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Mobility Patterns of Rural Communities in Traveling from The Origin Area to the Destination

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Abstract
The development of toll roads plays a crucial role in enhancing regional connectivity and economic growth. This study examines changes in mobility patterns in Lamtamot Village before and after the construction of the Sibanceh Toll Road using a quantitative descriptive approach and an Origin-Destination (OD) survey. Data from 191 respondents were processed using ArcGIS to visualize movement patterns. The findings reveal that, despite improved accessibility, travel intensity remains relatively unchanged, with most movements occurring within the same sub-village. The toll road has not significantly altered community mobility, as economic and daily activities remain centred locally. These insights highlight the limited impact of toll roads on rural mobility and emphasize the need for integrated transportation planning to support sustainable development.

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1. Introduction
The construction of toll roads accelerates accessibility for the people of Indonesia, making it easier to move quickly and easily in various aspects, such as social and economic activities. The Sigli-Banda Aceh Toll Road (Sibanceh) is part of the Trans Sumatra Toll Road in Aceh Province, built based on the policy of the Aceh Provincial Government as instructed by President Joko Widodo on Friday, December 14, 2018. The Sigli-Banda Aceh Toll Road (Sibanceh) is a national strategic project of the Trans Sumatra Toll Road, officially inaugurated by President Joko Widodo on August 25, 2020. The toll road project is targeted to be completed by the end of 2021. The Sibanceh Toll Road has a total length of 74.2 km and comprises six sections (6 access points with seven toll gates).

Creating a new network (toll road) is one way to address congestion. Still, it does not necessarily solve the problem entirely, especially regarding demographic, political, geographical, ecological, and social aspects in the areas affected by this project. The definition of sustainable development provided in 1987 is: sustainable development is planning that meets the needs of the present without compromising the ability of future generations to meet their own needs (Beckerman, 2017; Holden, Linnerud, & Banister, 2014; Tomislav, 2018; Zaki, Adisalamun, & Saisa, 2025). The impacts of this toll road development can be both positive and negative. The positive effect of the Sibanceh Toll Road development is that it can stimulate economic recovery and activity in villages around the toll road's entry or exit points. The

negative impact may be a decrease in economic activity in some villages. For example, villages that were once rest stops for traffic along the Trans Sumatra route may experience a decline in activity. To minimize these negative impacts, two approaches can be taken: first, village planning, and second, village funds. Sustainable development concepts mainly focus on integrating social development, economic growth, and environmental protection. A more in-depth study is needed to understand the existing village conditions, how village planning responds to infrastructure development, and how to develop a sustainable village planning strategy.

Mobility is an important factor enabling any community, especially rural communities where many essential things are located somewhat far away. However, rural mobility receives less attention from policymakers than urban mobility. Many rural areas have few buses, fewer train stations, and almost total dependence on cars or motorcycles. The difficulty in providing transportation in rural areas has been well-documented over the years (Kenyan, Glitman, & McRae, 2009; Moseley, 1979; Selvakumar, Gani, Xiaoxia, & Salleh, 2025; Talpur, Napiah, Chandio, & Khahro, 2012). In the past, the village of Lamtamot had a railway used by the community for mobility, but the train no longer exists, and the railway line has now been replaced with an asphalt road. This forces people to spend more on travel and use private transportation at the expense of more sustainable alternatives. The lack of mobility in rural areas impacts people's ability to access certain services. As a result, rural communities' quality of life lags that of urban communities.

Specifically, those most negatively impacted by development are members of society who are more vulnerable, such as older people, people with special needs, and children, because these individuals tend to lack access to cars (Shergold & Parkhurst, 2012). The need for movement will always create problems, especially when people wish to move for the same purpose within a particular area simultaneously. Additionally, the value of other services, such as education and healthcare services, that people wish to access will be significantly reduced if they are unable to access these services due to a lack of rural mobility; similarly, employment opportunities will be challenging to reach without access to adequate transportation services (Wright et al., 2009). Traffic congestion, delays, noise pollution, and air pollution are some issues arising from movement. One way to address this is by understanding the mobility patterns that will occur, such as where people are coming from and going to, how much, and when it happens. Moving beyond the precise observation that mobility involves movement across space and between places, there is an acknowledgement that places and the processes of making places are crucial components of mobility. As Urry (2007) suggests, “places are economically, politically, and culturally produced through various mobilities of people, but also capital, objects, signs, and information” (Verstraete & Cresswell, 2002).

With the construction of the toll road, the mobility patterns of some members of society have changed. Before the toll road was built, people who wanted to travel from the village to the city had to spend a significant amount of time, compounded by obstacles on the road that made the journey even slower. However, after the toll road was constructed, the travel time from the village to the city became faster, and the obstacles during the journey were reduced. They argue that outward migration does not necessarily mitigate attachment to place (Barcus & Brunn, 2010). Expanding the understanding of place attachment, they use the idea of place elasticity to embrace the possibility of virtual connections to distant places: "Place elasticity allows individuals to maximize economic or social opportunities far from the places to which they are temporarily attached while simultaneously extending their engagement with that place. Elasticity is now possible because extensive transportation and communication networks facilitate greater interaction among people in distant places."

