




Assessment of Road Network Connectivity in Support of New Capital Development

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Abstract

The shifting of the capital of Indonesia from Jakarta to East Kalimantan, or East Borneo, is underway. There are certain to be new issues that arise as a result of this migration. The state of the nation's current transportation infrastructure is one of the most prominent right now. The new capital of Indonesia, Jakarta, is situated in the midst of a jungle. For this reason, the road network should be established before, or at least concurrently with, the IKN construction. It is critical to understand the direction of future growth in the IKN region before developing a road network architecture. Potential partner locations might potentially benefit from enhanced access and connection to the existing road network in this situation as well. To ensure that the IKN is able to work properly and link additional nodes, many partner area points are being considered. A literature review, a focus group discussion, and in-depth interviews were conducted to come up with a development plan for IKN partner regions and highlight areas of special concern. It was also determined if the addition of a new node had a positive impact by utilizing a connection matrix and the accessibility index. Most linkages are found at five of the 26 nodes in the complete connectivity matrix of national highways around IKN in East Kalimantan. Node 3 and Node 7 are the most accessible and easy-to-access component nodes of the road network, compared to other nodes.

Keywords: Transportation Infrastructure; Road Network; IKN; Indonesia.

1. Introduction

Transportation is a crucial factor in ensuring the success of development, particularly in promoting community economic activity in all areas. The current transportation system is meant to enhance population mobility services and other resources that may promote regional economic and social development. Transportation development cannot exist independently and cannot be distinguished from the growth of other sectors, such as the economic, demographic, social, etc. The answer to transportation issues and regional accessibility will not be attained if the viewpoint on transportation issues remains restricted and case-by-case problem resolution continues to be the strategy. Improving the transportation system must be accomplished in a comprehensive, coordinated, and, of course, consistent manner. Determinants that directly or indirectly influence the operation of the transportation system and the accessibility of a region's road network must therefore be well coordinated.

Currently, the capital of Indonesia is being relocated from Jakarta (Java Island) to East Kalimantan on the island of Kalimantan (the Nation's Capital Region of Indonesia, referred to as IKN). Based on the existing state of affairs in Jakarta, the capital of Indonesia, there are numerous signs that new difficulties may occur as a consequence of this mobilization. The present condition of the nation's transportation infrastructure is one of the most significant factors in the world today. This region, which is the future location of the Indonesian capital, still lacks connectivity and

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accessibility. In addition, the master plan for the capital city will limit mobility inside and outside the inner ring. Thus, the new IKN will not get entrapped in Jakarta's clogged streets, which have become a source of pollution and security threats. It is essential to keep in mind that, in terms of regional expansion, connectivity and accessibility are crucial in guaranteeing that an area may expand in tandem with its neighbors. For this reason, the road network must be constructed either before or simultaneously with the IKN. The future capital city of Indonesia is situated in a region that is dominated by forest and to which there is still limited access. This article will analyze the accessibility and connectivity of the road network in the IKN region with and without shortcuts to assess the need to improve connectivity and accessibility in the IKN area.

Numerous countries have implemented the transfer, development, and restructuring of state capital control. More than thirty countries shifted their capitals with success in the preceding century. More than 35 countries throughout the world have actively discussed the prospect of relocating their capitals during the last few years. Throughout documented history, the national capital has been known to relocate every two to three years. It was an active year. Recent occurrences of the event occur every two years. The nations that have successfully moved their capitals and those that are in the planning phases are listed below.

Governments have a variety of reasons for relocating the capital city of a country. In general, however, the decision to relocate the country's capital city is made in order to address the country's political, economic, and cultural issues. In many nations, the capital city is relocated for one of four reasons. More than a few nations have been successful in relocating their capitals to new locations.

- Brasilia, Brazil

The move of the nation's capital to the city of Brasilia was meant to instill Brazilians with a feeling of national pride. The proposed capital city is situated around 581,400 hectares, or 5,814 square kilometres, to the west of Rio de Janeiro. One of the objectives that will be fulfilled simultaneously with the construction of the brand-new national capital is the creation of a Cerrado zone inside the Amazon region. Brasilia is sometimes seen as Brazil's "declaration of cultural independence" due to the city's architectural design, which emphasizes Brazilian traits. The city's master plan is shaped like an aeroplane, which serves as a visual representation of Brasilia's position as "the capital of aviation." In contrast to the prior capital city, which emphasised ship access and functioned as the historical capital, Brasilia was the first location to be established with jet access. One of the key objectives of the relocation of the capital city is the organization and development of technology and inventive endeavours. The city's master plan is shaped like an aeroplane, which serves as a visual representation of Brasilia's position as "the capital of aviation." Due to the expansion of Cerrado, Brazil has transformed from a food importer to one of the most successful "breadbasket" countries in the world [1].

- Canberra, Australia

The relocation of Australia's capital city was decided upon in 1908. Identifying a site that was unbiased and did not favour any one area was one of the most challenging tasks at the time. At that time, it was agreed that the nation's capital should be moved to a location about halfway between Sydney and Melbourne, the two most populated cities in Australia. The foundation for the brand-new capital city was built in 1913, but World War I and Australia's continuous economic crisis hampered construction. In 1911, a worldwide competition for the design of the capital resulted in the submission of 137 distinct ideas. At that time, the winning design in the competition was submitted by an American named Walter Burley Griffin. Griffin's urban planning framework is mostly centred on the utilization of a triangular shape. The three axes that intersect to form a triangle make up the parliamentary triangle. The city was built on three hills, which are an integral part of the urban architecture of the city. The government offices are centred around an artificial lake, but the surrounding areas of the towns are mainly undeveloped. It was chosen to construct Canberra as a garden city so that Australians would refer to the new capital city as "the bush capital." Both the selection of the name and the site were based on their importance [2].

The location of Canberra with respect to its surroundings displays the harmony between the topography, scenery, and natural beauty. Native to the region, the term "Kambera" means "the gathering place". This is the origin of the name "Canberra." In ancient times, this region functioned as a ceremonial gathering place for Aboriginal people from several tribes, who had their gatherings here. Numerous street names in Canberra have Aboriginal origins, and the National Museum of Australia contains an extensive collection of Aboriginal cultural artefacts [3]. Despite the fact that the city occupies an area of 814 km² and is positioned 280 kilometres south-southwest of Sydney, construction on Canberra did not conclude for another 50 years, beginning in 1911. The new government structure has two levels of planning: the Australian Capital Territory (ACT) and the centre, which is responsible for the strategic direction of the central government [4].

