Land use change due to road construction

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Abstract. Roads is one of the main infrastructures to support the realization of economic development. The economic development resulting economic activity and the emergence of new industrial and activity centers, and then will stimulate population movement and growth. The increase of the population number and movement will encourage changes in land use. This study conducted to analyze the effect of road construction on the rate of land use change. Land use change caused by the construction of this road was identified by analyzing land use change with the help of a geographic information system. Satellite imageries are processed into maps based on geographic information systems to classify land use gradually over years. The results of this classification are then used for land use change analysis. The analysis carried out shows that there is a change in land use rate growth for building classification before and after road construction. Land use for growth for building classification is developed faster when a new road is built than before a road is built. In the area around the Salatiga and Ambarawa Ring Roads, the increase in the proportion of built-in land use is the conversion of forest land use and open land. Meanwhile, in the area around the Manado Ring Road, the increase in the proportion of built-in land use is the conversion of forest land use.

1. Introduction

Roads play an important role in the development of a region. The main function of roads is to support the development in production and service sectors as well as regional development of a city or region. Transportation and land use are two different but closely related aspects [1]. Another study also stated that transportation and land use are related to one another [2]. Previously, the construction of transportation infrastructure, particularly roads, was based on the location of residential areas and activity centers. However, nowadays, road infrastructure attracts more development and creates activity centers in the vicinity of the road infrastructure. The relationship between road infrastructure development and land use changes around the road infrastructure is crucial to be explored. The construction of a road, which initially aims to connect activity centers, in fact also encourages the development of activity centers around the road. This study was conducted to analyze the impact of the construction of a road on changes in land use, especially the change of a land use into a residential area.

2. Objective

The objective of this study is to analyze the impact of road construction on land use change. This study is focused on analyzing changes in land use, from non-residential land to residential land, to prove that road infrastructure investment generates new activity. The benefit of this study is to
specifically determine the relationship between the impact of road construction and the growth rate of settlements around the new road alignment. The growth rate of this residential area is then analyzed based on the stages of the development year. The analysis starts before the road is built, when it is built, until the road is operational.

3. Literature review

3.1. Land Use Change Due to Road Infrastructure
Various empirical and theoretical approaches found in various studies show that the existence of road infrastructure will encourage economic growth, foreign investment, and domestic trade activities in a country [3]. Moon [4] also stated that regional economic development will encourage land use change. The change that occurs is usually a change from land use without occupants to land use with occupied land or buildings. Examples of uninhabited land uses are forests, open land, and roads, while examples of inhabited land uses are residential area. Land use change is affected by many different factors, such as economic factors, human factors, and other physical factors [5]. According to Schneeberger [6], there are 5 main factors that drive land use change, namely political policies, economic conditions, cultural conditions, technology or availability of infrastructure, and natural factors. Investments in road construction are often carried out to increase the economic capacity of a region. The construction of this road is usually based on the direction of development policies in an area that has limited economic activity, for example, there is no industry or other economic activity. With the existence of road infrastructure, these activities will emerge, along with increasing population movements [7].

3.2. Geographic Information System (GIS)
Geographic Information System (GIS) is a software development for processing geographic data. The software includes mapping points, lines and regions, which are defined as coordinates. GIS translates the map data as layers, where each layer has certain data information. Once processed, the data can be stored in the Database Management System (DBMS). This GIS combines 3 technologies, namely user tools, DBMS, and spatial modeling tools [8]. Mapping using GIS began in the mid-1960s, using mainframe computers. GIS began to be used on personal computers since the early 1980s. At first, GIS was an interesting application, but it had many shortcomings, such as limited geographic data. The advantage of using this software is its ability to provide a database of historical image maps and facilitate the processing of existing satellite image information [9].

4. Methodology
In this study, data from Google Earth’s satellite imagery was used, with an eye height of 1.2 km. The range of image data used is 20 years, starting from 2000 to 2020. This research was conducted with the help of the Geographic Information System (GIS). The base map obtained from satellite imagery is then processed using the isolating spectral color band method and processed into a thematic map of each type of land use as shown in Figure 4. Satellite images are processed based on each time sequence until the operation period of the road. For each time sequence, the amount of land use cover is analyzed by spatial data. The change in increment rate of residential area is then plotted on a graph to compare the increment rate of residential area before and after a road is built.