Their focus is on young people who leave their homes and, according to them, have moved away from their original communities, but their identity and attachment to that place remain

strong. Furthermore, they argue that this mobility has the potential to create meaningful attachments to multiple locations. While the development of toll roads is often associated with increased accessibility and economic growth, the impact on rural communities remains underexplored. Unlike urban areas, where transportation infrastructure is well-integrated, rural regions face unique mobility challenges due to limited public transport options and economic constraints. Understanding rural mobility patterns is crucial for assessing whether toll roads effectively improve connectivity or merely reinforce existing disparities. This study addresses a critical research gap by analyzing how the construction of the Sibanceh Toll Road influences daily travel behaviour in Lamtamot Village. By identifying shifts in movement patterns and accessibility limitations, the findings contribute to a more comprehensive transportation planning strategy that ensures equitable benefits for rural populations.

2. Methodology

Research Location

The Origin-Destination (OD) Survey was chosen as the primary data collection method because it provides a detailed understanding of individual travel behaviour, allowing for an accurate assessment of mobility patterns before and after the toll road construction. This method is widely used in transportation studies to capture trip purposes, frequencies, and spatial distribution, making it particularly suitable for analyzing changes in rural mobility. Additionally, ArcGIS was employed for data processing and visualization due to its ability to generate spatial representations of movement patterns, such as Desire Line Maps, which effectively illustrate shifts in travel behaviour. By integrating these methods, the study ensures a comprehensive analysis of mobility trends, supporting data-driven policy recommendations for rural transportation planning.

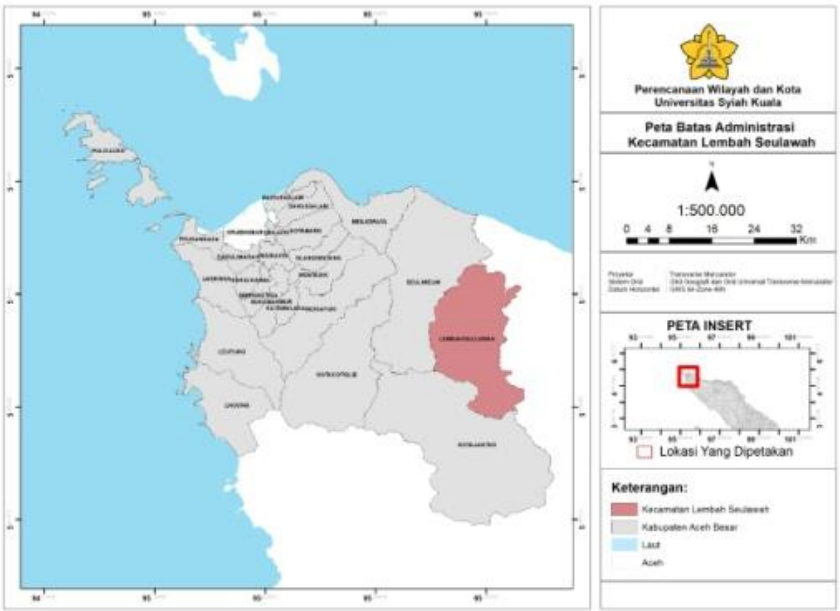

Fig. 1. Boundaries of Lembah Seulawah Subdistrict (Source: ArcGIS, 2022)

a. Macro Planning Location

This research activity was conducted in Lembah Seulawah District, one of the subdistricts in Aceh Besar Regency, Aceh Province. The area of this subdistrict is 319.60 km², and it has two residential and 12 villages.

The administrative boundaries of Lembah Seulawah Subdistrict are as follows:

a) North: Seulimum District
b) South: Jantho City District

c) West: Seulimum District
d) East: Pidie Regency

b. Micro Planning Location

The research area is in Gampong Lamtamot, one of the villages in Gunung Biram Residential, Lembah Seulawah District, Aceh Besar Regency. This village has an area of 69.49 km². The administrative boundaries of Gampong Lamtamot are as follows:

a) North: Gampong Pulo
b) South: Gampong Lamkubu
c) West: Gampong Teuladan
d) East: Gampong Suka Damai

