased community mobility, travel time efficiency, and the implementation of community empowerment around toll roads trigger positive economic impacts.

In the regional aspect, the literature review reveals that positive economic impacts occur in urban areas, areas around toll gates, and areas with communities that tend to be adaptive, especially after empowerment. Meanwhile, negative impacts occur in rural areas with trade and agriculture as the main sectors of the economy. Trade in the village mostly relies on consumers from passing vehicles. Likewise, agriculture whose productivity level only relies on land area. Furthermore, areas with neutral impacts occur in rural areas that have local economic growth centers and provide alternative transportation. Rural areas with a strong local economic base are not too dependent on additional infrastructure such as toll roads. Likewise, if the area already has a decent and efficient highway, the function of arterial roads tends not to be replaced by toll roads.

The area of agricultural land on the islands of Java and Sumatra has undergone dynamics influenced. In Java, especially West Java, data shows fluctuations in the area of rice fields from 4,475,033 ha in 2017 to 3,466,475 ha in 2019, and 2,551,067 ha in 2023, reflecting a significant decrease in that period (Rasmikayati et al., 2024). Meanwhile, in Sumatra, shows that in 2019, North Sumatra Province had a rice harvest area of around 419, 089.12 ha with a production of 2,154,117.08 tons, while in 2023, this figure is estimated to decrease to 296,215.93 ha with a production of 1,352,048.77 tons (Badan Pusat Statistik, 2024). This decrease is largely due to land conversion for housing, industry, and infrastructure which reduces the area of agricultural land which ultimately have a negative impact on the community's economy.

While no economic impact or neutral, occurred in Jatihurip village (Oktafiani, 2023), Minas Jaya village and Muara Fajar village (Sembiring, 2022), Agom village (Qomariyah, 2022), Pisang village (Saputra et al., 2020), Bebekan village (Hadiyanti and Sulistinah, 2019), and so on. In these areas, there were no changes in people's occupations and incomes. Community activities tend not to change before and after the toll road.

The construction of toll roads in Indonesia during the 2019 to 2023 period has had a significant impact on income distribution, both on Java and Sumatra (Figures 6, 7). Toll roads increase transportation efficiency, shorten travel times, and strengthen connectivity between regions. In Java, the improvement of toll road infrastructure, such as the Trans-Java toll road, has supported faster

