Impact of transportation on urban compactness index in South Tangerang City, Indonesia

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Abstract. This study aims to identify the impact of transportation on the urban compactness index in South Tangerang. The urban form of a compact city was influenced by transportation. The implement of a compact city is necessary to measure the impact of transportation as a variable of this paper itself. This paper uses quantitative statistical methods to identify the effect of transportation on the urban compactness index. The variables used include Urban Compactness index, road networks, public transportation routes, public transport services, and public transportation accessibility. The results of this research indicate that, first, there is a positive influence on the arterial road density and the distance from the farthest houses to the bus stop, and second, the ratio of the length of public transport routes has a negative effect on the Urban Compactness index were the proportion of routes in areas which not served by public transport networks will make the areas not compact. The conclusion is the linkages between regions from a transportation system connected to the road network indicate that travel distances tend to be shorter in a compact city, so the three factors could be a reference to optimizing development in the application of Compact City in South Tangerang City.

1. Introduction
South Tangerang City is one of numerous cities that highly influence and influenced by urban sprawl phenomenon occurred in Jabodetabek area. Compact city concept is one of a number of city planning approaches produced as a response towards urban sprawl phenomenon development which is considered harmful for city development process [1]. A compact city formation is seen by the existence of mixing between land utilization and an interconnected roads layout, supported by strong transportation [2]. Compact City can be acknowledged by measuring urban compactness index [3]. Based on a research result produced by Mahriyar et al [4], there is a variation of urban compactness index valuation in each village located in South Tangerang City. However, a research conducted by Zalsabila et al [5] stated that city compactness is affected by transportation. Based on that, to apply Compact City index valuation is not the only thing that matters [6], but a valuation of transportation aspect as a variable of compact city to acknowledge impacting factors of transportation aspects towards urban compactness index is required [7]. This research is aimed to identify the impact of transportation factor towards urban compactness index by using two approaches [8] namely, analyzing each aspect of transportation and identifying influencing factor of transportation towards urban compactness index [9].
2. Research methodology

This is a quantitative descriptive and a quantitative statistics research. Descriptive quantitative approach was carried out to determine the urban compactness index obtained from previous studies, then the calculation of transportation aspects obtained from previous studies and theoretical reviews in the form of variables and quantitative statistical approaches were carried out to identify factors of transportation aspects that influenced the urban compactness index. The following Table 1 describe the variables and indicators used in this research.

| Variables            | Indicators                        | Type of Data |
|----------------------|-----------------------------------|--------------|
| Urban Compactness Index | Densification Index | Secondary   |
|                      | Mixed Use Index | Secondary    |
| Roads Network        | Arterial Road Density | Secondary   |
|                      | Collector Road Density | Secondary   |
|                      | Local Road Density | Secondary    |
|                      | Connectivity Level (Beta Index) | Secondary |
| Public Transportation Route | Public Transportation Route Length Ratio | Secondary |
| Public Transportation Service | Service Frequencies | Secondary   |
| Public Transportation Accessibility | The Distance from The Farthest Houses to the Bus Stop | Secondary |

The urban compactness index calculation is obtained from previous studies determined by the addition of the densification index and the mixed use index [10]. Index in this case is a scale of values or index that contains valuation levels from highest to lowest. The higher the value or urban compactness index, a city can be said to be more compact. After acknowledging the level of the urban compactness index, the road network, public transportation routes, public transportation services, and public transportation accessibility is calculated [11]. Then, a multiple linear regression statistical analysis is performed to identify transportation aspect factors that affect urban compactness index.

3. Results and discussion

Based on the previous research, urban index compactness in Tangerang City is highly varied for every village. The existence of other aspects that might affect urban compactness index measurement in Tangerang City is examined by focusing on transportation aspect.