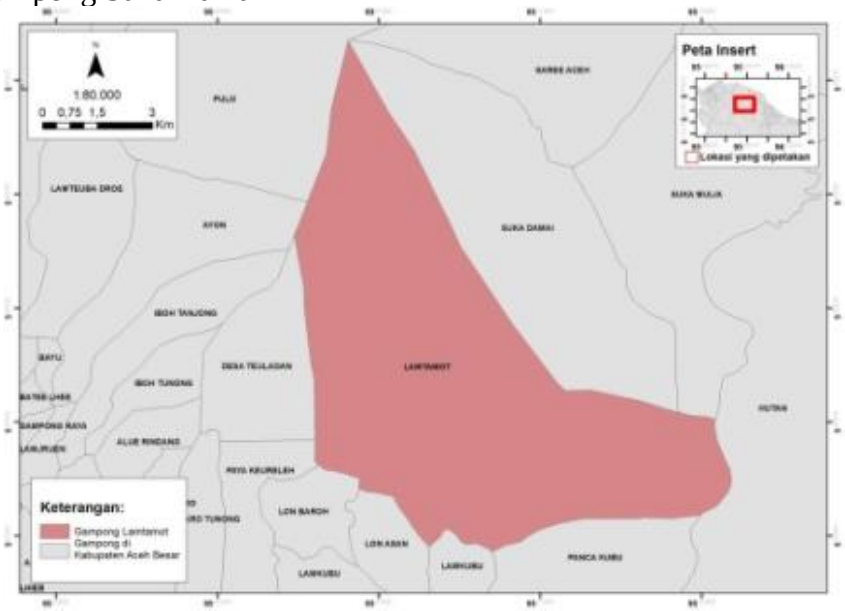

Fig. 2. Research Location (Source: (Kpiebaya, Osei-mensah, Ebenezer, & Abdul-ganiyu, 2022)

The Desire Line Map provides a visual representation of mobility trends by illustrating the intensity and direction of travel before and after the construction of the Sibanceh Toll Road. The map reveals that most movements remain concentrated within the same sub-villages, particularly in Peukan, Blang Lhok, and Lapang. This indicates a firm reliance on local infrastructure rather than the toll road for daily activities. The consistency of these patterns suggests that the toll road has not significantly altered travel behaviour, as most trips are still short-distance and localized. Additionally, the map highlights that long-distance travel outside the village remains relatively low, reinforcing that economic factors and the availability of essential services within Lamtamot Village play a critical role in shaping mobility decisions. Analyzing these spatial trends shows that infrastructure alone is insufficient to drive behavioural change; complementary policies, such as improved public transportation access and economic incentives, may be needed to encourage more excellent regional connectivity.

Methods

This research is qualitative and quantitative (mixed methods) with the Origin-Destination Matrix method based on the results from the distribution of questionnaires. The data obtained from the research are presented in the form of percentages and a desired line map, from which conclusions can be drawn. The aim is to provide an overview of the existing conditions observed and analyzed based on theory. This research emphasizes understanding the problems on the ground based on realistic conditions regarding the mobility patterns of the community

found at the research site, which will be analyzed based on the research variables that have been defined. The variables in this research are the mobility patterns of the population before and after the construction of the toll road, as well as other complementary activities as research indicators to be used in the questionnaire. The tool used to collect primary data in this research is a questionnaire.

The results obtained through this Origin-Destination Matrix will be visualized as a map, namely the Desire Line Map. The classification of the travel frequency criteria, obtained through the questionnaire, is calculated based on the class interval calculation using the formula proposed by (Aschauer, Hössinger, Axhausen, Schmid, & Gerike, 2018).

$$P = \frac{R}{K} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where: P = Interval
R = Rentang (nilai maks. – nilai min.)
K = Banyak Kelas

Hence, based on the calculation, the class intervals for the number of trips are as follows:

Table 1
Classification of Travel Criteria Before the Toll Road was Built

Number of Trips	Travel Criteria
0-12	Very Low
13-25	Low
26-38	Medium
39-51	High
52-64	Very High

Based on this classification, the community's travel criteria will be determined according to the purpose of their trips. The number of respondents who provide an overview of their movements will be shown on a map, which will later be classified according to each type of trip. This map is generated by calculating the number or percentage of the origin-destination matrix of the trips, which is then processed through ArcGIS software to visualize the movement patterns made by the community from each village. After all processes are completed, the resulting pattern will reflect the number of trips made by the community before and after the toll road was constructed.

For this research, the population is taken from all residents living in the village of Lamtamot, and the population size is determined using the total number of residents. The Slovin formula and Stratified Random Sampling method were used to determine the sample size. The sample size was based on a 90% confidence level, with a 10% margin of error due to sampling mistakes/errors.

$$n = \frac{N}{1+N.e^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Where: n = sample size
N = total of population
e = standard error (10%)

The population and sample sizes are shown in the table below:

Table 2. Population and Sample (Andriani, Adriani, Fitria, & Rahmi, 2021)

No.	Sub-village	Population (Household)	Sample (Household)
1.	Peukan	163	62

No.	Sub-village	Population (Household)	Sample (Household)
2.	Blang Lhok	34	25
3.	Cot	56	36
4.	Lapang	214	68
Total		**467**	**191**

The population of Lamtamot Village is 1,866 people. For the questionnaire distribution, the number of samples obtained in the Peukan Sub-village was 62 questionnaires, in the Blang Lhok Sub-village was 25 questionnaires, in the Cot Sub-village was 36 questionnaires, and in the Lapang Sub-village was 68 questionnaires. Thus, the total number of respondents required was 191 samples.

