Land use and trip production model in central and peri-urban Semarang to anticipate land use conversion in post pandemic era

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Abstract: The development of core and peri-urban Semarang has land use conversion that increases human mobility. If this phenomenon is not well anticipated, it will cause transportation problems such as inefficiency of energy, and pollution. After the pandemic, the urban activity will be normal, and land use conversion will be more extensive again. A transportation model is needed to understand the land use that most influences the movement. This article aims to formulate a mathematical model that can identify land uses that affect trips or movement. To build a model, data on trip production in each village in core and peri-urban Semarang as the dependent variable and the various land use as independent variables. The regression model obtained by D = 0.009 residence + 1432.529 with R2 0.597 in the core of Semarang and D = 0.004 residence – 991.223 with R2 0.791 in peri-urban. The results of this model show that the most influential type in causing trip attraction is residential land use both in peri-urban and in core Semarang with a different coefficient. According to these findings, it requires more attention from the Semarang City Government to regulate land use in anticipation of transportation problems.

Keywords: mobility, pandemic, peri-urban.

1. Introduction
Activities, networks, and flows built the urban transportation system [1]. The activity system could be represented by land use and the flow system by trip production. The interaction and relationship between them can be explained through a model. This model can predict trip production as a demand of travel by some variable of land use. One of the famous models to predict travel demand and indicate the transportation system performance is the Four Step Model [2]. The basic step is trip generation which indicates trip production for mobility out of the region and trip attraction for mobility into the region [3]. The flow system will affect the load of the network system and could cause the congestion represented by the magnitude of mobility. This interaction implies the need for modelling land use and trip attraction to predict human mobility. Using this model can overcome the transportation problem indicated by predicting the number of mobility. Knowing the number of mobility can be used to anticipate transportation problems such as congestion, pollution, and the use of energy. Besides this, the model can be used for another preventive problem solving to make the urban transportation system strong and in line with the sustainable development concept.
Semarang has grown rapidly and caused land use conversion mostly in the peri-urban area. Some conversions make sprawl of residential use. In the core of the city, there was mixed use from residential, commercial, and industrial. The land use conversion is different in the core of urban and in peri-urban Semarang. Economic activity has some influence on this conversion.

In early 2020, there was a bad phenomenon in the world announced by The World Health Organisation (WHO) [4] as a COVID-19 pandemic. This phenomenon is classified as a global world pandemic [5] and declared as destructive natural disaster [6]. This pandemic has numerous and serious social problems and economic implications in various sectors, including transportation, travel, and human mobility. Safety in the conditions of an epidemic becomes a high priority in problematic issues due to the social individual’s behavior and their diverse behavior attitudes in the mobility [7]. Human mobility numbers and patterns were used as a measure of behavioral indicators and responses during the COVID-19 pandemic [8]. On the other hand, the number and the pattern of human mobility have a significant relation to social economy interaction. Furthermore, the number of human mobility varieties is an important thing to determine and predict the socio-economic status of a region or urban. Both diversity and socio-economic beliefs have a two-directed relationship. The more high-developed region will provide a wider range of human mobility. On the other side, higher human mobility diversification will drive higher economic opportunities. This opportunity will lead to a higher socio-economic development index [9]. After 2 years, the pandemic gets better and the human activity is normal again. The economic rise will affect the land use conversion in part of the city like in the core of the city and peri urban area.

According to that situation, the trip attraction model is needed to develop to understand the interaction of type of land use as a representation of economic activity and the numbers of mobility. It is necessary to understand the difference of model in the case of core and peri urban Semarang. The land use that produces the large mobility must be anticipated and controlled due to the effect of trip production like congestion and energy issue.

2. The Study Purpose
This study provides and compares trip production model in four types of land use in two cases of core and peri urban Semarang.