5. Data Analysis
The main data used in this study is historical satellite image of a road development area. This satellite image is obtained based on a database from Google Earth. The road sections that are analyzed in this study are the Salatiga, Manado and Ambarawa Ring Road. The Salatiga Ring Road began operating in 2010 with 4 lane 2-way divided configuration. This road divides through traffic so they do not enter the Salatiga city area. This road length is 11.3 km. The Salatiga Ring Road Map is shown in Figure 1.
Figure 1. Salatiga Ring Road map.

The second road that was analyzed in this study is the Manado Ring Road. The length of Manado Ring Road is 8.27 km and it began to be used in 2013. The Manado Ring Road has 4-lane and 2-way (divided) configuration. The Manado Ring Road Map is shown in Figure 2.

Figure 2. Manado Ring Road map.

The third road that was analyzed in this study is the Ambarawa Ring Road. Ambarawa Ring Road began operating in 2011 with an undivided 2-lane and 2-way configuration. The length of Ambarawa Ring Road is 7.28 km as shown in Figure 3.
The analysis was carried out in several stages. The first stage is to carry out the process of isolating the spectral color band for each year in the time series as shown in Figure 4.

After this process is complete, conversion of each of the existing color spectrums into land use classifications is then carried out. The land use classification used is forest, road, building, and open land. The last stage of the analysis is to plot the proportion of buildings each year which are analyzed against the entire area of the satellite image to obtain patterns of land use change due to road construction. The analysis of land use proportion for Salatiga Ring Road is shown in Table 1.
Table 1. Time series of land use proportion on Salatiga Ring Road.

| Year | Forest   | Road    | Building | Open Land |
|------|----------|---------|----------|-----------|
| 2000 | 86.59%   | 0.00%   | 6.93%    | 6.48%     |
| 2001 | 86.25%   | 0.00%   | 7.42%    | 6.33%     |
| 2002 | 85.91%   | 0.00%   | 7.94%    | 6.15%     |
| 2003 | 85.57%   | 0.00%   | 8.36%    | 6.07%     |
| 2004 | 85.23%   | 0.00%   | 8.74%    | 6.03%     |
| 2005 | 84.89%   | 0.00%   | 9.16%    | 5.95%     |
| 2006 | 84.55%   | 0.00%   | 9.52%    | 5.93%     |
| 2007 | 84.21%   | 0.00%   | 9.91%    | 5.88%     |
| 2008 | 83.87%   | 0.00%   | 9.93%    | 6.20%     |
| 2009 | 83.53%   | 0.00%   | 10.32%   | 6.15%     |
| 2010 | 83.19%   | 1.01%   | 10.47%   | 5.33%     |
| 2011 | 82.85%   | 1.01%   | 10.81%   | 5.33%     |
| 2012 | 76.12%   | 1.42%   | 18.79%   | 3.67%     |
| 2013 | 76.00%   | 1.42%   | 18.91%   | 3.67%     |
| 2014 | 75.86%   | 1.42%   | 19.05%   | 3.67%     |
| 2015 | 75.02%   | 1.42%   | 19.89%   | 3.67%     |
| 2016 | 75.00%   | 1.42%   | 19.91%   | 3.67%     |
| 2017 | 74.82%   | 1.31%   | 20.35%   | 3.52%     |
| 2018 | 74.12%   | 1.31%   | 21.05%   | 3.52%     |
| 2019 | 73.92%   | 1.31%   | 21.25%   | 3.52%     |
| 2020 | 73.33%   | 1.31%   | 21.84%   | 3.52%     |

Figure 5. Change of land use proportion on Salatiga Ring Road.

When the road is built, there is a significant reduction in the proportion of forest and open land use. This reduction represents the conversion of forest and open land use to developed land use. This is supported by the illustration in Figure 5 which shows that the proportion of built-up land is increasing from year to year. Changes in the land use became more significant after the Salatiga Ring road was built. Analysis of land use proportion was carried out to investigate the impact of Manado Ring Road construction. Table 2 shows the change in the proportion of land use from year to year. It can be seen
that the proportion of developed land uses is increasing every year. In the vicinity of the Manado Ring Road, there has been a decrease in the proportion of forest land use area and an increase in the proportion of land use area for open land and built land. This is supported by the illustration in Figure 6 which shows the rapid growth of the developed land use proportion after the Manado Ring Road has been operated.