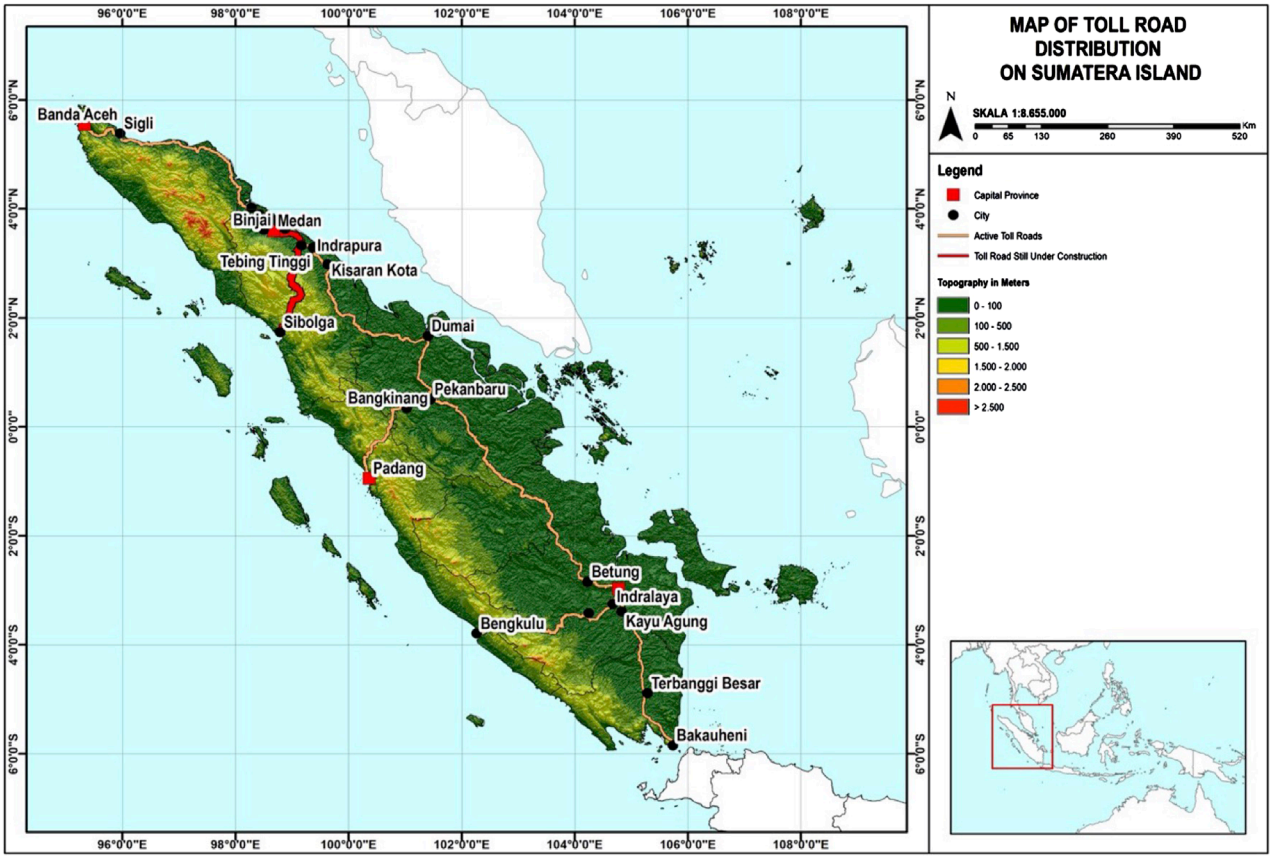

FIGURE 7
Sumatra island toll road network map.

economic growth in urban areas and major industrial areas, such as DKI Jakarta, West Java, and East Java. This is reflected in the increase in Gross Regional Domestic Product (GRDP) *per capita*, especially in Jakarta which reached $21,166 in 2023, which contributes greatly to the national economy (Badan Pusat Statistik, 2023). However, although regions on the island of Java tend to feel the greater benefits of toll road construction, income inequality between urban and rural areas remains high. The construction of toll roads accelerates the distribution of goods and facilitates market access, but is not always followed by the equitable distribution of benefits across all regions, especially in more remote and less developed areas (Taqiyya, 2024).

On the other hand, on the island of Sumatra, toll roads connecting areas such as Lampung and Palembang with other regions have provided opportunities for regional economic development. For example, Riau province, which has the highest *per capita* GDP on the island of Sumatra $10,138 in 2023 (Badan Pusat Statistik, 2023), benefits from the development of toll roads that support the trade and distribution of goods sector. However, more remote areas of Sumatra, such as Aceh, still experience significant inequality (Muljono et al., 2010). The existence of toll roads in these areas has the potential to reduce disparities by improving access to markets and infrastructure, but the effects are slower than in more developed areas.

Toll roads have a multifaceted impact on the economy, influencing regional development, firm activity, housing markets, and public finance. Research on the Egnatia Odos Motorway in Greece indicates that toll roads can positively affect regional economic development by enhancing passenger and freight transportation, which correlates with increased regional GDP *per capita* growth rates (Magoutas et al., 2022). However, the introduction of tolls can also have adverse effects, as evidenced by the unexpected imposition of tolls on Portuguese highways, which led to a significant decline in the number of firms and private sector employment in affected municipalities, particularly impacting larger and manufacturing firms (Audretsch et al., 2020). In urban settings, toll roads can create an accessibility premium, as seen in Orange County, California, where the construction of toll roads increased house prices, reflecting the value home buyers place on improved accessibility (Boarnet and Chalermpong, 2001). The Spanish experience with toll highway concessions highlights the risks and challenges associated with public-private partnerships, especially during economic downturns, where the allocation of risks to private concessionaires can lead to financial instability and potential negative outcomes for users (Vassallo et al., 2012). Additionally, the implementation of congestion pricing in the Greater Los Angeles area demonstrates that toll revenues, when recycled to reduce income or sales taxes, can yield substantial aggregate benefits, including increased gross regional product and more equitable distribution of benefits among consumers, landlords,

and importers (Anas, 2020). Overall, while toll roads can drive economic growth and urban development, their impact varies depending on the context, implementation, and accompanying fiscal policies.