The persistence of existing mobility patterns despite the construction of the toll road can be attributed to several socio-economic factors. First, Lamtamot Village residents' primary occupations, predominantly in agriculture and small-scale trade, do not necessitate frequent long-distance travel, reducing the incentive to use the toll road. Second, the cost of toll fees poses a financial barrier, as many households operate on limited and fluctuating incomes, making them more inclined to use traditional routes to minimize expenses. Additionally, essential services such as markets, schools, and workplaces remain concentrated within local sub-villages, reinforcing intra-zonal mobility rather than encouraging inter-regional travel. Cultural factors also play a role, as rural communities often have strong social ties within their villages, leading to movement patterns that prioritize local interactions over external trips. These findings highlight the need for a more inclusive transportation strategy that considers economic constraints and localized travel needs in rural infrastructure planning.

3. Result & Discussion

Origin-Destination Matrix Before and After the Sibanceh Toll Road Construction

Based on the results obtained from the calculations using the Origin-Destination Matrix before the Sibanceh toll road was built, the results from the questionnaire distribution in the four hamlets in Lamtamot Village show the number of trips represented in the origin and destination matrix according to all types of trips made between subdistricts/districts/cities. Looking at the results of the Origin-Destination Matrix based on all kinds of trips, the total number of trips made by the people from the four sub-villages before the construction of the Sibanceh toll road was 405 trips, with the highest number of trips originating from Peukan Sub-village, totalling 129 trips.

The highest number of destination trips before the construction of the Sibanceh toll road was also recorded by Peukan Sub-village, with a total of 126 visits, or 31%. The second-highest destination was Blang Lhok Sub-village, with 67 trips or 17%. This was followed by Lapang Sub-village as the third-highest destination, with 61 visits or 15%. The destination with the lowest number of trips was Blang Bintang District, with only nine visits originating from the four sub-villages, or 2%. Meanwhile, trips to other destinations were randomly distributed across many zones of villages/districts/cities. This indicates that Peukan Sub-village, Blang Lhok Sub-village, and Lapang Sub-village have high mobility rates, where the mobility of the population is still concentrated within the village.

After constructing the Sibanceh toll road, the questionnaire results obtained from the four subdistricts regarding the trips made by respondents after the toll road was built were also represented in the form of an Origin-Destination Matrix. After the toll road construction from the four subdistricts, the total number of trips made by the people did not change, remaining at 405 visits, with the highest number of origin trips still from Peukan Sub-village.

The highest number of destination trips after the toll road construction is Peukan Sub-village, with a total of 119 visits or 29%. Following that is Blang Lhok Sub-village, with 65 destination trips or 16%. The third-highest destination is Lapang Sub-village, with 60 destination trips or 15%. Meanwhile, the lowest destination is Blang Bintang District, with 10 visits from the four sub-villages, or just 2%.

This indicates that even after the construction of the toll road, Peukan Sub-village, Blang Lhok Sub-village, Cot Sub-village, and Lapang Sub-village remain the highest destination areas based on all types of trips from the four origin areas. However, despite these three sub-villages still being the highest destination areas, when looking at the number of trips made by the community after the toll road was built, there was no significant change in the number of trips because the community primarily conducted their activities from one sub-village to another sub-village without needing to use the toll road. The trends in destination areas, based on the Origin-Destination Matrix, are as follows.

