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Identification of Sprawl Development Typologies around Toll Road Gates in Java, Indonesia

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Abstract: In the last 2 decades, hundreds of kilometers of toll roads have been built on Java, stretching from the east to the west of the island. Many researchers have examined the impact of the physical development of toll roads. From these previous studies, no one had ever identified the types of sprawl development resulting from toll gates. This research aims to identify the types of sprawl developments caused by the existence of toll gates. This research uses 2 methods: spatial development analysis using Google Earth Pro and literature reviews from publications on the topic of the impact of toll gates. We selected 12 toll gates based on the following criteria: toll gates must represent the western, central, and eastern regions of Java Island & toll gates must represent the periods of toll development, which were more than 2 decades old, under 2 decades old, and less than 1 decade. The findings show there are varieties of sprawl development as a result of the existence of toll gates or exits. The three types of sprawl developments include (1) linear/corridor and leapfrog; (2) concentric/radial and leapfrog and (3) a combination of linear and radial coupled with a leapfrog.

Keywords: Toll gates, Sprawl Development, Linear Sprawl, Radial Sprawl, Leapfrog Sprawl

INTRODUCTIONS

Transportation infrastructure plays an important role in improving accessibility and encouraging the growth of economic systems. The better the condition of the infrastructure, the better the level of accessibility, mobility, and economy of a region, thus, triggering the progress and development of the region. The construction of toll roads as a part of the physical development of transportation infrastructure is growing fast on Java Island. In the last two decades, hundreds of kilometers of toll roads have been built on Java Island, stretching from the east to the west of Java Island (Hoffman, 2016). The existence of toll roads is estimated to have an important role in creating a great region unit in Java Island, known as megaregionalisation (Hudalah et al., 2020). One of the many factors causing this phenomenon is the existence of toll gates that trigger physical urbanization such as land development and the conversion of land (Ayu Andani et al., 2019; Hoffman, 2016; Makbul et al., 2019).

Many studies have been conducted to assess the effect of toll roads' physical construction including those located on Java Island. One agreeable research finding is that the toll gates have significant roles in spurring the physical development and land use conversion around the area. (Aji et al., 2019; Ayu Andani et al., 2019; Hoffman, 2016; Makbul et al., 2019; Nathania et al., 2017; Prasetyo & Djunaedi, 2019; Susanto & Marsoyo, 2019). However, among those previous studies, no researcher has done a study on the identification of the sprawl development typologies caused by the existence of toll gates. The purpose of this research is to identify the typology of

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sprawl development caused by the toll gates as a form of contribution to the literature on regional development and land use management.

This research uses the sprawl development theory as the foundation to analyze the phenomena of land development occurring around the toll gates. Sprawl development is a development that happens in the sub-urban area as a result of uncontrolled expansion, characterized by low density and fragmented development patterns. Sprawl development is usually categorized by the conversion of productive land, growth of housing, and commercials with low density in the non-built-up area. This research uses the sprawl typologies of sprawl development stated by Harvey & Clark (1965): (1) linear / corridor, which s the land development stretching along with the road networks, while the other used is the ribbon development; (2) radial / concentric, is the land development that slowly extends away from the gates in an imperfect or almost a full circle shape, the other term that used is the low-density development; (3) leapfrog development, is the land development that leaps from non-developed area to other separated areas. Although it has been stated decades ago, the three typologies are still very relevant to the current condition so they can be used in the latest studies related to the identification of sprawl development (see Cengiz et al., 2017; Mosammam et al., 2017).

METHOD

This research used two (2) research methods. The first is spatial development analysis using Google Earth Pro, while the second is literature reviews from the publications of previous studies on the topic of the effect of the existence of toll gates. Google Earth Pro is an application developed by Google that provides the public a chance to access satellite images of the earth for various purposes and knowledge, including spatial planning (Patterson, 2007; Taylor et al., 2011; Yu & Gong, 2012). The main information used by *Google Earth Pro* is spatial information with different ranges of time also known as Spatio-temporal information (Jacobson et al., 2015; Mering et al., 2010). Spatiotemporal information is very suitable for use to identify the development, conversion, land, or land cover that happened in a region from time to time (Jacobson et al., 2015; Nidhinarangkoon et al., 2020). In this research, the land development information around the toll gates area was retrieved from the Google Earth Pro satellite images by comparing two to three map images with different time series. To add more discussion and observe the trends, the authors also did a literature review of some previous research related to the development caused by the existence of toll gates. The literature used include the literature review of Kedung Halang toll gate (Susanto & Marsoyo, 2019), Pejagan toll gate (Mukhlis & Soetomo, 2017) and Ungaran Timur toll gate (Aji et al., 2019; Nathania et al., 2017; Putro et al., 2019)

The temporal scope of the literature review used in this research was quite varied, depending on the age of the toll gates. The area scope of the study used involved the toll roads situated on Jona island. Java Island is in Indonesia; it is an island with the longest toll roads and the most toll gates (Hoffman, 2016). These toll roads also connect Java from one region to another region and the island is predicted to be a mega-region with high a urbanization rate (Hudalah et al., 2020).

