Urban development control based on transportation carrying capacity

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Abstract. Severe transportation problems in Indonesian urban areas are stimulated by one fundamental factor, namely lack of awareness on transportation carrying capacity in these areas development control. Urban land use development towards more physical coverage is typically not related with the capability of transportation system to accommodate additional trips volume. Lack of clear connection between development permit with its implication on the transport side has led to a phenomenon of exceeding transport demand over supply capacity. This paper discusses the concept of urban land use development control which will be related with transport carrying capacity. The discussion would cover both supply and demand sides of transportation. From supply side, the analysis regarding the capacity of transport system would take both existing as well as potential road network capacity could be developed. From demand side, the analysis would be through the control of a maximum floor area and public transport provision. Allowed maximum floor area for development would be at the level of generating traffic at reasonable volume. Ultimately, the objective of this paper is to introduce model to incorporate transport carrying capacity in Indonesian urban land use development control.

1. Introduction
In Indonesia urban areas, land use development keeps going on to fulfil the residents needs for housing as well as other facilities. However, in most cases, urban land use development does not seem to have a clear reference on transport carrying capacity. Despite long awareness of land use development impact on transport system: land use development causes new trip generation/attraction in urban road network that increases the traffic volume [1], we hardly found a systematic method to take it into land use development control account, especially for Indonesia case. It would be necessary then, to develop a model that systematically incorporate transport carrying capacity as one crucial element in urban land use development control.

In environmental study, carrying capacity is the ability of the environment to support humans and other living beings. Analogically, in transportation study, carrying capacity could be define as the ability of the whole transport system to accommodate trip volume at the level in which a reasonable level of service is maintained. Since we understand that land use development implies additional trip volume, then it should be stopped at the level in which its implication on transport system start to threat the reasonable level of service. (e.g. by using VCR/volume to capacity ratio criteria).
Transport level of service is the reflection of volume to capacity ratio. Solving the problems of traffic that comes from an imbalance proportion between volume and capacity can be solved in three ways [2]:

1. Adding supply capacity by building new roads or widening existing roads. This method may not be carried out continuously since there is certainly limitations of the space for road widening as well as economic-social-cultural problems.
2. Reducing the volume of traffic by reducing the number of vehicles through land use management, public transport provision, etc.
3. Combining the first and the second method through traffic management.

This paper uses those three ways to further discuss the analytical model of using the transport carrying capacity as the basis for urban land use development control that is able to provide guidance for land use development control to maintain reasonable transport level of service. In this study, land use development control is approached by supply and demand management. According to Massachusetts Highway Department [3] in Setiawan [4], traffic management is a process of setting on supply and demand in existing road system for specific purpose without adding new infrastructure, through the reduction and regulation of traffic movement. From that definition, it is clear that traffic management is done by optimizing the supply and controlling the demand [5].

From demand management point of view, land use development control is done by determining maximum floor area allowed for development, as this will manage trip generation at the required level. Next section will discuss model development to incorporate all the above variables which basically incorporate transport carrying capacity to urban land use development control. This model may be further develop as a practical tools for urban land use planning permit.

2. Methodology of The Research
This section describe the data collection and analysis methods of this urban land use control-transport carrying capacity model.

2.1 Data Collection Method
The type of data in this model include primary data and secondary data. The primary data is obtained from field survey. The secondary data is obtained from institutions, literatures, newspaper, and other sources. This survey is needed to get a description about transport condition and land use in urban area.

2.2 Data Analysis Method
Methods of data analysis in this section is the result of analysis from secondary data. The method developed in this paper is expected to be the initial form of model for future urban land use development control that accommodate transport carrying capacity. The sequential step of the model is based on transport supply and demand management as can be seen in Figure-1.
Figure 1. Flow chart: Analysis of transport carrying capacity for urban development control

Supply

Determination of maximum road area

More than 20% of urban area is developed for road area

Less than 20% of urban area is developed for urban area

Adding road area is possible

Determination of possible road capacity improvement

Determination of maximum additional traffic volume can be accommodated

Demand

Determination of maximum trip generation that is allowed

Determination of maximum floor area that can be developed

Existing developed area less than maximum floor area that is allowed for development

Existing developed area exceeds maximum floor area that is allowed for

Developing public transportation (as a case study)

Shifting of private car users to Public Transportation

Decreasing traffic volume on road

Increasing level of service (LOS) on road

Land use development is allowed up until maximum limitation is reached
2.3 Transport Supply
From supply side, the analysis is proceed by calculating maximum road space that still can be developed in urban area. Here are the stages of the analysis carried out from the supply side.