3. Data and Method
Data used in this study are land use of Semarang in 2019 (Figure 1.) and trip production that was modified from 2017 to 2019 according to the population rate of the Semarang City consist 16 districts that consist of 177 villages and classified by 4 major land use such as residential, commercial, industry and open space. [10] The core area of Semarang consists of 35 villages (see Table 1, Table 2 and Figure 2) that have functions to be commercial and residential according to the master plan Semarang 2010-2030. The peri-urban consist of 27 villages, and the function is agriculture and residential. The trip production for each village (see Table 1 and Table 2) represent human mobility and depends on land use configuration both of core and peri urban.
Figure 1. Land use Semarang City 2019

Figure 2. Core and peri urban Semarang
Table 1. Trip Production and Land use in Core of Semarang

| District       | Social Facilities | Industry | Resid- | Commercial | Open Space | Trip Attraction |
|----------------|-------------------|----------|--------|------------|------------|-----------------|
| Bangunharjo    | 8052.5            | 0.0      | 20201.1| 61842.7    | 0.0        | 2669            |
| Barusari       | 21485.2           | 0.0      | 49425.5| 22261.6    | 2053.3     | 6193            |
| Brumbungan     | 12801.8           | 0.0      | 32947.5| 4103.3     | 944.3      | 2855            |
| Bugangan       | 10245.6           | 0.0      | 43514.5| 1421.5     | 0.0        | 6303            |
| Bulustalan     | 2899.1            | 0.0      | 28226.0| 31424.2    | 2846.8     | 5019            |
| Gabahan        | 6705.9            | 0.0      | 24403.7| 903.3      | 5293.9     | 5110            |
| Jagalan        | 11012.1           | 0.0      | 32556.3| 3686.3     | 4643.3     | 5038            |
| Karang Kidul   | 47324.9           | 0.0      | 43893.9| 33989.2    | 1349.6     | 3974            |
| Karangtempel   | 32018.0           | 0.0      | 71743.2| 689.0      | 3383.3     | 3153            |
| Karangturi     | 31588.2           | 0.0      | 24417.7| 698.1      | 0.0        | 2713            |
| Kauman         | 16685.6           | 0.0      | 18432.2| 30755.0    | 20467.7    | 3129            |
| Kebonagung     | 5542.3            | 0.0      | 21683.5| 19486.5    | 0.0        | 3388            |
| Kembang Sari   | 3488.3            | 0.0      | 20870.3| 77733.4    | 0.0        | 3263            |
| Kemijen        | 6182.8            | 0.0      | 87001.2| 2758.7     | 385140.2   | 9735            |
| Kranggan       | 6728.0            | 0.0      | 26230.7| 2650.2     | 3375.9     | 4448            |
| Lamper Kidul   | 10866.2           | 0.0      | 34447.9| 72805.9    | 11790.7    | 4129            |
| Lamper Lor     | 1917.7            | 0.0      | 34393.2| 1853.0     | 3589.0     | 5016            |
| Lamper Tengah  | 23646.7           | 0.0      | 68063.0| 4960.5     | 25994.9    | 10101           |
| Miroto         | 14920.8           | 0.0      | 33477.6| 1248.9     | 511.3      | 4111            |
| Mlatibaru      | 9553.9            | 0.0      | 60639.1| 1692.4     | 2048.3     | 6543            |
| Mlatiharjo     | 10797.9           | 0.0      | 47419.1| 2130.8     | 0.0        | 4222            |
| Mugasari       | 16240.4           | 0.0      | 58554.8| 62933.6    | 48063.2    | 6890            |
| Padangsari     | 60472.9           | 0.0      | 96048.8| 10860.5    | 417646.5   | 9272            |
| Pekunden       | 17118.4           | 0.0      | 36026.0| 16563.1    | 2170.4     | 3309            |
| Peterongan     | 49527.5           | 0.0      | 50776.2| 29986.8    | 7331.2     | 6353            |
| Petompon       | 92129.9           | 0.0      | 64606.7| 13510.5    | 119649.1   | 6158            |
| Pindrikan Kidul| 34196.5           | 0.0      | 33967.4| 4030.3     | 5272.3     | 3184            |
| Pindrikan Lor  | 13876.8           | 0.0      | 31642.3| 4668.4     | 394.9      | 5702            |
| Pleburan       | 135966.2          | 0.0      | 55438.9| 50225.5    | 40687.8    | 5036            |
| Purwodinatan   | 1865.0            | 0.0      | 24131.3| 135887.7   | 11315.5    | 3769            |
| Randusari      | 32827.1           | 0.0      | 57647.7| 32763.4    | 199404.3   | 6051            |
| Rejomulyo      | 9478.4            | 0.0      | 24108.3| 19200.6    | 2639.8     | 3146            |
| Rejosari       | 17213.2           | 0.0      | 83897.9| 10258.9    | 7415.3     | 11808           |
| Sarirejo       | 36656.1           | 0.0      | 37189.2| 37615.1    | 0.0        | 7188            |
| Sekayu         | 101778.1          | 0.0      | 46342.2| 77526.5    | 9959.4     | 3115            |
Table 2. Trip Production and Land Use in Peri Urban Semarang