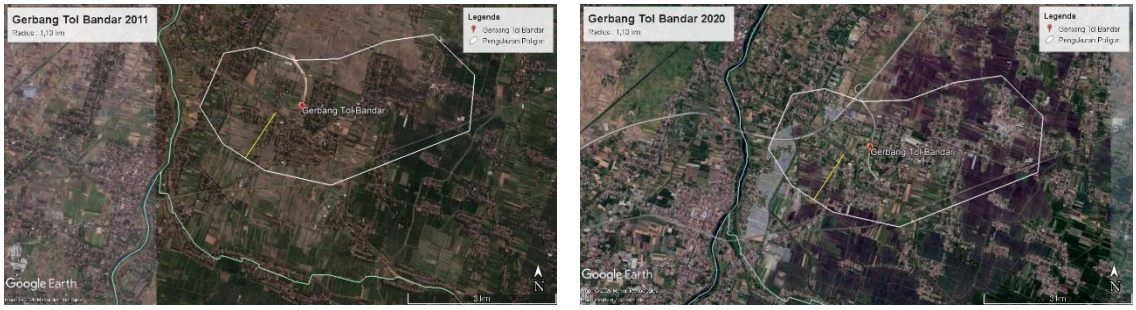
In choosing the location case, two criteria were used. First, the toll gates must represent the west, the middle, and the east side of Java Island. Second, the toll gates must represent the periods of toll roads' construction on Jona Island, with the age category of more than two decades, less than two decades, and less than a decade. From the selection, 12 toll gates have been selected spreading from the east to the west side of Java Island. The 12 toll gates are: (1) Kedung Halang Toll Gate; (2) Bandar Toll Gate; (3) Romokalisari Toll Gate; (4) Pejagan Toll Gate; (5) Jagorawi (Sentul 1 dan 2) Toll Gate; (6) Kalijati Toll Gate; (7) Kebomas Toll Gate; (8) Manyar Toll Gate; (9) Kopo Toll Gate; (10) Tandes Barat Toll Gate; (11) Ungaran Timur Toll Gate and (12) Jatiluhur Toll Gate.

RESULTS AND DISCUSSIONS

Type 1: Linear/Corridor and Leapfrog

This research found that one of the sprawl-type developments, which is quite dominant around the toll gate, is the linear sprawl development. The linear type is always marked by a land development trend that follows the road corridors. Besides, the linear sprawl is always followed by the leapfrog sprawl type. Here are some explanations about the phenomena of linear sprawl and leapfrog sprawl development found in some toll gates.

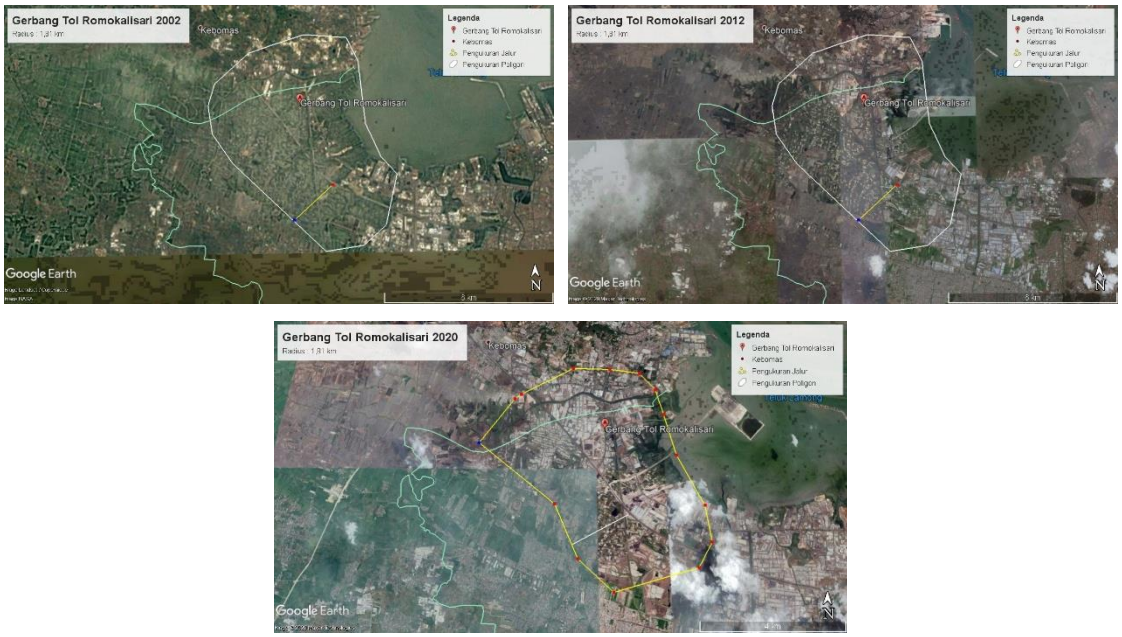
The sprawl developments in Bandar Toll Gates and Romokalisari Toll Gates are heading toward the urban area that stretches along the road corridors for about 2 km (picture 1). The low density of settlements around the Romokalisari Toll Gates appeared in 2020 within a radius of 1.8 km with a length of 5 km along the toll roads of Romokalisari and was ominated by a land-use conversion from ricefields into settlements (Picture 2). The sprawl development direction in Bandar Toll Gates is heading toward the Jombang urban area, while the settlements in Romokalisari Toll Gate are heading toward Surabaya City. Besides the linear sprawl type, one of the sprawl developments identified is the leapfrog sprawl development that has been converting some rice field areas into a settlement.