- Washington DC, USA

Political compromise resulted in the permanent relocation of the US Federal Government to Washington, D.C. As part of the Hamilton administration (President George Washington's first secretary of the Treasury), Congress supported the United States Bank's location in Philadelphia. In exchange, Congress (government) was awarded

the unique District of Columbia to build the nation's capital along the Potomac River. Hamilton's policy favoured the concentration of economic power in the hands of capitalists and merchants in the urban northeast; the capital city as a political force had to be located in the more rural areas to the south [5].

In 1790, President Washington enlisted the French engineer and experienced leader of the Continental Army, Pierre Charles L'Enfant, to build and expand the 177 km² capital city. The Master Plan envisioned a magnificent city worthy of the nation, devoid of its colonial origins and boldly establishing a new identity. The Capitol was to be built on an elevation overlooking the flat Potomac lowlands. A National Mall links the legislature to the river, bordered by imposing buildings. Large motorways will connect the outside of the area to the presidential house. Beginning in 1922, L'Enfant's primary objectives were realised [6].

Developing a wealthy and independent capital city takes time and work. 1791 design, 1922 execution. Especially after the War of 1812 and the 1814 fires at the White House, Capitol Building, and Library of Congress, Washington, D.C. relied heavily on government spending throughout the first four decades of its relocation. In the 1960s, slavery and population growth generated societal problems. After the failure of Jay Cooke & Company in 1872, the district government became bankrupt (the holding company of the first national bank in New York and holder of 100 percent of public works bonds) [7]. After 200 years, DC is becoming a government hub with a high GDP and expanding population [8].

- Sejong, South Korea

In 2005, the South Korean government named Sejong as the State Capital by special legislation. The relocation of the National Capital was designed to move two-thirds of government agencies from Seoul. Sejong City is 120 kilometres from the country's economic capital, Seoul. Sejong, situated in the centre of South Korea, was chosen as the capital city to promote balanced development and alleviate pressure on Seoul. Sejong City was built to accommodate the South Korean government, a research center, and a high-tech company. Over a decade, from 2007 to 2017, 40 government agencies and 15 research institutions were constructed as part of the Sejong City development. The Sejong development plan emphasizes allocating up to fifty percent of the total area to green open space. Green city principles are also realised through reducing the use of private vehicles and increasing the use of public transportation. In addition, 40 million trees and a 350-kilometer bicycle lane have been planted [9]. The layout of Sejong City is based on the expansion of public and pedestrian transportation to suit public needs. With the development of public transportation, Sejong City has become the focal point of the nation's transportation network, with direct links to other major cities. The government established the Multi-Functional Administrative City Building Agency to manage Sejong City's building and growth (MACCA). The agency has the authority to execute, issue permits, plan, and construct in the central part of Sejong City. The target of Sejong City's growth is to reach a population of up to 500,000 in less than 25 years. In 2016, Sejong City's population hit 250,000, and the government relocation was nearing completion [10].

In 2005, it was estimated that the construction would cost around \$8 billion, while the present expansion of Sejong City is likely to cost the government \$22 billion over the next 30 years. The property for the projected city was secured via a public involvement process that included present landowners in the Sejong development region. Since they had always supported the new town's development plan, the landowners were ready to converse [11].

- Islamabad, Pakistan

The move of the capital to Islamabad was necessitated by inadequate infrastructure services and congestion in the previous capital. Islamabad is located in the middle highlands of Pakistan and is traversed by the main Asian route. Islamabad, which has existed since 1960, is also intended to strengthen the nation's identity, which is inextricably linked to Islam. This city is the political capital of Pakistan, and it is governed by the Islamabad Metropolitan Corporation, which is supported by Capital Development (CDA). The administrative centre of Islamabad encourages modern urban development and cleanliness. The location of Islamabad is influenced, among other things, by the fact that it is the capital of many transportation, communication, defense, economic, communal, and utility systems. The residents of Islamabad are a mixture of government employees and the general populace, whose income levels range. Therefore, it is essential to continue with caution, both to help low-income folks become competent and to ensure the comfort of the upper class. Islamabad was meant to accommodate a population of around 2,500,000 people over the course of two generations; as a result, the population of the Pakistani metropolis increased from 45,408 in 1960 to 568,689 in 2000 to 1,095,500 in 2019. Islamabad was governed by an administrative center until the 1980s, when it transformed into a commercial hub that attracted workers from Karachi, Lahore, and Quetta. The Islamabad-Rawalpindi metropolitan area is Pakistan's third largest city (highest GDP per capita). Islamabad has attracted people from all around Pakistan, making it one of the most populated and urbanized cities in the nation [12].

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Islamabad lies in close proximity to Rawalpindi, which provided major assistance in terms of services and housing needs from the beginning of the relocation. The Rawalpindi Chaklala Airport will contribute to the growth of air transportation, the Rawalpindi Dam will secure water supplies, and the existing rail and road connections will facilitate communication. All of these factors will aid in preventing massive investments during Islamabad's first era of expansion. The services provided by the two cities complement one another. Islamabad will serve primarily as a narrative and cultural role as the nation's capital. Rawalpindi will continue to be a hub for industrial and commercial services in the area [3].

- Astana, Kazakhstan

Kazakhstan's separation from the Union of Soviet Socialist Republics (USSR) motivated President Nursultan to transfer the capital city of Kazakhstan from Almaty to Astana in 1997. Astana, whose population is now 380,000, is increasing. In 2019, the Kazakh parliament designated Astana's New Capital as "Nursultan" in honour of the President's service [14].

The relocation of Kazakhstan's capital city has various objectives, including the selection of the "Center of the Eurasian Continent" as a reflection of a multi-vector-oriented foreign policy, a new capital city as a symbol of the nation, and the promotion of national unity. To accomplish this objective, the building's design aims to harmonise eastern and western cultures in the development of the city and urban environment elements. The path of Astana's development encourages innovation, a journey into the spiritual world, and the growth of the notion of harmony and sustainability between nature, the urban environment, humanity, and the environment [15].

The master plan for Astana was produced in three years, from 1997 to 2000. The creation of the master plan was a worldwide competition in which architects from Europe, Asia, and Australia participated. Astana's construction phase was envisioned as a 30-year expansion plan. The development stages were divided into four segments, spanning the years 2000 to 2030 [13].