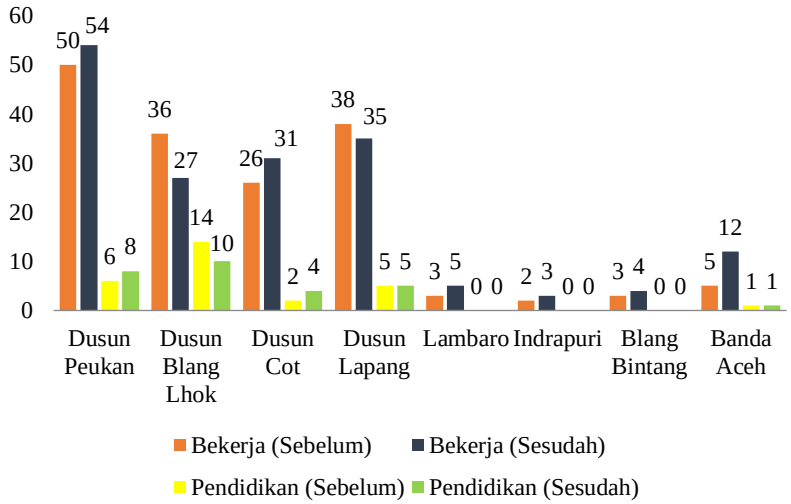

Fig. 3. Mandatory Trips Before and After the Toll Road Construction

Work activities tend to be directed towards Peukan Sub-village, with 50 trips. However, it should be noted that some respondents from Peukan Sub-village work as village officials, so they make trips where their origin and destination are still within the same area. For educational activities, the trips are directed towards Blang Lhok Sub-village, with 14 visits. Based on the survey results, many respondents only travel between sub-villages. After the toll road was built, the intensity of work and education activities generally increased slightly, although not significantly. Respondents working as village officials still work in the office as usual. Similarly, educational activities did not show a significant increase or decrease.

Improved mobility is crucial in promoting sustainable rural development by enhancing access to essential services, economic opportunities, and social interactions while minimizing environmental and financial costs. However, the findings of this study indicate that merely constructing a toll road does not automatically translate to increased regional connectivity or sustainable mobility. For mobility improvements to contribute meaningfully to sustainability, they must be accompanied by policies supporting equitable access to transportation, such as affordable public transit options and infrastructure accommodating non-motorized transport. In the context of Lamtamot Village, sustainable rural development requires an integrated approach that balances economic growth with social inclusion and environmental responsibility. Strengthening local economic hubs, improving road networks beyond toll roads, and facilitating multi-modal transportation options would help ensure mobility enhancements contribute to long-term sustainability rather than reinforcing existing disparities.

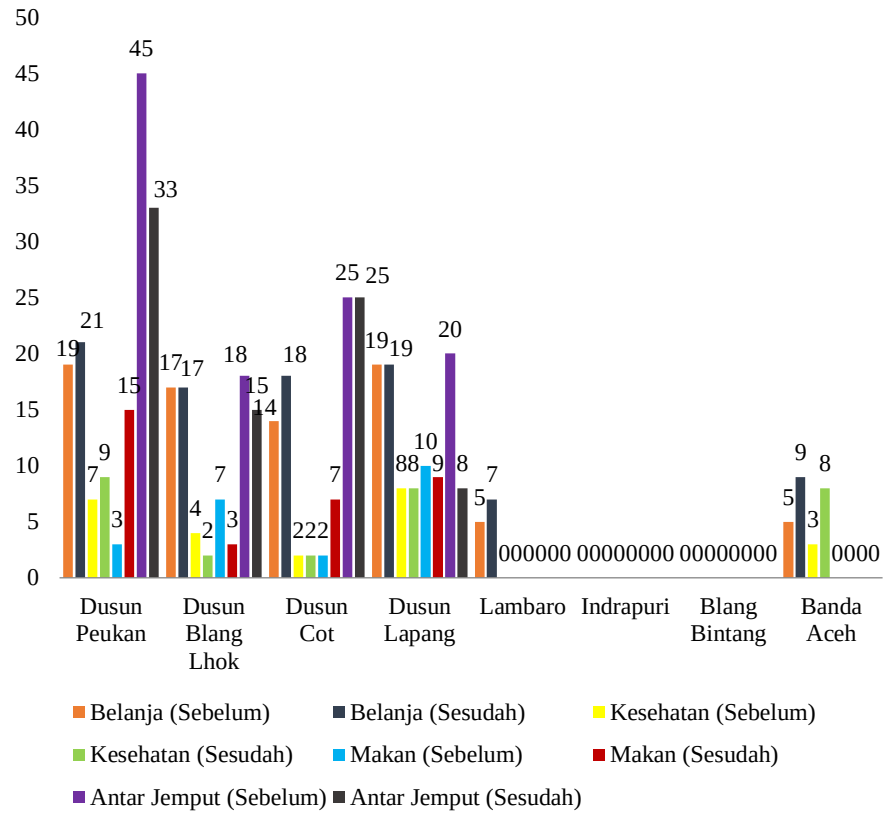

Fig. 4. Trips Maintenance Before and After the Sibanceh Toll Road Was Built

Generally, every household still has family members attending Kindergarten (TK) and elementary school, so parents still engage in daily drop-off and pick-up activities. Shopping activities are mainly carried out in Peukan Sub-village and Lapang Sub-village, each having 19 trips. Thus, people typically shop in Peukan Sub-village because every Friday, this sub-village holds an event called Uro Peukan, where many goods, including clothing and vegetables, are sold to meet daily needs. However, some residents shop at the Pasar Lambaro (Lambaro Market). As for eating-related activities, most trips are directed towards Dusun Lapang. This is because many people move around their residential areas and prefer to buy food nearby. Drop-off and pick-up activities occur daily among respondents, especially those with children still in school.