3.1. Road network

Indicators on this variable are Arterial Road Density (X1), Collector Road Density (X2), Local Road Density (X3), and Connectivity Level (X4). Road network density analysis was conducted by using main data of road network length in every village divided by the area of each village. The lack of network connectivity between the location of the residence and the workplace results in low accessibility of the facility [12]. Connectivity measurement is conducted by using network analysis on Geographic Information System (GIS) software to acknowledge beta index valuation [13].

3.2. Public transportation route (X5)

The indicator in this variable is the length ratio of public transportation route which is one of the building factors affecting the size of urban compactness [13]. In the analysis, public transportation route data required is digitized using GIS (Geographic Information System) software and compared with the total
length of roads in each village. By doing so, the ratio of public transportation length and the total length of each road is obtained.

3.3. Public transportation service
Service frequencies (X6) and public transportation service time (X7) acts an indicator in this variable, from the results of digitized public transport routes, routes are obtained in each village. Analysis of service frequency by calculating the average number of operating vehicles within one hour on each route. While, the analysis of public transport service time is conducted by focusing on the average time required by the number of operating vehicles within one hour on public transport routes, where the availability of public transportation supported by the timeliness of services will increase city compactness level.

3.4. Public transportation accessibility (X8)
Accessibility of public transportation is done by analyzing the distance needed from the farthest houses to arrive at the bus stop, where proximity is one of the main physical elements of a compact city, meaning that the closer to the bus stop, the higher Urban Compactness index in the area. This analysis uses network analysis using GIS (Geographic Information System) software. Furthermore, overlay techniques are carried out with public transportation routes that have been digitized, so that it is seen which area have not been facilitated by public transportation to the bus stops.

3.5. Transportation aspect affecting urban compactness index
In multiple linear regression analysis, the independent variables used are Arterial Road Density (X1), Collector Road Density (X2), Local Road Density (X3), Connectivity Level (X4), Public Transportation Route Length Ratio (X5), Service Frequencies (X6), Service Time Public Transport (X7), The Distance from the Farthest Houses to the Bus Stop (X8), while the dependent variable used is the urban compactness index (Y). Based on the results of the multiple linear regression analysis of stepwise methods, which interpret aspects that significantly affect the urban compactness index, namely the regression model:

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Y = 14.958 + 0.549 (X1) - 0.746 (X5) + 0.005 (X8)
\]

Y: Urban Compactness Index
X1: Arterial Road Density
X5: Public Transportation Route Length Ratio
X8: The Distance from the Farthest Houses to the Bus Stop

The results of the regression show three indicators that affect the value of the Urban Compactness index. The following values from the transportation aspects that affect the urban compactness index of transportation can be seen on Table 2.

Based on the resulted regression model, there are three factors that significantly affect the urban compactness index in South Tangerang City, namely the arterial roads density, public transportation route length ratio, and farthest houses to the bus stop. The variables can explain the urban compactness index with a percentage of 93.4% in the R square value. Other variables do not affect the urban compactness index because they produce significant values that are not in accordance with the probability value equal to <0.05.

The road network aspect shows the role of arterial road density in shaping South Tangerang City compactness. This can be seen with the higher urban compactness index indicating the higher road network in the area, where the road network is an infrastructure in the transportation system. Linkages between regions cannot be separated from a transportation system connected to the road network. In this case, the arterial road in South Tangerang City can provide access towards activity centers and the city center which is relatively close to DKI Jakarta, Tangerang City, Tangerang Regency, Bogor City, and Depok City.
Table 2. Statistical value indicators affect the urban compactness index.