There are three sources of funding for the new capital city: government investment of around USD 4,560 million (50.7%); private sector investment of approximately USD 2,970 million (33%); and foreign investment of approximately USD 1,470 million (16.3 percent). The government uses these funds for non-profit public amenities and basic infrastructure, but the private sector and foreign investors are more interested in profit-driven projects, such as shopping malls and office complexes [16].

2. Literature Review

The majority of traffic congestion is due to a growth in the number of cars, but it may also be inversely proportionate to the percentage increase in the number of roads being constructed. Consequently, cities are plagued by traffic congestion as a consequence of the irregular and much less consistent mobility of vehicle flow, which makes it difficult to develop and maintain new highways. Due to the heavy amount of traffic, there are more cars on the road [17]. Congestion occurs when commute times slow, travel times increase, and vehicle lineups expand. Congestion may be associated with an increase in vehicle use, which is commonly expressed in VKT or VMT units, according to research. Even though the study suggests a connection between the increase in online VKT and road congestion [18].

The University of Pennsylvania has also conducted research on various types of U.S. roads, demonstrating that improving roads, both road widths and the construction of new roads or the availability of public transit, does not reduce traffic congestion; therefore, traffic pricing policies, such as Electronic Roads, are an evaluated alternative for reducing traffic jams [19]. Typically, knowledge of VKT is associated with urban planning and infrastructure design, especially sidewalks. In some instances, such as the Los Angeles Effect, there is a link between population density and highway density. Los Angeles has one of the highest population densities in the world, particularly in the United States, and its complex road network is comprised of multiple interstates and important arteries [20]. Moreover, Los Angeles has the greatest VKT per capita and the worst traffic in the nation. The externalities of driving in Los Angeles increase according to the number of automobiles and the city's size [21]. Functional density is when the population density in Los Angeles is too high for private car use but the spatial pattern and structure are not properly organized enough to accommodate mass transportation [22]. Further study revealed a link between a community's population and the quantity of road space available for commercial reasons, as well as the accessibility and mobility of these activities. To minimise vehicle kilometres travelled (VKT), compact cities with low-average road areas may be developed, pedestrian and bicycle infrastructure may be prioritised, and business and retail establishments may be positioned in regions accessible without a car.

As a result of this focus on congestion, new roads, and enhanced facilities for motorized vehicles, automotive usage has expanded, leading to a rise in economic and environmental problems [23, 24]. Roads must be repurposed and public transportation options must be made more attractive. According to him, growing urban mobility now results in an integrated transportation system. In light of this, the whole purpose of transportation infrastructure and services, as well as their interconnectedness, must be re-examined [25].

The provision of safe and efficient transportation remains a key challenge in Indonesia's major cities. Public transit and non-motorized mobility, especially extensive pedestrian amenities, are crucial for a more interconnected and compact city design concept [26]. In the building of transportation infrastructure, sustainable development ideals are implemented via the use of technology. Mobility, equitable distribution of goods and services, increased productivity, and global competitiveness are all objectives of a transportation system based on technology [27]. In the 1930s and 1940s, residential neighbourhoods were dominated by a grid of straight and curved parallels, but by the 1950s, the grid had been replaced by a labyrinth of twisting, isolated cul-de-sacs and loops [28]. Cul-de-sacs have a disadvantage when it comes to accessing activity places, while the conventional grid layout has none [29]. Accessibility for pedestrians and cyclists is seen as a priority for motorised vehicles in urban situations when access to the road network is difficult and fragmented or when there are a large number of dead-end streets.

The conventional concept of urban planning, which is built on a road network, serves as the basis for the New Urbanist approach to urban planning, which places a key focus on connectedness. Graph theory defines connectivity as the degree to which points or nodes in a network (in this case, the transportation or road network) are connected to one another [30]. Connectivity may be measured in two ways: by the number of intersecting highways and the quantity of open space around those junctions. Curvy or dead-end roads are typically less interconnected than grid road designs. In transportation planning, "connectivity" refers to the movement across several modes of transport or capital systems [31].

The capacity to move around quickly and avoid "breaks" in connections in residential areas is often seen as an advantage of urban design that emphasises connectedness (neighbourhoods). In the MTC Connectivity Transit Report, the capacity of customers to use several modes of transportation during a single journey is assessed by connection [32]. A "good" link facilitates the employment of many carriers to travel to work, schools, government service centres, shopping areas, or other locations. In the Transit Connectivity Plan, "connectivity" refers to the capability of road users and other mobility players to utilise several transit systems for a single trip. A well-functioning transportation system (convenient) may cut travel times and facilitate transactions (pay for modes) [33].

Between 113°44' and 119°00' East Longitude and 2°33' North Latitude and 2°25' South Latitude lies East Kalimantan, a landmass of 127,267.52 square kilometres and a marine management area of 25,656 square kilometres. East Kalimantan had a 2003 population of 2,311,162 and a 2010 population of 3,047,500, according to the census. East Kalimantan's population grew by 736,338 over this time period, for a yearly rise of 3.60 percent on average. There were 3,300,517 people in 2013, with a male population of 1,731,820 people (52.47 percent) and a female population of 1,568,697 persons (53 percent) (47.53 percent) [34].

It is believed that the designation of East Kalimantan as a new IKN area would just "export" Jakarta's issues to the region. To recall, while declaring that he would relocate the capital, Indonesian President Joko Widodo said that he would await a research to select the IKN region. According to the Civil Society Coalition, the research planned by the President and used as the foundation for designating the East Kalimantan area as the capital city remains unclear. In other words, East Kalimantan's designation as the capital city is not based on an exhaustive examination. The report issued by the government is a brief Strategic Environmental Study (KLHS). This KLHS research was conducted after East Kalimantan's new capital city was built; it does not examine why East Kalimantan, and no other areas, was selected as the IKN area. Even in the quick KLHS, possible environmental difficulties in the IKN region, including risks to water systems, flora and animals, and pollutants, may be disclosed later.



Figure 1. East Borneo province

This region's landscape is undulating, with slopes between 0 and 60 percent and elevations between 0 and 1500 m above sea level. Typically, lowlands are located near rivers. The hilly and mountainous terrain are located in the northwest area of the nation. With an average height of more than 1,000 feet above sea level and a slope of over 300 percent, the hilly and mountainous terrain are located in the northwest area of the nation [35]. The topographical characteristics have a significant impact on the potential and water supply, hydrological dynamics, and sensitivity to erosion of a particular commodity [33]. For East Kalimantan Province's land use, it is essential to consider the topography, which indicates that 43.35 percent of the land area has a slope of more than 40 percent, and 43.22 percent is located between 100 and 1000 meters above sea level [36].