| District              | Social Facilities | Industry | Residence | Commercial | Open Space | Trip Production |
|-----------------------|-------------------|----------|-----------|------------|------------|----------------|
| Bubakan               | 5174.5            | 0.0      | 700217.0  | 1758.6     | 1983110.5  | 1317           |
| Cangkiran             | 5346.2            | 0.0      | 710726.3  | 2229.1     | 1683693.9  | 1986           |
| Cepoko                | 29757.6           | 0.0      | 579721.9  | 2533.8     | 2093916.8  | 2268           |
| Gedawang              | 10999.3           | 0.0      | 1340877.2 | 857.18     | 1630927.4  | 4481           |
| Gunungpati            | 17318.9           | 0.0      | 1521719.3 | 1103.45    | 4464055.2  | 4189           |
| Jabungan              | 990.3             | 0.0      | 616207.5  | 1702.8     | 2797685.8  | 3674           |
| Jatisari              | 55427.0           | 0.0      | 1531593.4 | 9416.5     | 1459212.7  | 6478           |
| Karang Malang         | 7885.2            | 0.0      | 461758.5  | 1998.5     | 1034145.3  | 1400           |
| Kudu                  | 39877.4           | 0.0      | 355458.1  | 782135.0   | 4545598.8  | 5221           |
| Mangkang Kulon        | 39877.4           | 0.0      | 355458.1  | 782135.0   | 4545598.8  | 5221           |
| Mangunsari            | 4214.6            | 0.0      | 1446831.1 | 3247.8     | 1953940.2  | 3395           |
| Meteseh               | 33154.7           | 0.0      | 2607444.2 | 18963.9    | 652756.2   | 10634          |
| Pedurungan Kidul      | 35225.4           | 0.0      | 1341206.8 | 8124.2     | 124144.2   | 9273           |
| Penggaron Kidul       | 13632.4           | 0.0      | 1761589.1 | 38385.0    | 652756.2   | 4482           |
| Penggaron Lor         | 3118.2            | 0.0      | 1000164.6 | 2705.4     | 546304.0   | 3994           |
| Plalangan             | 41509.8           | 0.0      | 898805.4  | 38188.1    | 3086771.1  | 2904           |
| Plamongansari         | 20138.8           | 0.0      | 2307338.8 | 6387.1     | 317565.3   | 9274           |
| Podorejo              | 39920.2           | 0.0      | 1796896.1 | 29534.1    | 6034390.1  | 5181           |
| Polaman               | 7072.2            | 0.0      | 418630.8  | 1804.9     | 1005130.0  | 1486           |
| Pudak Payung          | 548634.1          | 0.0      | 3109019.8 | 34781.4    | 2731663.2  | 14928          |
| Purwosari             | 12506.0           | 0.0      | 1351863.4 | 7054.7     | 2493749.2  | 3277           |
| Rowosari              | 17648.1           | 0.0      | 3173794.2 | 6958.4     | 5181848.2  | 7350           |
| Sendang Mulyo         | 85406.6           | 0.0      | 3985883.5 | 23172.3    | 1696371.7  | 22489          |
| Sumurejo              | 35774.5           | 0.0      | 1612809.9 | 3795.3     | 2100330.1  | 4414           |
| Wonoplombon           | 3467.9            | 0.0      | 1104147.7 | 2013.0     | 6913751.8  | 2887           |
| Wonosari              | 139622.4          | 0.0      | 4017522.0 | 38451.7    | 1400058.7  | 13517          |