Source: Google Earth Pro, 2020

Figure 1. The Comparison of Bandar Toll Development from 2011-2020

Moreover, based on the literature review, the linear and leap sprawl patterns were also identified around the Bogor Outer Ring Road tolin precise, in the Kedung Halang (Susanto & Marsoyo, 2019). The existence of toll gates has caused land conversion in a radius of 0-1000 meters from the toll gates location, with the total area being more than 11,4 hectares. The sprawling area in the exit toll of the Kedung Halang location had a linear pattern following the main road corridors connected to the toll gate and paired with leapfrog sprawl although it was not dominant. The other linear pattern with a distance of 1-2 km appeared in the area development around the Mojokerto-Kertosono Road Tolls (Hadiyanti & Sulistinah, 2019) precisely in the Bandar Toll Gates and Romokalisari Toll Gates in Surabaya-Gresik in Surabaya-Gresik Toll Roads.



Source: Google Earth Pro, 2020

Figure 2. The Comparison of Romokalisari Toll Gate Development Between 2002-2020

The corridor development also appeared in Pejagan Streets as the alternatives routes of inter-cities within the province and the southern part of Java, acting as the exit toll routes of Kanci-Pejagan. This condition caused the surrounding community to hold commercial activities in the surrounding area so the land conversion happened massively for 2 kilometers in length and with an approximated total area of 20 hectares from the exit toll point (Soedarsono, 2017). The conversion started from 2007 until 2016 with a function conversion percentage of 77% of the total buildings along the 2 km corridor. The land-use conversion in the corridor or linear pattern also appeared in the Brebes Timur Toll Gate with the land-use conversion from the settlements into the mixed-use buildings (housing and shops) for 800m length in Pemuda Corridor. The commercial utilization as chosen by the community included restaurants, minimarkets, and souvenir shops. The research also identified a connection between the toll gates and the community livelihood around Gadjah Mada Street, Brebes. The social factor indicators used as the variables were land price, security, and orderliness, newcomers, kinship, and accessibility. The economic factor indicators used were jobs, change of professions, business opportunities, business turnover, and the new field of work. The environment factor indicator included the air quality, traffic, noise, solid waste volume, and land use.

Type 2: Radial / Concentric and Leap Frogs Sprawl Type

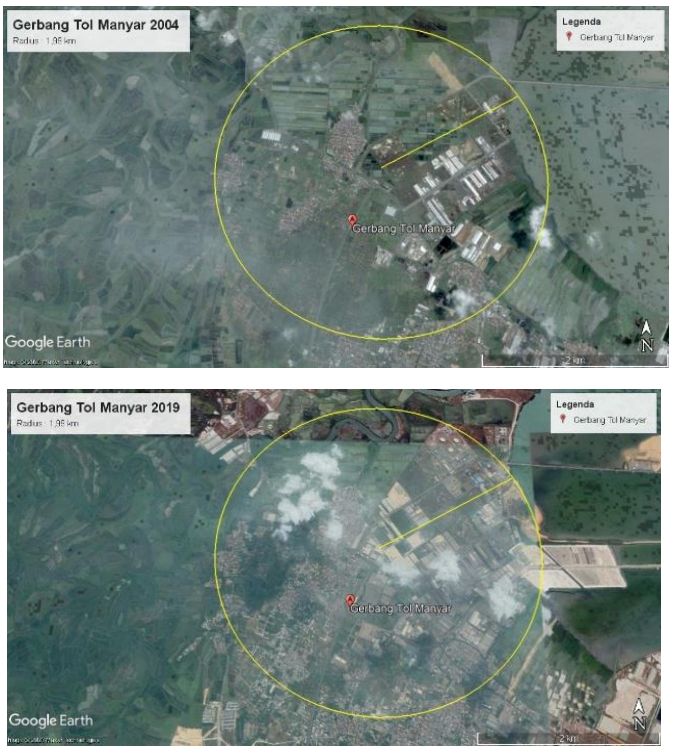
The second sprawl type in this research is the radial/concentric type paired with the leapfrog sprawl type. The radial/concentric sprawl type is usually characterized by the land development extending away from the toll gate and is usually low-densified. The pattern that appeared from this type is not following the main road network but tends to be widened by creating a lower hierarchy of street networks. As for the leapfrog sprawl development, it also can be found especially in the housing development, even though the land conversion from agriculture into warehouses with leapfrog sprawl cases also can be found. Here is the explanation of the cases that have been analyzed in this research.

The land development within a radius of 1 kilometer happened in the area around the Surabaya-Gresik Toll Gates, especially in the Kebomas Toll Gate in the years 2004-2019 (Figure

3). The sprawling development with concentric type also appeared in the radius of kilometers around the Manyar Toll Gates for the last 15 years with the development direction expanding toward the northern and the southern (Figure 4). Then, in the Tandes Toll Gates and Kopo Toll Gates, a land development can be found expanding with a radius of 4 kilometers during 20 years with the dominating land use of housings (Figure 5 and Figure 6). From the three cases, the sprawl development with the leapfrog sprawl type appeared to be dominant.