The road network in East Kalimantan spans 15,106.72 kilometres [27] (Figure 2). A total of 10,735.25 kilometres of district/city roads and 1,710.9 kilometres of national road sections run through East Kalimantan Province [37]. This includes 326.22 kilometres of primary arterial, 1,384.68 kilometres of primary collector road, 884.80 kilometres of provincial road, and 64.87 kilometres of toll road [38]. 80% of East Kalimantan's road sections are regency or city roads. Provincial roads account for 6.6 percent of the overall length of the country's roadways, compared to 12.8% for national highways. Toll roads represent a 0.5 percent share of the total population [39].

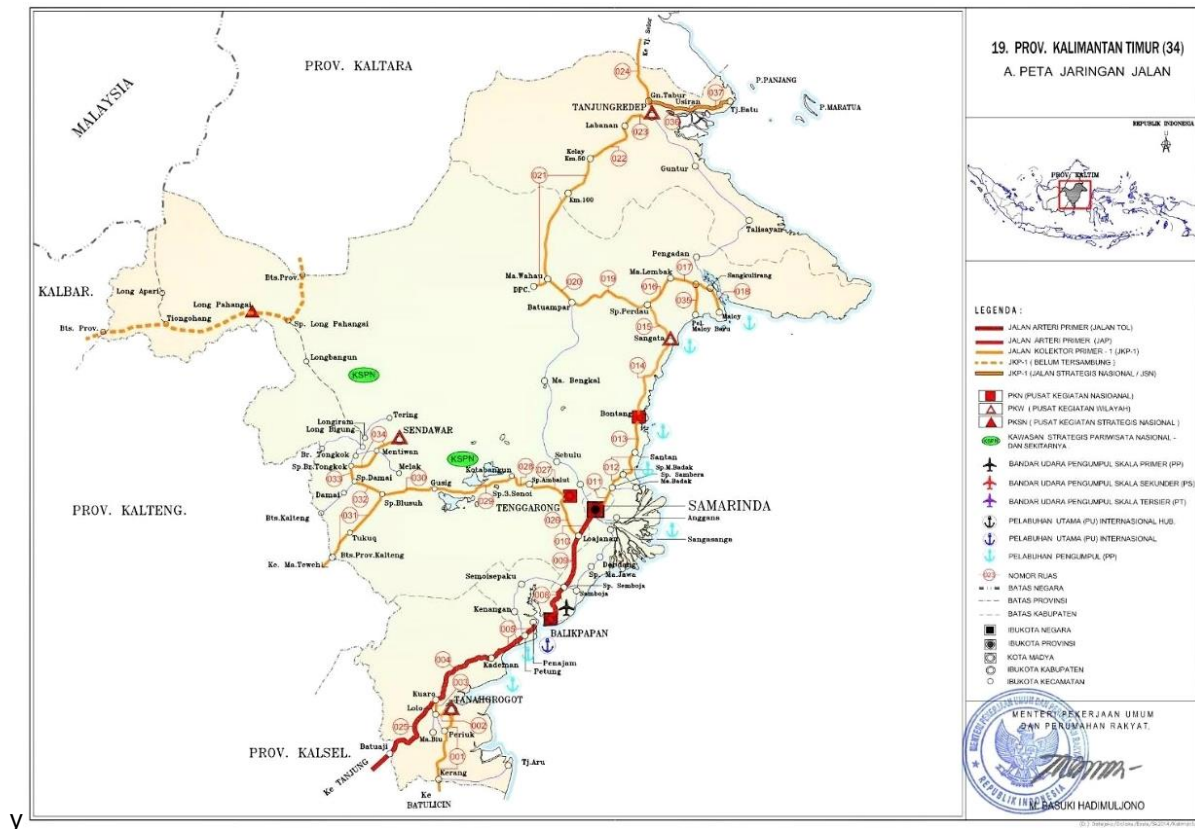


Figure 2. East Borneo Road Network

The 37 major highways in East Kalimantan are split into eight circuits, with 26 nodes connecting each circuit. A total of 15 national road nodes are studied in this research, all of which are located within a radius of the IKN.

3. Methodology

Analyzing the cyclic number of an area is a critical first step. A cyclomatic number studies the formation of a circle by analysing the origin and endpoints of each section. This allows you to determine the number of possible circles in the city. The following are the alpha and beta indices for the road network in East Kalimantan. The Alpha index determines the number of potential pathways between two nodes. A network's complexity may be assessed using the beta index. Beta varies between 0 and 3. The bigger the beta value, the more complex the network.

$$\beta = \frac{x}{2v-5} = \frac{8}{10-5} = 1.6\alpha \tag{1}$$

$$\alpha = \frac{e}{3(v-2)} = \frac{8}{3 \times 3} = 0.8 \tag{2}$$

where β is Circuit count, v is Node count, and e is Circuit count.