| Sub-District   | Village        | Urban Compactness Index | Arterial Road Density | Route Length Ratio | Farthest Houses to the Bus Stop |
|----------------|----------------|-------------------------|-----------------------|--------------------|---------------------------------|
|                |                | Y  | X1  | X5  | X8  |                      |                                    |
| Ciputat        | Serua          | 71.58 | 9.69 | 1.25 | 3.60 |                      |                                    |
|                | Jombang        | 92.44 | 11.18 | 0.66 | 0.93 |                      |                                    |
|                | Sawah Baru     | 88.97 | 8.11 | 0.28 | 2.00 |                      |                                    |
|                | Serua Indah    | 72.77 | 3.78 | 2.58 | 3.16 |                      |                                    |
|                | Sawah Lama     | 87.87 | 0.00 | 1.36 | 2.94 |                      |                                    |
|                | Ciputat        | 112.3 | 1.24 | 2.01 | 2.34 |                      |                                    |
|                | Cipayung       | 64.29 | 15.26 | 0.72 | 1.22 |                      |                                    |
| East Ciputat   | Pisangan       | 66.71 | 2.16 | 0.52 | 1.72 |                      |                                    |
|                | Cirendeu       | 69.03 | 0.55 | 0.00 | 1.54 |                      |                                    |
|                | Cempaka Putih  | 89.73 | 2.91 | 0.22 | 0.99 |                      |                                    |
|                | Rempoa         | 99.25 | 3.80 | 0.33 | 2.16 |                      |                                    |
|                | Rengas         | 71.37 | 12.32 | 1.37 | 1.28 |                      |                                    |
|                | Pondok Ranji   | 78.49 | 32.00 | 0.45 | 1.76 |                      |                                    |
| Pamulang       | Pondok Benda   | 124.01 | 0.00 | 0.57 | 1.81 |                      |                                    |
|                | Pamulang Barat | 83.87 | 0.00 | 1.48 | 0.43 |                      |                                    |
|                | Pamulang Timur | 93.89 | 0.00 | 0.30 | 0.96 |                      |                                    |
|                | Pondok Cabe Udik | 41.93 | 0.00 | 0.74 | 2.79 |                      |                                    |
|                | Pondok Cabe Ilir | 101.53 | 0.00 | 2.23 | 1.48 |                      |                                    |
|                | Kedaung        | 140.78 | 0.00 | 0.95 | 2.17 |                      |                                    |
|                | Bambu Apus     | 108.75 | 0.00 | 0.63 | 3.63 |                      |                                    |
|                | Benda Baru     | 66.88 | 0.00 | 0.63 |                  |                                    |
| Pondok Aren    | Perigi Baru    | 56.33 | 5.22 | 0.31 | 3.35 |                      |                                    |
|                | Pondok Kacang Barat | 88.13 | 0.00 | 0.40 | 0.71 |                      |                                    |
|                | Pondok Kacang Timur | 119.42 | 0.00 | 0.32 | 2.69 |                      |                                    |
|                | Parigi         | 44.12 | 7.01 | 0.33 | 2.74 |                      |                                    |
|                | Pondok Pucung  | 71.32 | 4.51 | 0.51 | 1.93 |                      |                                    |
|                | Pondok Jaya    | 45.65 | 21.00 | 0.30 | 1.17 |                      |                                    |
|                | Pondok Aren    | 89.77 | 0.00 | 0.47 | 3.22 |                      |                                    |
|                | Jurang Mangu Barat | 109.88 | 2.68 | 0.32 | 1.76 |                      |                                    |
|                | Jurang Mangu Timur | 116.72 | 1.25 | 0.65 | 1.34 |                      |                                    |
|                | Pondok Karya   | 117.85 | 9.21 | 0.75 | 1.08 |                      |                                    |
|                | Pondok Betung  | 120.37 | 13.89 | 0.15 | 1.63 |                      |                                    |
| Serpong        | Buaran         | 52.92 | 0.00 | 0.89 | 2.34 |                      |                                    |
|                | Ciater         | 67.00 | 5.77 | 0.29 | 2.31 |                      |                                    |
|                | Rawa Mekar Jaya | 44.89 | 28.31 | 0.35 | 1.60 |                      |                                    |
|                | Rawa Bantu     | 54.25 | 28.25 | 0.29 | 0.70 |                      |                                    |
|                | Serpong        | 72.00 | 0.00 | 0.70 | 3.03 |                      |                                    |
|                | Cilenggang     | 35.80 | 37.83 | 0.37 | 1.45 |                      |                                    |
|                | Lengkong Gudang | 31.50 | 11.77 | 0.08 | 0.83 |                      |                                    |
|                | Lengkong Gudang Timur | 32.78 | 14.44 | 0.79 | 1.16 |                      |                                    |
|                | Lengkong Wetan | 56.58 | 6.01 | 0.25 | 1.70 |                      |                                    |
| North Serpong  | Lengkong Karya | 23.97 | 10.36 | 0.54 | 1.99 |                      |                                    |
|                | Jelupang       | 59.69 | 0.00 | 0.13 | 2.14 |                      |                                    |
|                | Pondok Jagung  | 78.42 | 0.00 | 0.00 | 1.34 |                      |                                    |
|                | Pondok Jagung Timur | 75.33 | 11.69 | 0.11 | 0.80 |                      |                                    |
|                | Pakulonan      | 46.21 | 8.25 | 0.00 | 0.61 |                      |                                    |
|                | Paku Alam      | 48.35 | 10.12 | 0.00 | 0.53 |                      |                                    |
|                | Paku Jaya      | 82.70 | 3.02 | 0.00 | 0.72 |                      |                                    |
| Setu           | Kranggan       | 47.04 | 0.00 | 0.52 | 3.95 |                      |                                    |
|                | Muncul         | 35.27 | 0.00 | 0.79 | 2.13 |                      |                                    |
|                | Kademangan     | 86.15 | 1.62 | 0.72 | 2.51 |                      |                                    |
|                | Setu           | 30.63 | 3.02 | 1.42 | 0.64 |                      |                                    |
|                | Babakan        | 30.38 | 0.00 | 0.37 | 2.72 |                      |                                    |
|                | Bakti Jaya     | 101.58 | 0.00 | 0.00 | 3.55 |                      |                                    |