2.3.1 Maximum Area for Road Development
Construction on the street in urban area in this study refers to Ministry of Public Work Regulation No 05/PRT/M 2008 which guide the provision and utilization of green open space in Urban Area [6]. The proportion of the road network in urban areas based on this regulation is 20% of the urban area. Therefore, road space that can be developed can be calculated with the following formula:

\[
\text{Road Area}_{\text{mx}} = 20\% \times \text{Urban Area}
\]  

(1)

2.3.2 Maximum Traffic Volume.
The maximum volume of traffic on this study is maximum traffic volume that can be allowed to pass road network based on volume capacity ratio (VCR) plan. VCR plan that is used in this study is 0.75 which is the limit of level of service (LOS) that is considered a good LOS for road in Urban Area.

Once the Volume Capacity Ratio (VCR) is known, the maximum traffic volume \( V_{\text{max}} \) can be calculated. \( V_{\text{max}} \) can be described as maximum traffic volume that can be accommodated by the road at the planned VCR. \( V_{\text{max}} \) can be calculated by multiplying VCR plan with existing road capacity (C). Maximum traffic volume \( V_{\text{max}} \) is calculated as follow:

\[
V_{\text{max}} = VCR_{\text{plan}} \times C_{\text{existing}}
\]

(2)

Once \( V_{\text{max}} \) has been known, \( V_{\text{max}} \) in this study is considered as maximum trip generation maximum \( (TG_{\text{max}}) \) that is allowed. So, the trip generation that is produced by land use may not exceed the maximum trip generation.

2.4 Transport Demand
From transport demand management point of view, the approach that is by reducing private car users. These methods are expected to reduce total traffic volume to maintain a reasonable transport level of service. The method of calculation is developed as follows:

2.4.1 Maximum Floor Area Development Allowed
To calculate trip generation produced by one area, trip rates of each type of land use are required. The value of trip generation can be calculated by using trip rate standard for each land use type. The formulation to calculate trip generation is:

\[
TG_{\text{max}} = \sum \text{Trip Rate}_{GL} \times A_{GL}
\]

where:

\( TG_{\text{max}} = \) Maximum trip generation (pcu/hour)

\( \text{Trip Rate}_{GL} = \) standard trip rate for land use type GL (pcu/ hour/m²)

\( A_{GL} = \) Area Floor of land use type GL (m²)

The above formula can be used to calculate the maximum additional floor area development (of land use type GL) allowed, by using the formula:
\[ A_{GL} = \frac{T_{G_{\text{max}}}}{\sum \text{Trip Rate}_{GL}} \] (4)

where:
\begin{align*}
A_{GL} &= \text{maximum additional floor area development, of land use type GL (m}^2) \\
T_{G_{\text{max}}} &= \text{Maximum trip generation (pcu/hour)} \\
\text{Trip Rate}_{GL} &= \text{standard trip rate for land use type GL (pcu/hour/m}^2)
\end{align*}

Therefore, \( A_{GL} \) can be referred as the parameter to control land use development in that area. Land use development permit should be subject to criteria that no further permit would be granted if the total area development has reached \( A \) m\(^2\).

2.4.2 Percentage of Private Vehicle Users that can be converted to Public Transport

The objective of this section is to estimate the potential traffic volume reduction, by shifting some of the traveller from private to public transport. There are numbers of method could be chosen to proceed the calculation, e.g. based on modal choice questionnaire. Results of the survey is the percentage of private vehicle users who are shifted to public transport. In this section, the percentage of mode shift from private car to public transport is based on types of private vehicles used (this study assesses private car and private motorcycle).