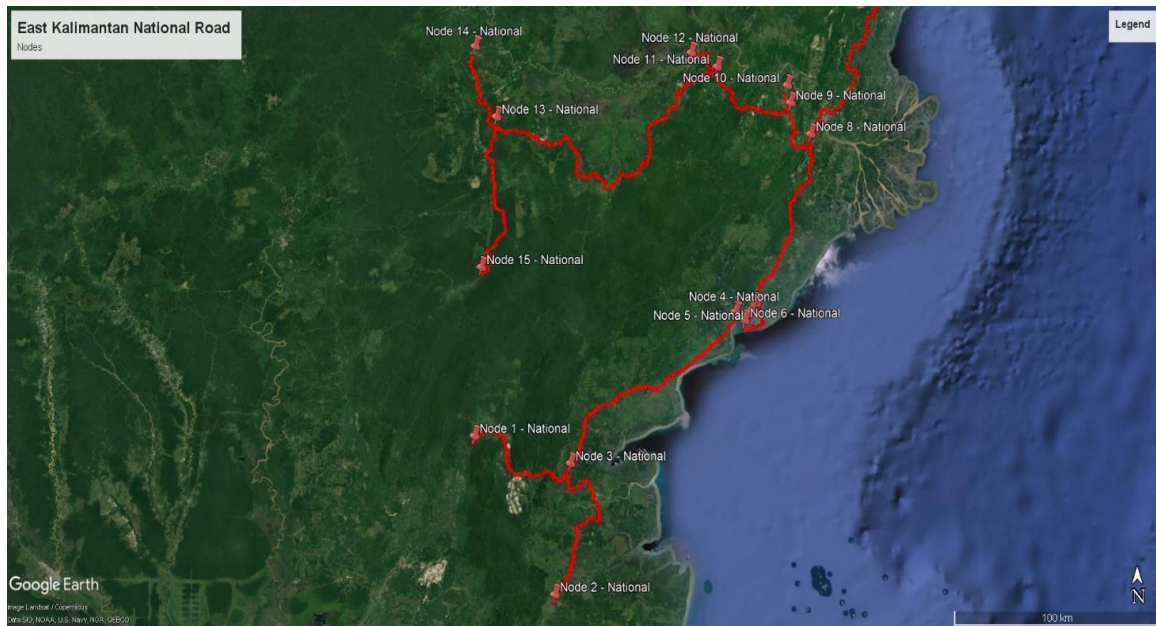


Figure 3. East Borneo Road Network Node

The study nodes are used to create the connection matrix. An example of how the connection matrix is formed using 10 nodes and 13 roadways is shown in the following diagram (Figure 4).

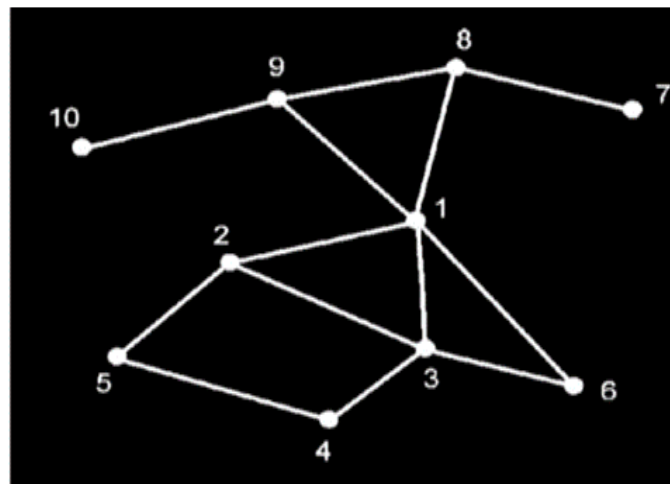


Figure 4. Illustration of a road network in the formation of a matrix

The above graph may be used to create a direct relationship matrix. A 1 represents a link between two nodes, whereas a 0 denotes a state of disconnection. The distance between nodes has no bearing on the matrix. The following matrix (Table 1) displays the direct relationships between nodes.

Table 1. Direct Relationship Matrix between Node

Line/Row	1	2	3	4	5	6	7	8	9	10
1	0	1	1	0	0	1	0	1	0	0
2	1	0	1	0	1	0	1	0	0	0
3	1	1	0	1	0	1	0	0	0	0
4	0	0	1	0	1	0	0	0	0	0
5	0	1	0	1	0	0	0	1	0	0
6	1	0	1	0	0	0	0	0	0	0
7	0	1	0	0	0	0	0	1	1	0
8	1	0	0	0	1	0	1	0	1	0
9	0	0	0	0	0	0	1	1	0	1
10	0	0	0	0	0	0	0	0	1	0

To activate the first matrix, for example, at the intersection of nodes 5 and 7, multiplication is carried out between row 5 and column 7, as shown in the accompanying Table 2.

Table 2. Matrix Activation Results row 5 column 7

Line/Row	1	2	3	4	5	6	7	8	9	10
1	0	1	1	1	0	1	0	1	0	0
2	1	0	1	0	1	0	1	0	0	0
3	1	1	0	1	0	1	0	0	0	0
4	0	0	1	0	1	0	0	0	0	0
5	0	1	0	1	0	0	0	1	0	0
6	1	0	1	0	0	0	0	0	0	0
7	0	1	0	0	2	0	0	1	1	0
8	1	0	0	0	1	0	1	0	1	0
9	0	0	0	0	0	0	1	1	0	1
10	0	0	0	0	0	0	0	0	1	0

Rows and columns of the matrix are all exposed to this technique. The activation procedure continues until the first row and column of the matrix contain the value 1. If every row and column has a value, this matrix is known as the whole connection matrix. Choosing where to begin the construction of a road network depends on the kind of connection between nodes to examine, as well as the size of the connection between nodes. A matrix and beta index analysis is done on maps of the IKN and East Kalimantan road networks to determine the present conditions of connectivity and to identify new node locations that must be established to increase the degree of connectivity in the road networks.