The indicator of public transportation route length ratio shows the role in shaping the structure of Compact City in South Tangerang City, which in urban areas linked by public transport systems is one of the characteristics of the compact city. The ratio of the length of public transport routes has a negative
effect on the Urban Compactness index. However, that does not mean that public transportation routes are not the concern of the concept of a compact city. In South Tangerang City itself, one of the policies in spatial structure in the South Tangerang City Spatial Plan is to develop and improve transportation infrastructure based on integrated and controlled public transportation. Therefore, the provision of public transportation systems plays an important role in the concept of space compacting, but the percentage of private vehicle users in South Tangerang is still relatively greater than public transportation and there are still several areas that have not been served by public transportation.

The last aspect that influences the urban compactness index is the distance from the farthest houses to the bus stop. This can be seen with the closer to the bus stop, the higher Urban Compactness index in the area. This aspect is very closely related to the availability of public transport routes. The importance of adding public transportation routes in areas that have not been served by the public transportation network in forming the compactness structure can be seen as in North Serpong and Setu Districts in a number of villages that have not been facilitated by public transport routes, thereby the increasing of the underdeveloped urban compactness areas tends to be low.

4. Conclusion
Based on the results of the study, the measurement of urban compactness index is significantly influenced by three factors, namely arterial roads density, public transportation route length ratio, and the distance from the farthest houses to the bus stop. For the aspect of road network, it can be said that the higher the value of the aspect, the more compactness in the area is formed. The ratio of the length of public transport routes has a negative effect on the Urban Compactness index. This is due to several things, the percentage of private vehicle users in South Tangerang is still relatively greater than public transportation and there are still several areas that have not been served by public transportation. Both aspects are inversely proportional to the distance of the farthest houses to the bus stop, namely the lower the value of the distance of the farthest settlement to the bus stop, the higher the value of the urban compactness index in the region, meaning that the closer the distance to the bus stop, the higher the Urban Compactness index in the region. The farthest houses to the bus stop is related to public transportation routes. The unavailability of adequate public transport routes in an area will become an addition to the underdevelopment of urban compactness areas. The three factors that can affect the urban compactness index can be a reference to optimize the development of transportation aspect in the realization of Compact City in the South Tangerang

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