Other research shows that toll roads, such as the Egnatia Odos Toll Road in Greece, can be positively correlated with regional GDP growth, mainly through increased passenger and freight transportation (Magoutas et al., 2022). However, the implementation of toll roads can also have a negative impact on the local economy, as evidenced by a study in Portugal which shows a reduction in the number of companies and jobs in cities that implement toll roads (Audretsch et al., 2020). Dynamic-toll roads in the United States have emerged as a potential solution to congestion, providing revenue for infrastructure while addressing equity concerns through reinvestment by the community (Farias et al., 2024). In addition, a comprehensive welfare analysis shows that high-occupancy toll (HOT) lanes can improve social welfare, outperforming other road expansion options in terms of regional economic impact (Do et al., 2020). Overall, although toll roads can generate the necessary funding and encourage economic activity, their implementation must consider broader implications because they can vary in some areas with certain characteristics.

In social studies, the negative impact of the existence of toll roads on the community occurs in a number of areas, such as Cinagasari village (Setiawan and Lilis, 2021), Pettarani (Hilmi, 2021), Tingkir Tengah urban village (Maulana and Sari, 2023), Tebanggi Besar (Ryandika, 2022b), Sumedang (Febrianty and Susilowati, 2022), Buni Bakti village (Syahrahma, 2021), Jurumudi urban village (Armanda et al., 2021), Kaligangsa Kulon (Rahmayanti, 2020), Ranuklindungan village (Fitri, 2019), Pejagan-Pemalan (Darwanto and Samadikun, 2019), and so on. The negative impacts include increased crime rates, decreased social interaction, loss of cultural treasures, and agricultural irrigation problems. The narrowing of land, the replacement of bridges, greater accessibility, and widening of social inequalities are the reasons for the negative impacts in these areas.

Positive social impacts occurred in Mekar Rahayu urban village (Rismawati, 2020), Medan-Binjai (Tarigan, 2021), Magelang city (Orbawati and Rusdjijati, 2021), Manado-Bitung (Kandiyoh et al., 2022), Citali village (Ramdani, 2022), Pasar Grosirsetono (Saputri et al., 2022), Wringinanom Village (Noor and Hamdan, 2017), Wonorejo village (Sumarmi et al., 2023), Jatihurip village (Oktafiani, 2023), Muara Fajar Timur village (Kusuma, 2022) and so on. Positive impacts such as reducing congestion and accidents on arterial roads, speeding up access, and the emergence of new settlements. Based on the literature study, it was found that industrial areas, areas with high population density, areas with potential for tourism and housing development are areas that are very likely to be positively affected socially.

Makassar city (Hamid, 2021), Padang-Sicincin (Hidayat, 2021), Bebekan village (Hadiyanti and Sulistinah, 2019), Saying district (Kurniawati, 2021), dan pasar bengkel (Dewi and Prakoso, 2019) are areas that are not socially affected by the toll road. People have both positive and negative perceptions of the toll road, and in Sayung sub-district in particular, people in each village have different perceptions. Various factors underlie each perception expressed by the community, such as educational and economic backgrounds.

In urban areas such as Lyon, France, toll roads can reduce inequality in suburban areas by improving accessibility, although they can have a negative impact on areas adjacent to the toll road zone (Souche et al., 2016). In Orange County, California, toll roads have increased house prices by improving accessibility, reflecting a premium that influences urban development and has the potential to encourage travel (Boarnet and Chalermpong, 2001). In addition, optimal toll rate setting can improve social welfare by balancing the cost burden between motor vehicle users and public funding, potentially generating revenue surpluses for broader social use (Ferrari, 2002). However, the distributional consequences of implementing toll roads can create winners and losers, requiring careful design to achieve Pareto improvements and maximize social welfare gains (Hall, 2021).