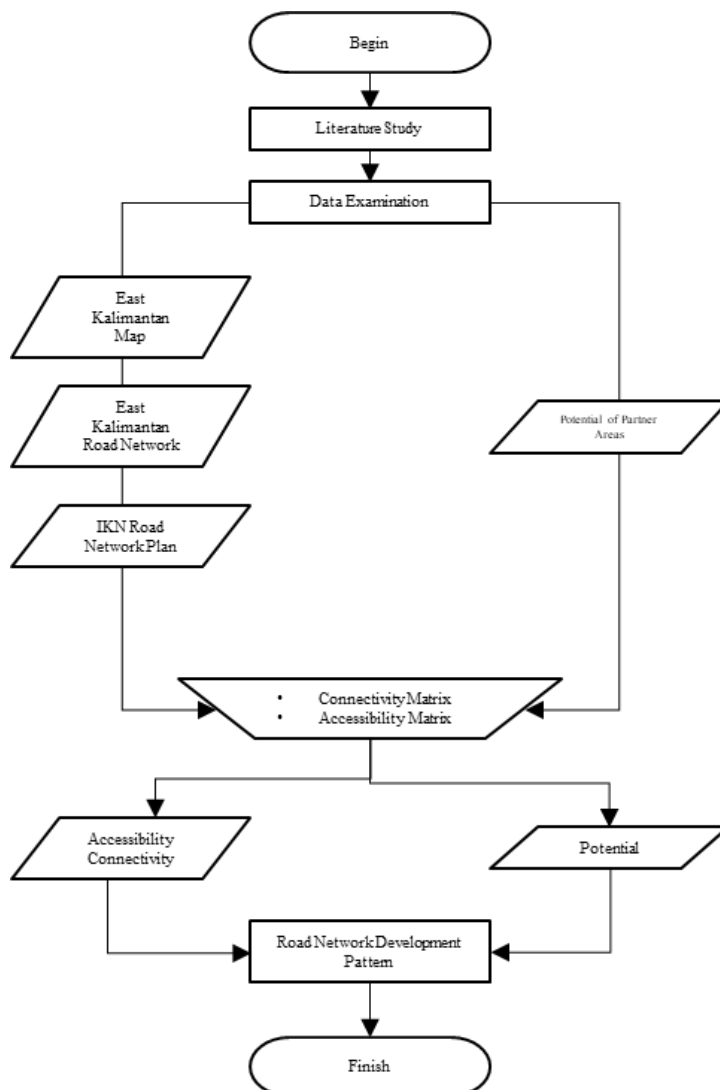


Figure 5. Flowchart of the study

There are 1,115,136 linkages based on the matrix iteration results up to three times, according to the findings. 431,649 connections is the lowest figure of connectivity. Due to the enormous number of nodes investigated and the number of iterations until it reaches 3 iterations, the value or number created by the matrix is rather big.

Table 5. IKN Road Network Plan Connection Average

Node	1	2	3	4	5	6	7	8	9	Av Conn
1	0	62.2	47.4	62.2	62.2	38.7	0.0	0.0	0.0	30.3
2	62.2	0	76.1	100.0	100.0	62.2	0.0	0.0	0.0	44.5
3	62.2	100.0	0	100.0	100.0	62.2	0.0	0.0	0.0	47.2
4	47.4	76.1	58.0	0	76.1	47.4	0.0	0.0	0.0	33.9
5	62.2	100.0	76.1	100.0	0	62.2	0.0	0.0	0.0	44.5
6	38.7	62.2	47.4	62.2	62.2	0	0.0	0.0	0.0	30.3
7	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
Av Conn	30.3	44.5	33.9	47.2	44.5	30.3	0.0	0.0	0.0	

Nodes 2, 3, 4, and 5 in East Kalimantan's road network have the greatest number of links, as shown by the matrix of connections. Only around 40% of the whole population has been reached. The shortcut is expected to lead to an increase in the number of connections. In order to activate the shortcuts at nodes 7, 8, and 9 after obtaining connection on the IKN, the same methods as previously are followed.

Table 6. IKN Partner Area Connectivity Index Matrix with Shortcut

Node	1	2	3	4	5	6	7	8	9
1	0	1	0	0	0	0	1	0	0
2	1	0	1	0	0	0	0	0	0
3	0	1	0	1	0	0	0	1	0
4	0	0	1	0	1	0	0	0	0
5	0	0	0	1	0	1	0	0	1
6	0	0	0	0	1	0	0	0	0
7	1	0	0	0	0	0	0	0	0
8	0	0	1	0	0	0	0	0	0
9	0	0	0	0	1	0	0	0	0

Table 7. The Results of the Third Phase of the Connectivity Index Matrix for IKN Partners with Shortcuts

Node	1	2	3	4	5	6	7	8	9
1	0	3E+07	3.3E+07	3E+07	3.9E+07	1.7E+07	1.7E+07	1.7E+07	1.6E+07
2	3E+07	0	3.3E+07	3E+07	3.9E+07	1.7E+07	1.7E+07	1.7E+07	1.6E+07
3	3.9E+07	3.9E+07	0	3.9E+07	5.1E+07	2.2E+07	2.2E+07	2.2E+07	2.1E+07
4	2.4E+07	2.4E+07	2.6E+07	0	3.1E+07	1.3E+07	1.3E+07	1.3E+07	1.3E+07
5	3.9E+07	3.9E+07	4.3E+07	3.9E+07	0	2.2E+07	2.2E+07	2.2E+07	2.1E+07
6	1.7E+07	1.7E+07	1.9E+07	1.7E+07	2.2E+07	0	9641025	9641025	8945505
7	1.7E+07	1.7E+07	1.9E+07	1.7E+07	2.2E+07	9641025	0	9641025	8945505
8	1.6E+07	1.6E+07	1.7E+07	1.6E+07	2.1E+07	8945505	8945505	0	8300161
9	1.7E+07	1.7E+07	1.9E+07	1.7E+07	2.2E+07	9641025	9641025	9641025	0

The presence of a shortcut, as established by the results of the three-stage iteration, indicates that the link has been significantly enhanced. The number of connections increased from 1,115,136 to 50,936,769 as a consequence of shortcuts (Fifty Million 936,769). The quantity of connections has increased by fifty percent. The minimal number of connections rose from 431,649 to 13,494,330. The third iteration's findings demonstrate that direct access to all nodes is available given that each matrix does not contain zeroes.

Table 8. Node Connection Percentage Matrix to Maximum Connection

Node	1	2	3	4	5	6	7	8	9	Av Conn
1	0	57.9	64.5	57.9	76.1	33.1	33.1	33.1	30.7	43.0
2	57.9	0	64.5	57.9	76.1	33.1	33.1	33.1	30.7	43.0
3	76.1	76.1	0	76.1	100.0	43.5	43.5	43.5	40.4	55.5
4	46.3	46.3	51.6	0	60.9	26.5	26.5	26.5	24.6	34.4
5	76.1	76.1	84.8	76.1	0	43.5	43.5	43.5	40.4	53.8
6	33.1	33.1	36.9	33.1	43.5	0	18.9	18.9	17.6	26.1
7	33.1	33.1	36.9	33.1	43.5	18.9	0	18.9	17.6	26.1
8	30.7	30.7	34.2	30.7	40.4	17.6	17.6	0	16.3	24.2
9	33.1	33.1	36.9	33.1	43.5	18.9	18.9	18.9	0	26.3
Av Conn	43.0	43.0	45.6	44.2	53.8	26.1	26.1	26.3	24.2	

As demonstrated in Figure 7, a short cut in the IKN outer ring zone increases the connectivity performance of the road network. Per-node connections are becoming more frequent. In addition, the number of connections at nodes 7, 8, and 9 is deemed sufficient if IKN's limited access policy is adopted. This connection is anticipated to simplify monitoring. In addition, it will help the expansion of IKN's partner territories and facilitate the expansion of the organization.