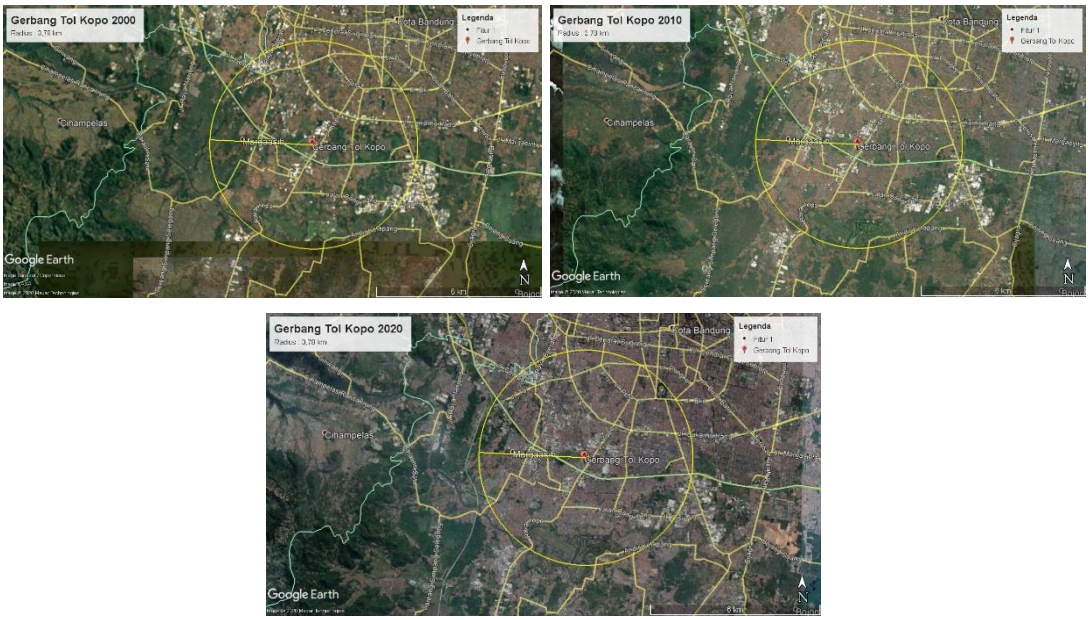
Source: Google Earth Pro, 2020

Figure 3. Comparison of Kebomas Toll Gate Development from 2004-2019



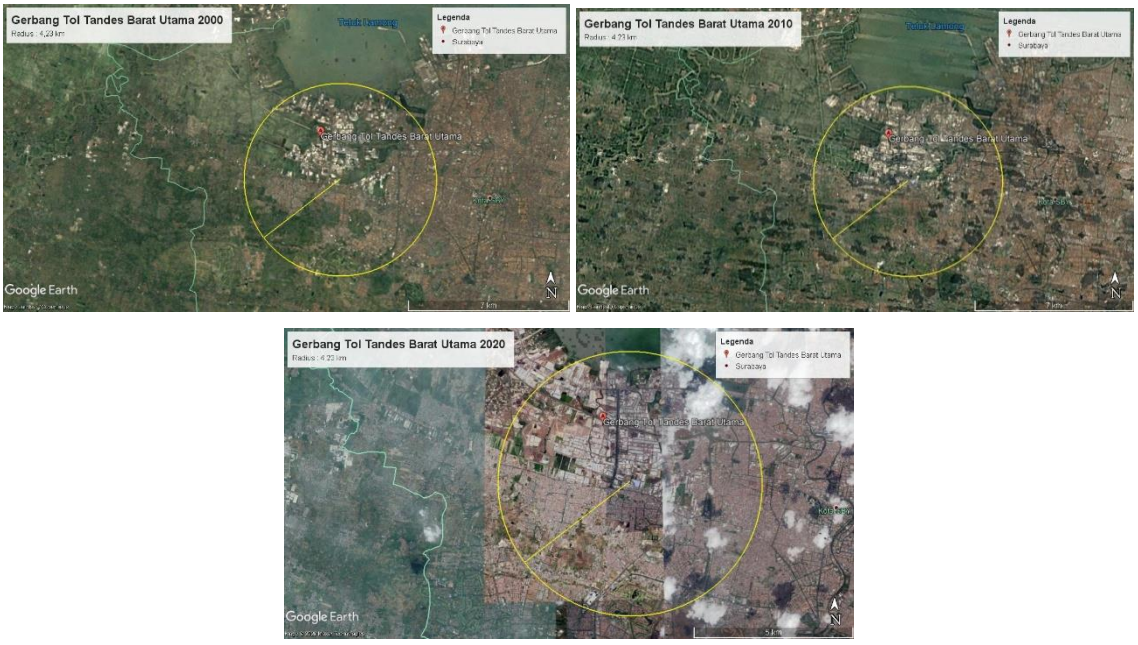
Source: Google Earth Pro, 2020

Figure 4. Comparison of Manyar Toll Gate Development from 2004-2019



Source: Google Earth Pro, 2020

Figure 5. Comparison of Kebomas Kopo Toll Gate Development from 2000-2020



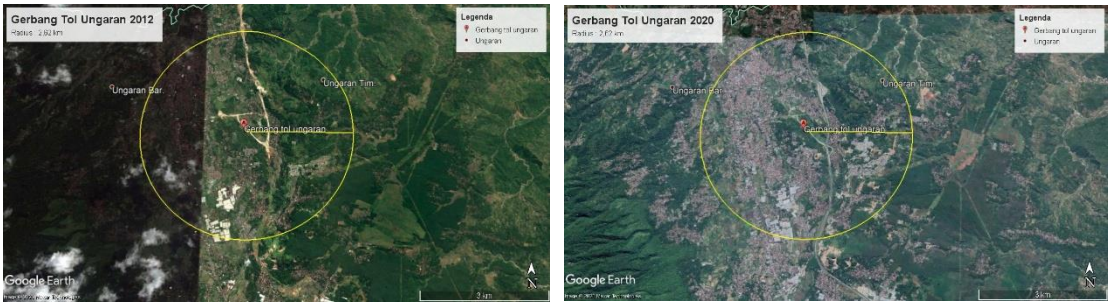
Source: Google Earth Pro, 2020

Figure 6. Comparison of Tandes Barat Utama Toll Gate Development from 2000-2020

The development of settlement activities also happened due to the existence of Semarang-Solo Toll gates in Ungaran Timur. From the observation, it can be seen that there was a change from the years 2008-2019 in the clustered and leaped areas around the toll gates, heading toward Ungaran Timur. The other study related to the Ungaran Timur Toll Gates with the time range of

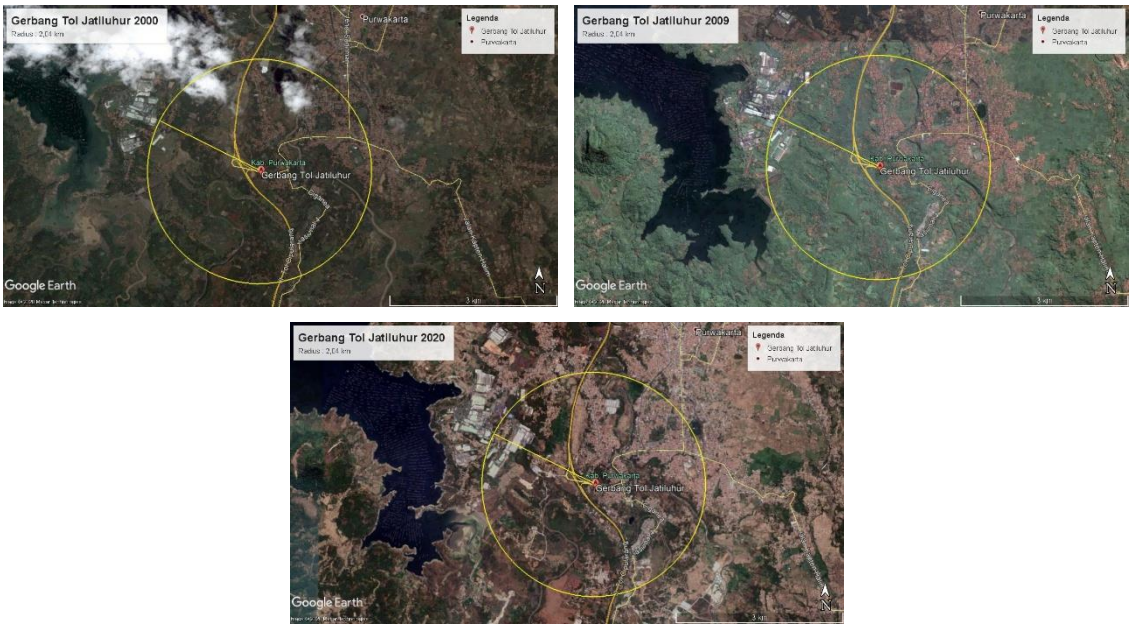
2008-2017, showed that the land-use change happened within a wide radius of 1 km from the toll gates point. There was a rising inland pricing around the toll gates starting from Rp 530.000 to Rp 5.039.000 within a radius of 1 km from the toll gates (Aji et al., 2019; Nathania et al., 2017). Both studies are consistent with the image satellite observation from the period 2012-2020, showing the land-use change up to the radius of 2 km with the development direction heading to the southeast or south or toward the Ungaran Timur District (Figure 7).

The expansion of the settlement area with radial/concentric pattern and leapfrog pattern also appeared in Jatiluhur Toll Gates, Purwakarta (Figure 8). The land-use change and the settlement development started in 2000 and continued to 2020 with a radius of 2 km from the toll gate point and heading toward the coastal of Purwakarta. The land-use change around the toll roads and the toll gates of Ulujami-Serpong in Tangerang appeared to have radial/concentric type pairs with the leapfrog sprawl type (Desinah & Tambunan, 2017). The land-use change happened between 2000-2016, doubled in the increase of housings and settlements area.