The existence of toll roads has multifaceted social impacts, influencing travel behavior, urban development, and equity among different income groups. Toll roads can improve accessibility, which is often reflected in higher land and house prices, as seen in Orange County, California, where the construction of toll roads created an accessibility premium that home buyers were willing to pay for, thereby affecting development patterns and potentially inducing more travel (Boarnet and Chalermpong, 2001). However, the introduction of tolls can also lead to increased vehicle miles traveled (VMT) and congestion, necessitating congestion pricing (CP) and road tolls to moderate demand and incentivize optimal travel choices. These strategies, while effective in reducing congestion, have varying social welfare impacts depending on their complexity and the reinvestment of toll revenues (Simoni et al., 2019). Equity concerns are significant, as stringent tolls tend to be more favorable to low-income motorists, while certain designs, such as inbound cordon tolls, can be detrimental to them. Rebates for low CO2 emission cars and exemptions for residents can slightly improve equity, though the allocation of toll revenues to all commuters or solely to public transport users has minimal impact on social equity (Bureau and Glachant, 2008). Additionally, road pricing policies can significantly reduce personal car use, fuel consumption, and pollutant emissions, as evidenced by the study in Tehran, Iran, where higher toll prices led to substantial decreases in toll acceptability, fuel consumption, and emissions of CO2, NOx, PM, and VOCs (Hosseinlou et al., 2016). Public perception of tolls also varies, with many considering traffic restrictions and congestion regulation unjust, though there is some support for tolls justified by pollution concerns and for reduced rates for low-income users, highlighting the need for equitable compensation mechanisms (Souche et al., 2012). Overall, the social impact of toll roads is complex, involving trade-offs between improved accessibility, congestion management, environmental benefits, and equity considerations.

The environmental study objects are mostly negatively affected by the existence of toll roads. Dusty road conditions, hotter weather, increased flood intensity, and noise pollution are negative environmental impacts that arise on the Pettarani toll road (Hilmi, 2021). and Buni Bakti village (Syahrahma, 2021). Declining soil fertility in Kaligangsa Kulon (Rahmayanti, 2020). Residents' health is compromised due to noise, air pollution, vibration, and waterlogging in Brebes district (Darwanto and Samadikun, 2019). Flooding in Cibeusi village (Ilham, 2023) and Bendomungal hamlet (Rahayu, 2019). Decreased air quality in Muara Fajar Timur village (Kusuma, 2022), and Pematang panggang (Ryandika,