The family members attending kindergarten (TK) and elementary school and their parents continue to engage in daily drop-off and pick-up activities. After the Sibanceh toll road was built, overall, the frequency of trips in the maintenance category did not experience significant changes. However, for shopping activities, some residents chose to shop in Lambaro District and Banda Aceh, with some using the toll road. Peukan Sub-village remains the highest destination location with 21 trips.

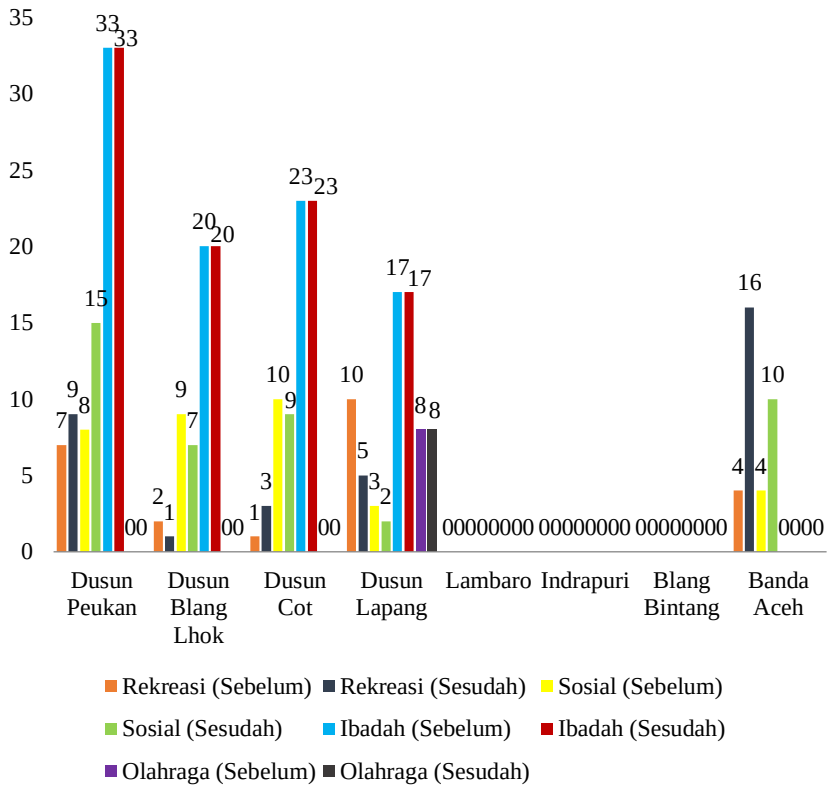

Fig. 5. Discretionary Trips Before and After the Sibanceh Toll Road was Built

Regarding recreational trips, Lapang Sub-village has the highest number of trips, totalling 10. Some of the residents of this sub-village occasionally choose to go to Banda Aceh for recreation, so the movement is not limited to just within the village. Next is the trip for social purposes, including activities such as meeting friends, relatives, and/or family members and social gatherings in cafes or coffee shops. The residents of Cot Sub-village mostly carry out social activities, with 10 trips. Based on the existing conditions, Cot Sub-village only has residential areas, so people tend to visit friends, relatives, or family members. At the same time, social gatherings in cafes or coffee shops are usually held in Peukan Sub-village. After the construction of the Sibanceh toll road, the discretionary travel category most frequently undertaken by residents is religious activities.

Based on the facts on the ground, many people engage in religious activities because the distance to the mosque is relatively short, making it easier to move around. The area with the highest number of trips for spiritual purposes is Peukan Sub-village, with a total of 33 visits. Additionally, although the frequency of trips has not changed significantly, there has been a noticeable change in the intensity of recreational activities, particularly in Banda Aceh, with 16 visits. Some residents engage in recreational activities using the toll road. In contrast, others opt not to use it, considering the relatively high toll fees, which leads them to prefer using national roads to reach their desired destination. There have been no significant changes for all activities carried out by the residents after the Sibanceh toll road was built, whether mandatory, maintenance, or discretionary. Therefore, changes in travel time may not be visibly apparent.

Community Mobility Patterns

The results from the previously conducted Origin-Destination Matrix calculations are then represented as a Desire Line Map to observe the community's travel patterns.

a. Before the Sibanceh Toll Road was Built

During the data and information collection period through the OD survey, the travels made by the community before the construction of the Sibanceh toll road were still like the usual daily travels to various directions, particularly within the internal zones. Thus, the intensity of daily travel before the toll road was built spread across several areas randomly but was predominantly centred in the origin zone. This can be seen from the number of travels made by the community, which not only tended to head toward one sub-village/district/city but also indicated movement directed to several locations of sub-villages/districts/cities. Referring to Bertaud's (2009) theory, the polycentric pattern forms from movement spread across many points.