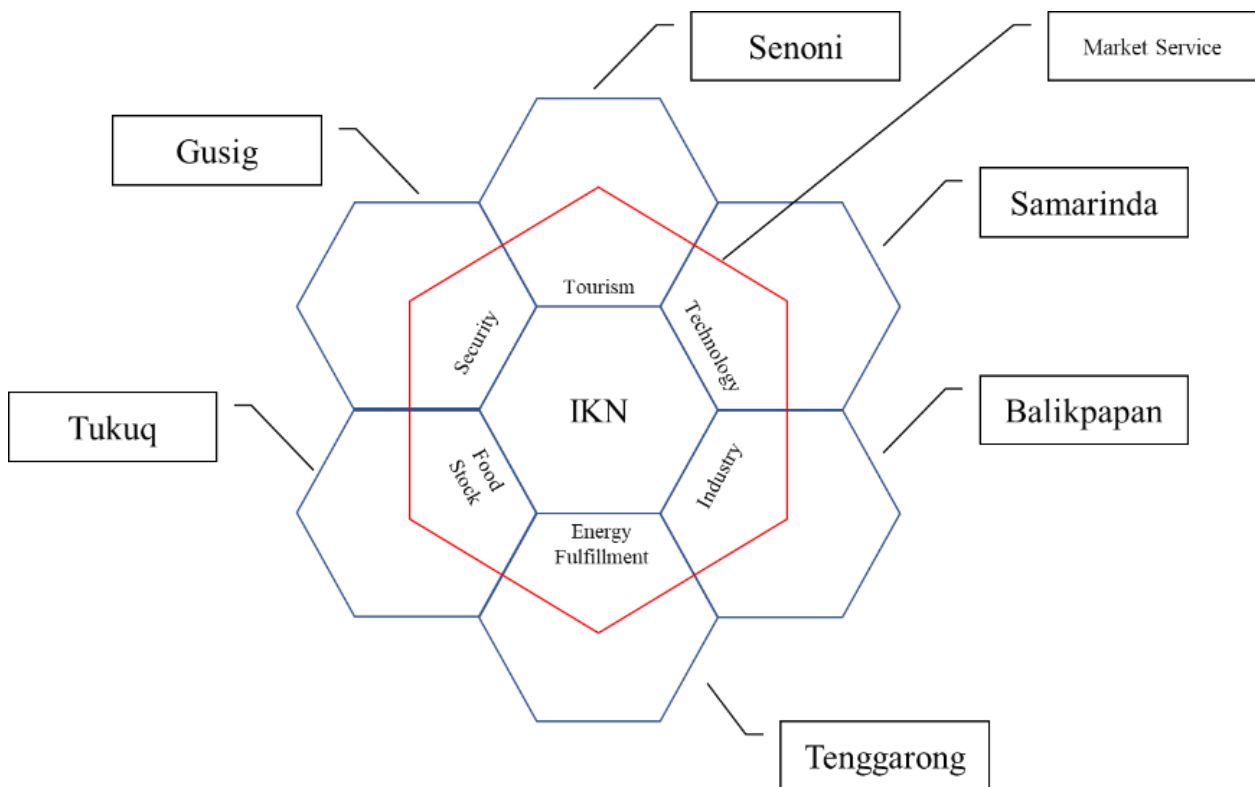


Figure 7. Illustration Central Place's K3 Hierarchy against IKN

In accordance with the IKN Development Master Plan, the IKN road network will be designed to facilitate the development of certain regions or industries. Based on these several factors, a qualitative graph titled the K3 Hierarchy of Central Place illustrates how the road network operates as a market service centre (Figure 8). The combined market/shared interest with IKN will account for one-third of the total market for certain commodities/aspects in partner areas. As markets and interests become increasingly dispersed, the K3 Hierarchy may serve as a starting point for IKN development in collaboration with other areas.