Source: Google Earth Pro, 2020

Figure 7. Comparison of Ungaran Timur Toll Gate Development from 2012-2020



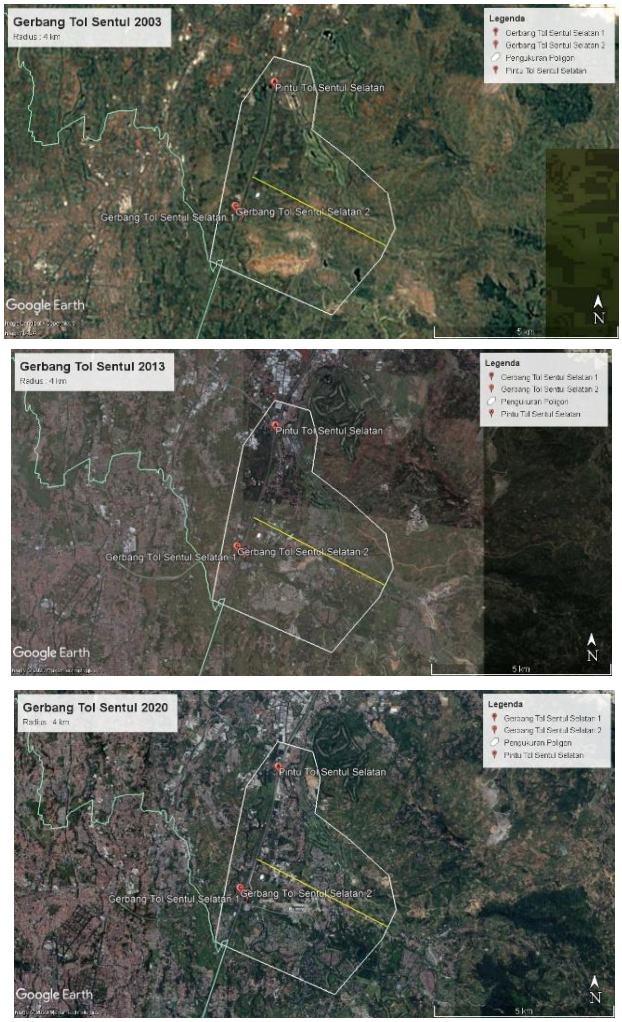
Source: Google Earth Pro, 2020

Figure 8. Comparison of Jatiluhur Toll Gate Development from 2000-2020

Type 3: Linear / Corridor, Radial / Concentric, and Leapfrogs

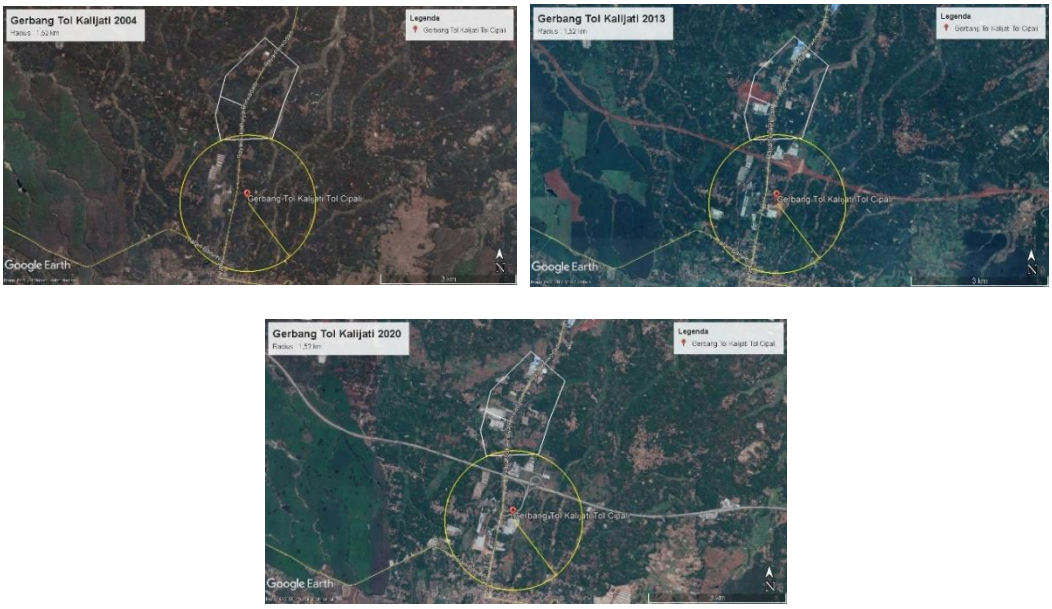
This research also found that the combination of linear sprawl and concentric sprawl occurred in sequence. The phase can be started from the linear into concentric or vice versa, from the concentric into linear. This research also found the phenomenon of leapfrog sprawl development in the area of observation.