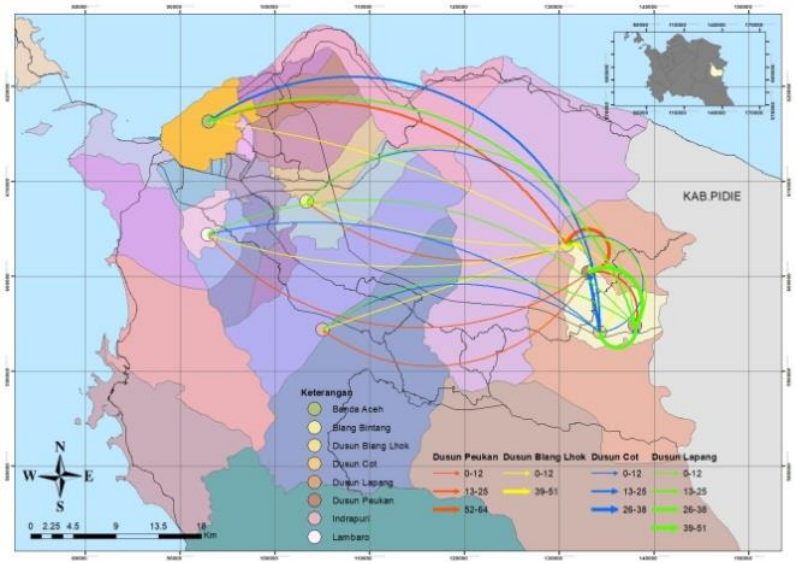

Fig. 6. Desirability Line Map Before Sibanceh Toll Road Construction

This is in line with the mobility pattern formed by the community before the Sibanceh Toll Road was built, a polycentric pattern. Although farming is the dominant occupation in Lamtamot Village, many people engage in high-intensity activities such as working, shopping for daily needs, pursuing education, socializing with family or friends outside the home, and recreation. Each journey made by the community from the sub-villages is spread across several areas outside of Lamtamot Village without causing agglomeration.

Looking at the type of movement of the community before the toll road was built, it tends to align with the internal movement type, where activities such as working, shopping, education, healthcare, sports, and socializing, like meeting friends at a café, still occur or are visited between sub-villages within Lamtamot Village. Therefore, it can be said that these activities can still be carried out within Lamtamot Village itself due to the availability of adequate social and public facilities.

Referring to Tamin's (2000) theory, internal movement is the type of movement that is prioritized in transportation planning. The high number of people engaging in such movements will assist the Aceh Besar District Government project traffic volume and policies that need to be considered in future transportation systems.

b. After the Sibanceh Toll Road Was Built

The results of the previously conducted Origin-Destination Matrix calculations were then represented as a Desirability Line Map to observe the movement pattern of the community after the Sibanceh toll road was built.

It can be said that the intensity of travel in Lamtamot Village after the toll road was built did not show a significant increase. However, the areas that remained heavily visited were Peukan

Sub-village, Blang Lhok Sub-village, and Lapang Sub-village, which still formed the same mobility pattern as before the toll road was built, namely the Polysentric pattern. Referring to Bertaud's (2009) theory, the polycentric pattern is formed by movements spread across many points.