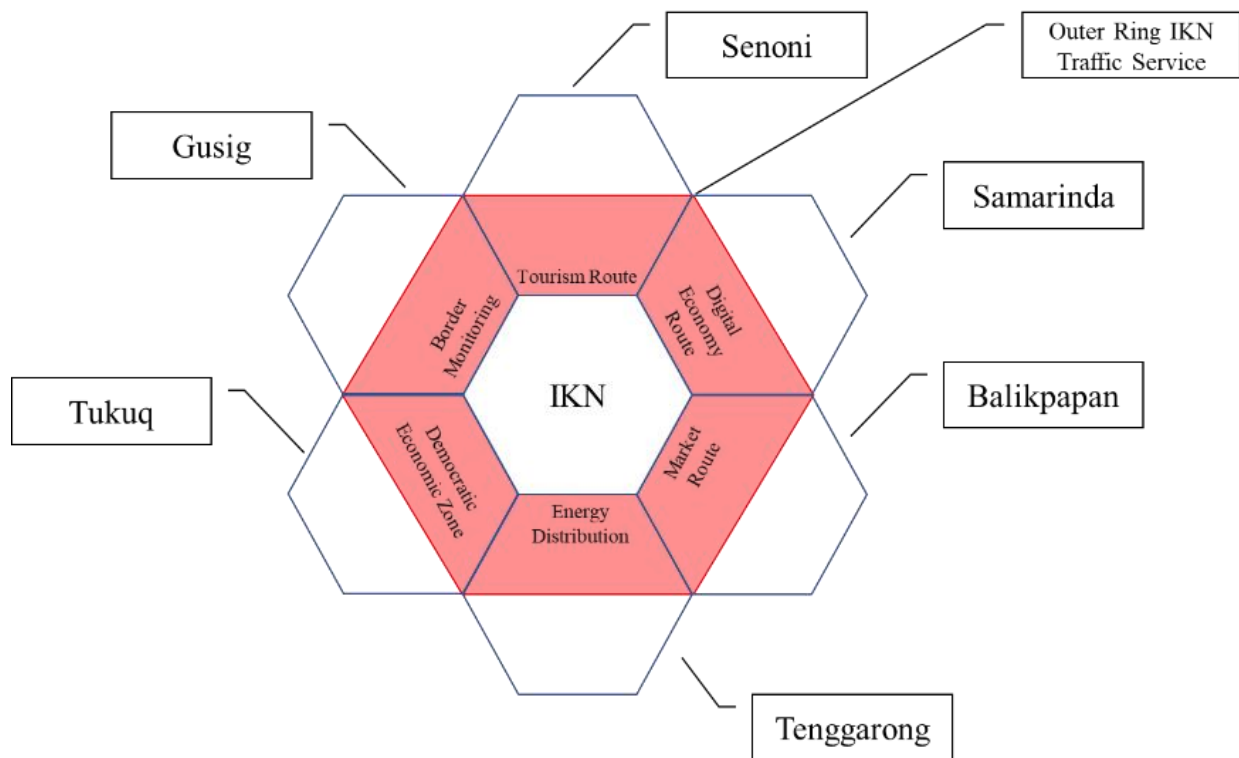


Figure 8. Illustration Central Place's K4 Hierarchy against IKN

Using K4 hierarchies, the transportation model is outlined. Thus, the network model may support the K3 hierarchy. In other words, transportation services contribute to their partner region's entire transportation needs (Figure 9). It is possible to define the number of logistical flows or public vehicles, as well as their frequency and routes, while designing this kind of transportation service. In this scenario, the transportation network supports not just IKN integration but also interregional integration. To realize the development clusters envisioned by IKN and its partner areas, each of these places must be linked. For example, to ensure that energy distribution can be completed in each cluster, it is necessary to build a central meeting site for all areas. As seen in the graph, IKN plays a growing role in facilitating the exchange of products, services, and shared goals.

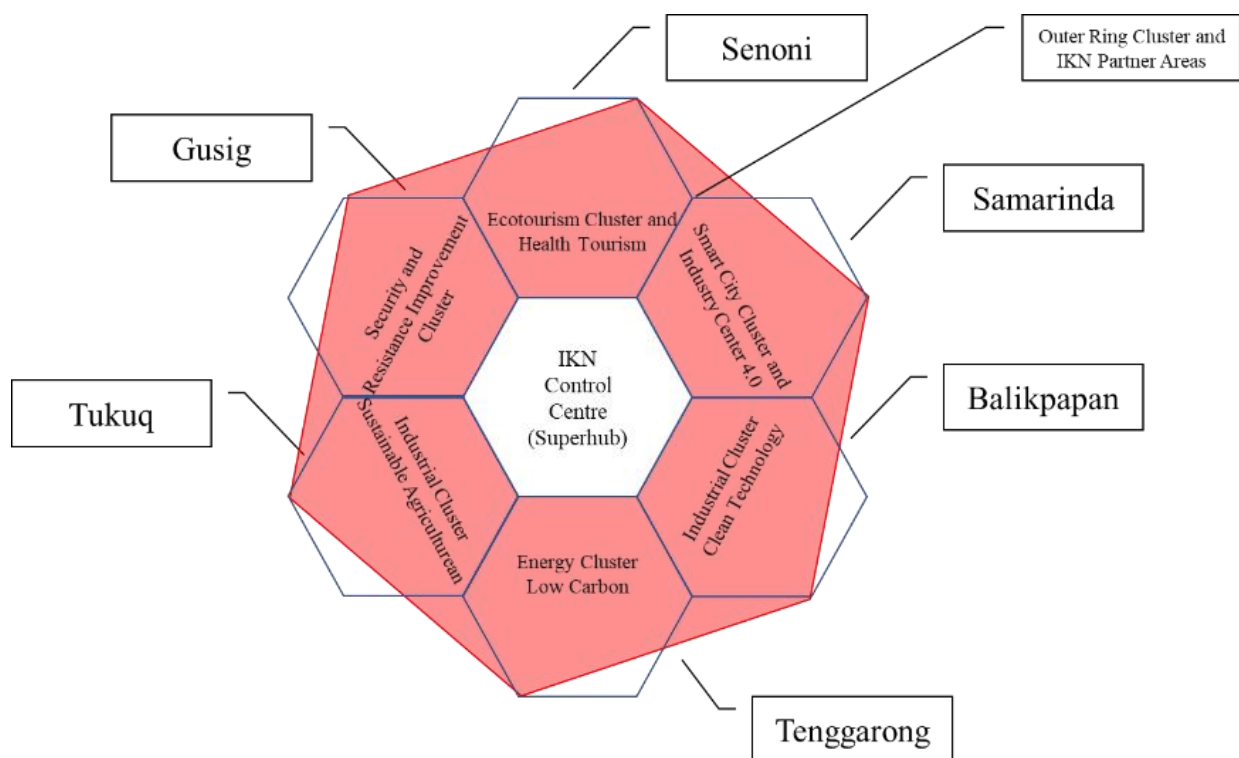


Figure 9. Illustration Central Place's K7 Hierarchy against IKN

As shown by the K7 Central Place Hierarchy, the IKN superhub connects many clusters from partner sites around IKN. In this case, IKN provides administrative services as the administrative hub for the surrounding area. Co-development and integrated development for IKN and partner areas demonstrate that the emphasis of road network development is on a number of hierarchically defined locations. East Kalimantan's economic and development strategies, as well as the administrative position of the State Capital in Kutai Kartanegara Regency and North Penajam Paser Regency, show significant potential for the development of a vast array of new business prospects in a number of sectors. It is feasible to operate a range of companies in the food and hotel industries, as well as travel agencies and other home-based operations.

5. Conclusion

According to the given study findings, the utilization of shortcuts from the IKN region to several node sites may increase road connectivity and enhance existing connections. The pattern of road network growth might be studied to reach this node. Five of the 26 nodes in the total connectivity matrix of national roads around IKN in East Kalimantan include the majority of connections. This indicates that the East Kalimantan National Road Network nodes close to the IKN play a crucial role. In order to promote the expansion of both IKN and its partner industries, the node must have efficient access to and from IKN. Nodes 3 and 7 are the most accessible and simple-to-accessible component nodes of the road network, as compared to the other nodes evaluated in this study. Comparatively, the accessibility index of nodes 3 and 7 is still close to 1, showing that they are effectively separated from the other nodes. The accessibility index values for nodes 9 and 11 are relatively high, while those for node 13 are rather low. These data indicate that the time and distance traveled provide little advantage. Consequently, the plan of road network construction should be carried out in the directions of Tukuq, Senoni, and Gusig. Thus, the design of the road network expansion will be able to satisfy the growth aspirations of the IKN region, which is connected to its neighboring partner areas.

6. Declarations

6.1. Author Contributions

Conceptualization, J.; methodology, J.; software, J.; validation, J.; formal analysis, J.; writing—original draft preparation, J.; supervision, S.A.A., M.S.P., and M.I.R.; project administration, J.; funding acquisition, J. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available in the article.

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6.5. Conflicts of Interest

The authors declare no conflict of interest.

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