The first case was around the Sentul 1 and 2 Toll Gates, which were parts of Jagorawi Toll. The satellite images show that there was a corridor-typed development then, followed by radial-type heading to the southeast and filling up the land in between the two toll gates. The development area was about 20 hectares within a radius of 4 km, stretching along the 5 km of the road corridor. The development could have happened intensely since the two toll gates were located closely between Sentul Selatan 1 Toll Gates and Sentul Selatan 2 Toll Gates. The finding of combined sprawl developments between the radial and the linear sprawls also appeared in Kaljati Toll Gate as part of the Cipali Toll. The radial sprawl development started from the toll gate with a distance of 1,5 km and then changed into linear sprawl along the road for 1.5 km in length heading toward the Purwodadi, with 0.5 m in distance from the roads.



Source: Google Earth Pro, 2020

Figure 9. Comparison of Sentul Selatan Toll Gate Development from 2003-2020



Source: Google Earth Pro, 2020

Figure 10. Comparison of Kalijati Toll Gate Development from 2004-2020

Table 1. The Development Trends of the Toll Gate Areas in Java Island

No	Toll Gates	Linear/ Corridor	Radial/ Concentric	Leapfrog	Radius	Length	Time Range of Analysis	Direction of Development	Average Speed of Development per Year
1	Kedung Halang Toll Gate[1]	•		•	0,2 km	1 km	11 years (2006 - 2017)	Along the corridor	90,1 m of the corridor extension
2	Bandar Toll Gate	•		•	1 km	2 km	9 years (2011 - 2020)	Along the corridor toward Jombang	222,2 m of the corridor extension
3	Romokalisari Toll Gate	•		•	1,8 km	5 km	18 years (2002 – 2020)	Heading toward Surabaya City	333,3 m of the corridor extension
4	Pejagan Toll Gate[2]	•		•	0,2 km	2 km	7 years (2009 – 2016)	Along the corridor of Jl. Pejagan	285,7 m of the corridor extension
5	Sentul & Sentul 2 Toll Gate	•	•	•	4 km	5 km	17 years (2003 – 2020)	Filling up the lands in between the toll gates	294,1 m of the corridor extension

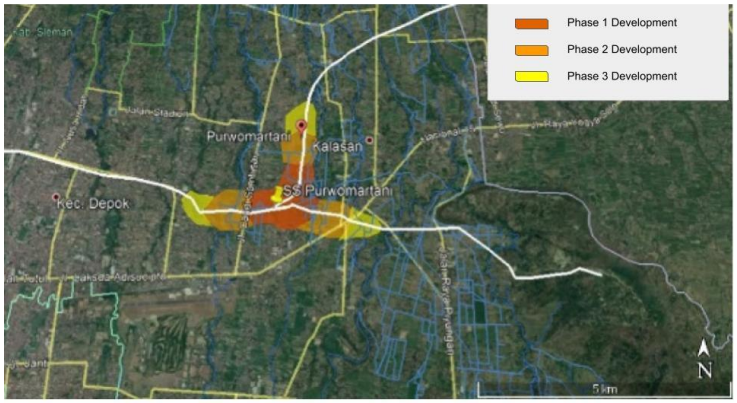
No	Toll Gates	Linear/ Corridor	Radial/ Concentric	Leapfrog	Radius	Length	Time Range of Analysis	Direction of Development	Average Speed of Development per Year
6	Kalijati Toll Gate	•	•	•	1,5 km	0,5 km	16 years (2004 – 2020)	Heading toward Purwadadi, Subang	93,75 m of radius expansion
7	Kebomas Toll Gate		•	•	1 km		15 years (2004 – 2019)	Expanding around Manyar Toll Gates	66,6 m of radius expansion
8	Manyar Toll Gate		•	•	2 km		15 years (2004 – 2019)	Expanding around the Kebomas Toll Gates	133 m of radius expansion
9	Kopo Toll Gate		•	•	4 km		20 years (2000 – 2020)	Expanding and Heading toward Bandung City	200 m of radius expansion
10	Tandes Barat Utama Toll Gate		•	•	4 km		20 years (2000 – 2020)	Heading away from Surabaya City	200 m of radius expansion
11	Ungaran Timur[3] Toll Gate		•	•	2 km		8 years (2012 – 2020)	Expanding around Ungaran Timur District	200 m of radius expansion
12	Jatiluhur Toll Gate		•	•	2 km		20 years (2000 – 2020)	Expanding toward/approaching the Coast of Purwakarta	100 m of radius expansion

[1] some of the information is cited from Susanto & Marsoyo (2019); [2] some of the information is cited from (Mukhlis & Soetomo, 2017), Suseno et al. (2017); [3] some of the information are cited from (Aji et al., 2019; Nathania et al., 2017; Putro et al., 2019)