Table 1 shows that the biggest trip attraction is in Rejosari village. The land use of both village is dominated by residence, commercial and social facilities rather than another village. Rejosari is located at the east of CBD Semarang and connected with the arterial road in the middle of Semarang. Many social facilities like Hospital, Junior and Senior High School and Market Rejosari have been the most popular location.

Table 2 shows that the biggest trip production is in Pudak Payung Village. The land use of both villages is dominated by open space and residence. Pudak Payung Village is located on an arterial road that connects Semarang to other cities in the South of Semarang. With this good accessibility Pudak Payung became the most popular location of a residential area.

To build the model, the method in this study is multiple linear regression. [12] In this model trip production is used as the dependent variable and land use type is used as the independent variable. The land uses type used are Residence, Commercial, Industry, Social Facilities, and Open Space.
The formula is following as below

\[ D = f\left( {\text{Residence}, \text{Commercial}, \text{Industry}, \text{Social Facilities}, \text{Open Space}} \right) \]
\[ D = A_0 + B_1 \text{Residence} + B_2 \text{Commercial} + B_3 \text{Industry} + B_4 \text{Social Facilities} + B_5 \text{Open Space} + e \]

In core urban Semarang the dependent variable that is used is trip attraction, according that core urban tend to attract human mobility. With 35 villages as cases, it is enough data to process in statistical analysis. In peri-urban Semarang the dependent variable that is used is trip production according to the mobility tends from peri-urban to core. With 27 villages as cases, it is enough data to process in statistical analysis.

4. Result and Discussion

According to the multiple regression model and the stepwise method, there are two mathematical models derivate.

1. At the core of the Semarang the model with \( R^2 0.597 \) is
\[ D = 0.009 \text{residence} + 1432.529 \]

2. At the peri-urban of Semarang the model with \( R^2 0.791 \) is
\[ D = 0.004 \text{residence} - 991.223 \]

It is contradictive with the assumption that commercial activities are believed to become the second most common factor to trip attraction besides work activities in urban activity [13]. In some cases, the contribution of commercial activity to trip attraction is indicated by 5% within the city [14]. In these models, both core and peri-urban trip production is generated by residential use. The different coefficient can analyze that residence in core urban generated trip little greater than in peri urban area. It showed that in the core of Semarang, there is still land that can convert to residential use and contribute to generating trips. On the demand side it showed that citizens in Semarang tend to locate their residence in the core of urban. Trip production in core urban tends to short distances. The citizen tends to choose their residence nearby their work or office.

In the peri-urban area, although the coefficient is less than in core urban, the residential use is the common factor that contributes the trip production. With the assumption for the citizen that their work location in the core of Semarang the trip production characteristic is long distance.

After the pandemic era the economic growth will increase optimistically [15]. That growth will be affected by demand for the residence. With two different characteristics of trip production, the Government of Semarang need a policy to anticipate the transportation problem. In core of Semarang need a mixed-used approach to serve short trip. In peri-urban of Semarang need public transportation approach to serve long trip.

5. Conclusion

There is no difference in land use that produces human mobility in core and peri urban Semarang. Both in the core urban and peri urban residential use is the activity that attracted human mobility. Although residential use is the common land use that generates trips, there is a different coefficient in core urban and peri urban. It must be caring for government to anticipate the rise of land use conversion to become residential by control and public transportation supply in order to reduce congestion and energy consumption in the future. This model can be used to generate and derivate the policy in order to strengthen city toughness in the sustainable development context.

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