**Table 2.** Time series of land use proportion on Manado Ring Road.

| Year | Forest    | Road      | Building | Open Land |
|------|-----------|-----------|----------|-----------|
| 2000 | 90.00%    | 0.00%     | 1.00%    | 9.00%     |
| 2001 | 86.00%    | 0.00%     | 1.00%    | 13.00%    |
| 2003 | 86.20%    | 0.00%     | 1.70%    | 12.10%    |
| 2004 | 74.60%    | 0.00%     | 2.40%    | 23.00%    |
| 2005 | 73.20%    | 0.00%     | 2.80%    | 24.00%    |
| 2006 | 75.20%    | 0.00%     | 2.80%    | 22.00%    |
| 2009 | 65.38%    | 0.00%     | 5.45%    | 29.17%    |
| 2010 | 63.20%    | 0.00%     | 5.30%    | 31.50%    |
| 2011 | 46.10%    | 0.00%     | 6.90%    | 47.00%    |
| 2012 | 41.93%    | 0.00%     | 6.07%    | 52.00%    |
| 2013 | 42.00%    | 3.53%     | 7.79%    | 46.68%    |
| 2014 | 32.00%    | 3.53%     | 9.47%    | 55.00%    |
| 2016 | 8.20%     | 3.29%     | 23.51%   | 65.00%    |
| 2017 | 4.30%     | 3.75%     | 23.94%   | 68.00%    |
| 2018 | 4.80%     | 3.75%     | 25.45%   | 66.00%    |
| 2019 | 5.20%     | 3.75%     | 26.05%   | 65.00%    |
| 2020 | 5.78%     | 3.34%     | 27.88%   | 63.00%    |

**Figure 6.** Change of land use proportion on Manado Ring Road.

This result also proved that road construction accelerates the growth of built-up land. As shown in Figure 6, there is a significant increase of the developed land use proportion after the road is built. The increase of developed land use area comes from the conversion of forest land use. Table 3 shows the change in the proportion of land use around the construction of the Ambarawa Ring Road. A significant change in the proportion of land use area occurred when the Ambarawa Ring Road was
built. The proportion of forest and open land use area is decreasing, while the proportion of building area is increasing.

Table 3. Time series of land use proportion on Ambarawa Ring Road.

| Year | Forest (%) | Road (%) | Building (%) | Open Land (%) |
|------|------------|----------|--------------|---------------|
| 2000 | 36.80%     | 0.00%    | 8.20%        | 55.00%        |
| 2003 | 36.37%     | 0.00%    | 9.05%        | 54.58%        |
| 2004 | 36.22%     | 0.00%    | 9.34%        | 54.44%        |
| 2007 | 35.79%     | 0.00%    | 10.19%       | 54.02%        |
| 2008 | 35.65%     | 0.00%    | 10.47%       | 53.88%        |
| 2009 | 35.50%     | 0.00%    | 10.76%       | 53.74%        |
| 2010 | 35.36%     | 1.01%    | 11.53%       | 52.10%        |
| 2011 | 34.96%     | 1.01%    | 14.47%       | 49.56%        |
| 2012 | 34.56%     | 1.42%    | 16.14%       | 47.88%        |
| 2013 | 34.16%     | 1.42%    | 18.38%       | 46.04%        |
| 2014 | 33.76%     | 1.42%    | 19.92%       | 44.90%        |
| 2015 | 33.36%     | 1.42%    | 22.46%       | 42.76%        |
| 2017 | 32.81%     | 1.31%    | 26.70%       | 39.18%        |
| 2019 | 32.51%     | 1.31%    | 30.08%       | 36.10%        |
| 2020 | 32.36%     | 1.31%    | 31.77%       | 34.56%        |

Figure 7. Change of land use proportion on Ambarawa Ring Road.

Figure 7 shows the proportion of constructed land to the total land area. It can be concluded that the growth rate of built area grows more rapidly when the ring road is built.

6. Conclusion

Based on the analysis, it can be concluded that every year there is an increase on proportion of the developed land use. This growth will accelerate when road infrastructure is built [5]. The analysis shows the difference in increment rate of residential area before and after new roads are operated [6]. After the operation of the new road, the increase in land use was significantly faster. For the Salatiga and Ambarawa Ring Road, the increase of developed land use area comes from the conversion of
forest land use. For the Manado Ring Road area, the increase of developed land use area comes from the conversion of forest and open area.

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