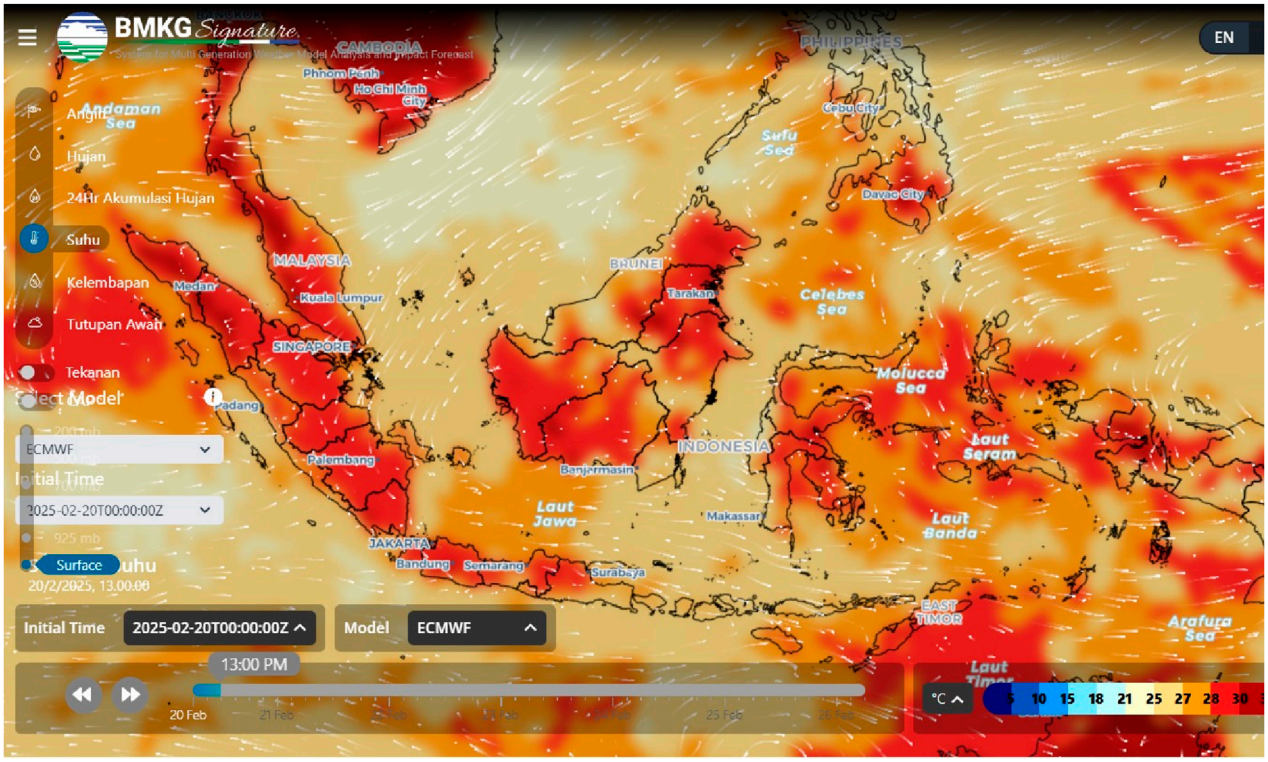

FIGURE 8
Temperature map.

2022b). As well as a decrease in the level of comfort, prone to flooding and landslides in river and rice fields in Citali village (Ramdani, 2022).

The existence of toll roads on the islands of Java and Sumatra can contribute to environmental damage, especially through deforestation and local climate change. The construction of toll roads often requires land clearing that reduces tropical forest areas, destroys animal habitats, and increases ambient temperatures due to the urban heat island effect. Toll road infrastructure made of hard materials such as asphalt and concrete also absorbs heat, which can exacerbate global warming and modify local weather patterns. In addition, toll roads increase greenhouse gas emissions from motor vehicles that contribute to air pollution and climate change, as seen on Figure 8 showing high temperatures.

The environmental impact of toll roads is multifaceted, involving both direct and indirect effects on emissions, congestion, and overall sustainability. Toll roads, particularly those implemented through public-private partnerships (PPPs), necessitate effective environmental impact assessments (EIAs) to ensure sustainable development. The effectiveness of these EIAs is influenced by the capabilities of consultants, project features, and community participation, which collectively determine the normative, procedural, substantive, and transactive dimensions of EIA effectiveness (Castelblanco et al., 2023). In urban areas, toll roads can help mitigate serious roadside pollution by managing traffic flow and reducing carbon dioxide emissions through road pricing schemes that impose higher tolls on fuel vehicles (FVs) compared to electric vehicles (EVs) (Zhong et al., 2021).

Additionally, environment-oriented toll designs, such as cordon- and link-based models, aim to balance emissions reduction and congestion mitigation by minimizing gross revenue while considering emissions treatment costs (Li et al., 2019). The implementation of electronic toll collection (ETC.) systems further enhances the flexibility of road pricing, allowing for distance-based and time-based schemes that can optimize traffic flow and reduce environmental impacts, as evidenced by the development of a Green Safety Indicator (GSI) to evaluate freeway traffic service levels (Chang et al., 2018). Moreover, GPS-based toll systems have been shown to reduce system emissions in intercity corridors by influencing travel behavior without significantly increasing travel costs for users (Sampaio et al., 2021). Collectively, toll roads can actually contribute to environmental sustainability through strategic pricing and technological advancements, the success of which depends heavily on comprehensive planning, stakeholder engagement, and adaptive management practices. But that didn't happen in Indonesia.

Based on the literature study, it was found that many areas are vulnerable to negative environmental impacts from the presence of toll roads. Such as areas with sensitive ecosystems such as forest areas, wetlands, and coastal ecosystems. Areas with limited clean water that rely on clean water from rivers or lakes. Densely populated areas experience negative impacts from air and noise pollution. Areas with limited land availability experience land

TABLE 1 Regional characteristics of community dynamics towards the existence of toll roads.

No	Study object	Regional characteristics		
		Positive	Negative	Netral
1	Economy	• Urban areas • Areas around toll booths, and • Areas with communities that tend to be adaptive, especially after the empowerment of the • Industrial areas	• Rural areas with trade and agriculture as the main economic sectors • Trade in the village mostly relies on consumers from passing vehicles • Agriculture whose productivity level only relies on land area	• Rural areas that have local economic growth centers, and • Areas that provide alternative transportation
2	Social	• Areas with high population density • Areas with potential for tourism development • Areas with potential for housing/settlement development	• Urban/rural areas with small land area • Areas with connecting infrastructure between regions • Areas with high crime rate • Areas with high gini ratio • Areas with rich local culture	-[a]
3	Environment	-[a]	• Areas with sensitive ecosystems such as forest areas, wetlands, and coastal ecosystems • Areas with limited clean water that rely on clean water from rivers or lakes • Densely populated areas experience negative impacts from air and noise pollution • Areas with limited land availability experience land conflicts and loss of productive land • Areas prone to natural disasters that are vulnerable to the risk of flooding, or landslides	-[a]

[a]Did not have enough data for analysis.

conflicts and loss of productive land and natural disaster-prone areas that are vulnerable to the risk of flooding, or landslides. More clearly shown in Table 1.