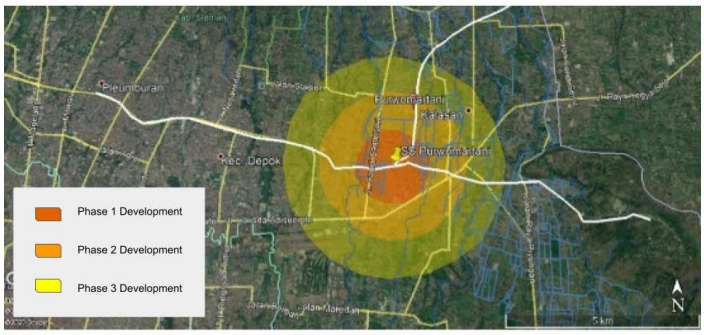
Based on the trend of toll gates development in Indonesia that has been analyzed from the 12 location cases, they have shown a variety of sprawl development types as the result of the existence of toll gates or exit tolls. The three types include (1). Linear/corridor and leapfrog (Figure 12. a); (2) concentric/radial and leapfrog (Figure 12. b), as well as (3) sequence combination of linear and radial paired with the leapfrog (Figure 12. c). The recap of all observed cases and the results can be seen in Table 1. Based on the research findings and some other studies, the sprawl caused by the existence of toll gates is still an unsolved phenomenon. The sprawl development phenomenon is seen as unsustainable land use due to the conversion of productive land, inefficient land use, and the behavior change of the people to be more dependent on private vehicles (Akhter & Noon, 2016; Al Jarah et al., 2019; Bhat et al., 2017; Lennert et al., 2020; Marks et al., 2016).

In the development context of Indonesia, primarily on Java Island, the previous studies have explained how the toll gates have roles in land development and conversion. For example, the research by Makbul et al. (2019) the study was about the effect of the existence of toll roads

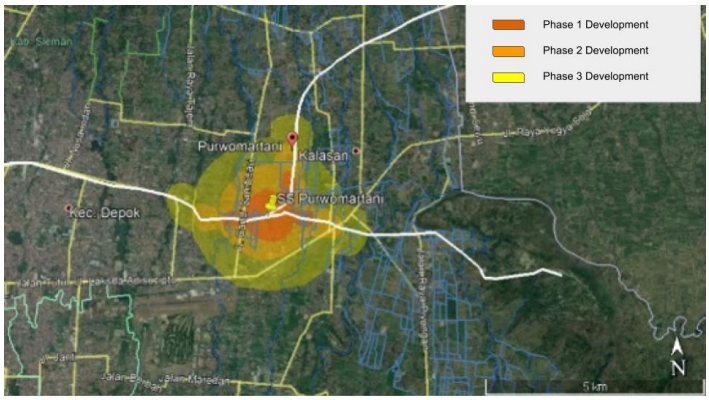
and the toll gates on the farmer's and agricultural landowners' decisions in converting their land use and selling them to other parties. In the other study, the massive toll roads construction is affecting stronger interconnectivity between the regions on Java Island (Hudalah et al., 2020). The strong interconnectivity tends to trigger wider urbanization to fill up the lands existing in between the cities and the regencies. For example, the additional road networking that connects the toll road corridors and the areas outside the toll roads (Ayu Andani et al., 2019), then triggers the land price development and land-use conversion, as found in the toll gate cases in this research.



(a)



(b)



(c)

Figure 11. Illustration of Sprawl Development Typologies
a. Linear/Corridor Type; b. Radial/Concentric Type; c. Combination Type

The solution to the sprawl development is to use some planning instruments such as directing the land development in the planned area, protecting the village area and coordinating with the stakeholders who have roles in land management, and providing affordable accommodation and amenities to increase public interest in the urban area (Fertner et al., 2016; Perrin et al., 2020). Directing the land development is usually done by institutionalizing the urban growth boundary (UGB) / urban containment boundary (UCB). The UGB/UCB is the spatial planning instrument in the form of overlay zoning that regulates how far an urban area is allowed to develop physically, accompanied by the incentive and disincentive instruments within (Fertner et al., 2016; Ren et al., 2020; Zheng et al., 2017). The second solution is to protect the village areas, especially the productive agricultural lands. The protection of the village areas can integrate with the agricultural land protection system (Huang et al., 2015; Perrin et al., 2020) which is in the Indonesian context known as the LP2B (Sustainable Agriculture Land) policy. The third solution is to increase the coordination of the stakeholders, especially those who have the authority in spatial management, issuing land use and business permission, and protecting the agricultural area. The last solution is to increase the interest in urban areas by intensifying amenities and providing affordable accommodations.

Finally, we recommend some studies in the future that have not been covered in this research. Firstly, research that assesses the synchronization and effectiveness of spatial planning implementation, especially in the areas around the toll roads. Secondly, research about the identification of public perception, understanding, and the willingness to preserve the non-built-up land around the toll gates. Thirdly, identification research about the most effective form of incentive and disincentive as an effort to reduce the sprawl development in the non-built-up areas, primarily those affected by the existence of toll gates, for example, the transfer development rights mechanism.

CONCLUSIONS

Based on the trend of toll gates development in Indonesia that has been analyzed from the 12 location cases, they have shown a variety of sprawl development types as the result of the existence of toll gates or exit tolls. The three types include (1). Linear/corridor and leapfrog; (2) Concentric / radial and leapfrog, (3) Combinations of linear and radial paired with the leapfrog. According to the research findings and some other studies, the sprawl development caused by the existence of toll gates is still an unsolved phenomenon. The sprawl development phenomenon is seen as unsustainable land due to the conversion of productive lands; inefficient land use and the behavior change of the people to be more dependent on private vehicles. The proposed solutions are using some planning instruments such as directing the land development in the planned area, protecting the village area, coordinating with the stakeholders who have roles in land management, and providing affordable accommodation and amenities to increase public interest in the urban area

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