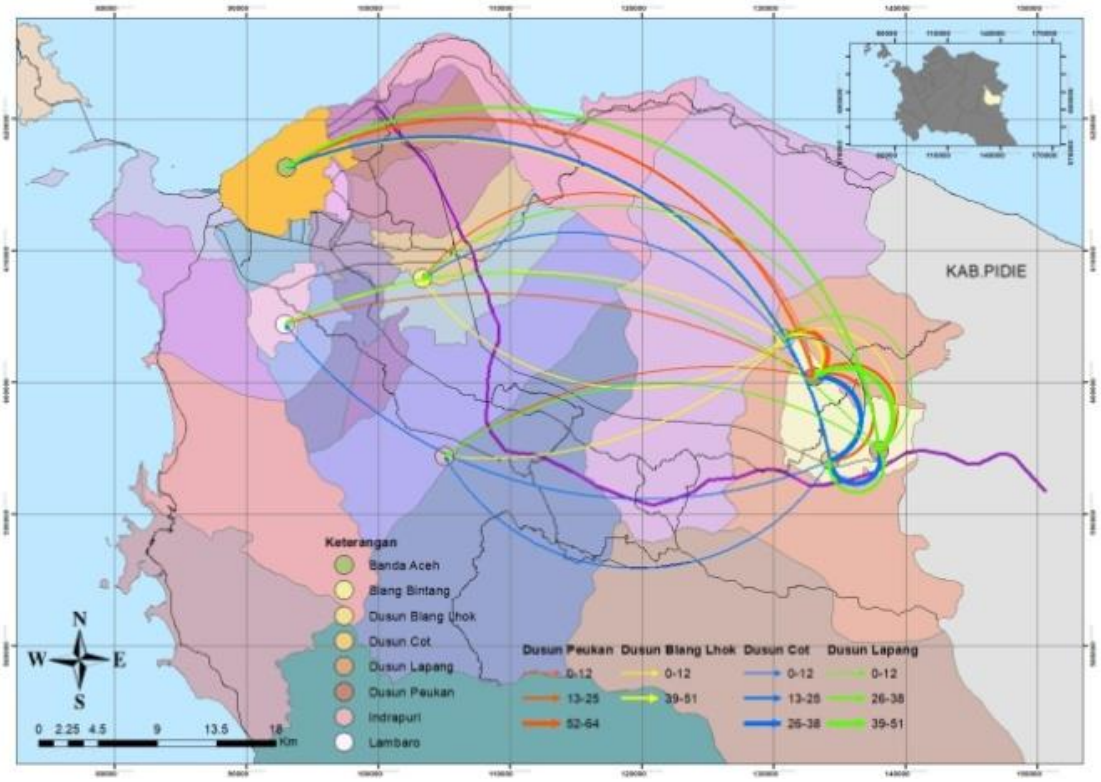

Fig. 7. Desirability Map After Construction of Sibanceh Toll Road

This indicates that even after the toll road was built, the movement of the community still leads to several sub-village/district/city locations, albeit with similar travel intensity. Two-wheeled vehicles continued to dominate after the toll road was built. Referring to Tondobala (2015), population density and economic activities in an area with a polycentric model are not focused on a single city centre but are spread across several other public service zones. Therefore, land use in the area can be more directed. According to Qanun Number 4 of 2013 concerning the Regional Spatial Planning of Aceh Besar, it currently has one local activity centre, one promotional local activity centre, several regional service centres, and several environmental service centres. This polycentric pattern will shape land use in Aceh Besar, making land allocation more directed due to the development of a distributed service centre system across various districts.

Some respondents believe that even after the toll road was built, they still prefer to use the national highway rather than the toll road. This is because using the toll road incurs a cost, and the toll rates are high, making the community reluctant to use it. The main livelihood in Lamtamot Village is farming, and many people say their income is often uncertain.

Before and after the construction of the Sibanceh toll road, the community's travel tends to follow an intrazone movement pattern, where their trips begin and end within the same area, without showing any mobility towards other regions. The limited number of trips outside the area has caused a change in mobility patterns, reducing travel and decreasing traffic volume or congestion. However, the high number of intrazone movements creates challenges for the city government in calculating and projecting traffic flow conditions in Aceh Besar.

4. Conclusion

The conclusion that can be drawn from this study is that the mobility pattern formed by people who come from the Peukan, Blang Lhok, Cot, and Lapang Sub-village areas when before the Sibanceh toll road was built and after the toll road was built is a polycentric form with the highest destination areas being Peukan, Blang Lhok, and Lapang Sub-village. The change after the toll road was built is that the intensity of travel did not experience much change, leading to intrazonal movements where the community travels within the same or nearby areas, making the mobility pattern stable without significant traffic congestion.

Before the toll road was built, mandatory activities like work were directed towards the Peukan Sub-village, and education was directed towards the Blang Lhok Sub-village. Maintenance activities such as shopping were directed towards Peukan Sub-village, while food purchasing and pick-up/drop-off activities were directed towards Lapang Sub-village. Discretionary activities such as recreation were directed towards the Lapang Sub-village, social activities were directed towards the Cot Sub-village, sports activities were directed towards the Lapang Sub-village, and religious activities were directed towards the Peukan Sub-village.

After the toll road was built, mandatory activities like education were directed towards Blang Lhok Sub-village and work towards Peukan Sub-village. Maintenance activities like shopping were directed towards Peukan Sub-village, while food purchasing and pick-up/drop-off activities experienced a slight decrease. Discretionary activities such as recreation were directed towards the Banda Aceh City, social activities were directed towards the Cot Sub-village, sports activities were directed towards the Lapang Sub-village, and religious activities were directed towards the Peukan Sub-village.

The village community prefers to use the national road rather than the toll road. Since their livelihood is farming, the toll fees are considered relatively high given their uncertain daily income. Based on the findings, several actionable recommendations can be proposed to improve rural transportation and infrastructure planning. First, policymakers should consider subsidizing toll fees or providing alternative incentives to encourage more significant toll road usage among rural communities with limited financial resources. Second, enhancing local road networks and integrating public transportation services, such as affordable shuttle buses or shared transport options, can improve mobility without increasing reliance on private vehicles. Third, investment in digital infrastructure and remote service access, such as online marketplaces and telehealth services, could reduce unnecessary physical travel while ensuring access to essential goods and services. Lastly, a community-centred approach to transportation planning, where local needs and travel behaviours are actively considered in infrastructure development, would help create a more inclusive and sustainable mobility system for rural populations. These strategies would ensure that transportation improvements effectively contribute to rural areas' economic growth, social inclusion, and environmental sustainability.

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