Furthermore, legally, negative impacts occur in the form of unfair land price differences, land measurements that do not match certificates and physical data, crop compensation that is not calculated, and compensation money that has not been fulfilled or not received (Alvianisa and Tiopan, 2023; Hamdani, 2023; Putri, 2023; Putra and Maulana, 2023; Ryandika, 2022b; Susanti, 2020; Faradilla, 2022). Meanwhile, positive impacts arise as a result of land acquisition that has been pursued by the government in a structured manner, and compensation for land losses that have been explained to the community so that an agreement has emerged (Alam, 2023; Fahmi and Putri, 2022). In addition, the provision of compensation after clarification/assessment of legal right holders and the acquisition of land rights in accordance with the applicable mechanism has made the community have a positive perception of the existence of the toll road (Amelia, 2022). The impact from the legal aspect cannot be categorized based on functional or geographical areas because it depends on political will and government policies.

Based on the results of this analysis, the main contribution of this study is to provide deeper insights into the variety of impacts of toll roads in Indonesia, both positive and negative, and how these impacts differ by regional context. For example, urban areas and the vicinity of toll gates show positive economic impacts, while rural areas experience negative impacts especially in terms of hindered trade and agriculture. The research also shows the social inequalities that arise from toll road development, which often favors certain areas while marginalizing others.

This research makes an important contribution to a sustainable infrastructure planning framework by emphasizing the need for a more holistic mitigation strategy, involving a wider range of stakeholders, and taking into account the diverse social,

economic and environmental impacts of toll road development. By understanding these dynamics, policymakers and infrastructure planners can make more thoughtful and balanced decisions that prioritize sustainability and equitable distribution of benefits.

4 Conclusion

The publication of articles related to toll roads and society during the 2019–2023 period experienced a growth rate of −5.43%, with an average of 18 scientific articles per year. This productivity remains lower than articles focusing on broader societal issues, bridges, and the National Capital City (IKN). Regarding the research focus, economic and social aspects were predominantly discussed, followed by legal and environmental considerations.

The societal dynamics surrounding toll roads in Indonesia are multifaceted and region-specific. Positive economic impacts were primarily observed in urban areas, regions around toll gates, and areas with communities that are more adaptable, particularly after receiving empowerment. Conversely, rural areas dependent on trade and agriculture, where trade relies heavily on passing vehicle traffic and agriculture is constrained by limited land area, experience negative effects. Areas with neutral impacts are typically rural regions with local economic growth centers that offer alternative transportation. In these areas, toll roads often do not replace the existing infrastructure, especially when the current arterial roads are already efficient.

Socially, industrial zones, densely populated areas, and regions with potential for tourism or housing development benefit from toll roads. However, these developments also contribute to negative social outcomes, including land scarcity, displaced bridges, increased accessibility that leads to social inequality, and broader social gaps.

Environmental impacts of toll roads were notably negative in areas with sensitive ecosystems, such as forests, wetlands, and coastal regions. The toll roads also affect regions relying on clean water from rivers or lakes, and densely populated areas, which suffer from air and noise pollution. In addition, regions with limited land availability face land conflicts and a loss of productive land. The risks of flooding and landslides are heightened in disaster-prone areas due to the toll road infrastructure.

This study provides a comprehensive framework for understanding the multifaceted impacts of toll roads on Indonesian society and the environment. It emphasizes the need for sustainable infrastructure planning, with a focus on mitigating negative social, economic, and environmental effects. Future research should explore strategies for minimizing environmental damage and addressing land use conflicts, as well as further investigating the long-term socio-economic effects of toll roads, particularly in rural communities. These insights offer valuable implications for global infrastructure development, advocating for inclusive and sustainable planning to balance infrastructure needs with environmental and social preservation.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

MR: Conceptualization, Formal Analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing. IP: Data curation, Writing – original draft, Writing – review and editing, Formal Analysis, Project administration, Resources, Validation, Visualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Generative AI was used in the creation of this manuscript.

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