2.4.3 Traffic Volume Reduction by Private to Public Transport Shift

Traffic volume reduction depend on the number private vehicle user shift to public transport. Once the percentage of private vehicle users who are shifted to public transport has been known, we can calculate the traffic volume reduction. There steps are :

1. Calculate the total passenger of private vehicle (P) by multiplying the number of private vehicle (Vp) with its average Load Factor (LF) :
\[ P = Vp \times LF_v \] (5)

2. Calculate the total passengers who are shifted from private to public transport (SP) by multiplying the probability of private to public transport shift (%P) with total passenger of private vehicle (P):
\[ SP = %P \times P \] (6)

3. Calculate the number of public transport (Npu) by dividing the total passengers who are shifted from private to public transport (SP) with the public transport average load factor (LFp)
\[ Npu = \frac{SP}{LFp} \] (7)

4. Then multiplying the number of public transport (Npu) with standard of pcu (sn) to get the number volume public transport in pcu unit (Vpu) :
\[ Vpu = Npu \times sn \] (8)

5. To calculate the new total traffic volume (Vn), the Vpu is added to the remaining volume of private vehicle (Vpr) whose passengers are not shifted to public transport
\[ Vn = Vpu + Vpr \] (9)
6. Lastly, to know the new traffic performance (VCRn), the new total traffic volume (Vn) is divided by road capacity (C). Whenever the VCRn shows the value of less than 1, it means there would be some additional traffic volume are allowed.

3. Model Application
The objective of this paper is to introduce model to incorporate transport carrying capacity in Indonesian urban land use development control. To do so, this paper examines the model in 2 Indonesian cities: Bandung and Cilegon. Those cities represent big city and small city. The results of the examination are as follow:

3.1 Bandung City
Bandung city is a city in West Java Province. The development of Bandung City is massive, so it would be hard to build new road in Bandung City. Therefore, Tansport Demand Management (TDM) is needed to manage the transport. There are two ways of TDM that can be introduced: controlling maximum floor area of development and promoting public transport.

3.1.1 Maximum Floor Area Development Allowed
Four roads are examined in Bandung City: Jl. AH. Nasution, Jl. Ahmad Yani, Jl. Raya Kopo, and Jl. Wastukencana. The following table show the existing traffic condition in peak hour in the four roads.

| No | Road Name          | Type of Road             | C (pcu/hr) | V (pcu/hr) | VCR               | LOS |
|----|--------------------|--------------------------|------------|------------|--------------------|-----|
| 1  | Jl. AH Nasution    | Primary arterial road    | 4236.96    | 4130.667   | 0.974913           | E   |
| 2  | Jl. Ahmad Yani     | Secondary arterial road  | 4236.96    | 3202.254   | 0.75579            | C   |
| 3  | Jl. Raya Kopo      | Primary collector road   | 4236.96    | 4158.996   | 0.981599           | E   |
| 4  | Jl. Wastukencana   | Secondary collector road | 3643.2     | 1869.75    | 0.513216           | C   |

When the existing VCR compared with planned VCR, all roads have exceeded the plan. The following table shows a comparison between the existing peak based-VCR with VCR plan. VCR plan is set at 0.75, which is the limit of degree of saturation (MKJI, 1997)

| No | Road Name            | VCR Existing | LOS Existing | VCR Plan | LOS Plan | Land Use Development Permit |
|----|----------------------|--------------|--------------|----------|----------|-----------------------------|
| 1  | Jl. AH Nasution      | 0.974913     | E            | 0.75     | C        | Not Allowed                 |
| 2  | Jl. Ahmad Yani       | 0.75579      | C            | 0.75     | C        | Not Allowed                 |
| 3  | Jl. Raya Kopo        | 0.981599     | E            | 0.75     | C        | Not Allowed, but Limited    |
| 4  | Jl. Wastukencana     | 0.513216     | C            | 0.75     | C        | Not Allowed                 |

Based on above table, the two roads still meet requirement: Jl. Ahmad Yani and Jl. Wastukencana. However, Jl. AH Nasution and Jl. Raya Kopo have exceeded LOS Plan. So, one way to improve LOS is through transport demand management (TDM) by land use development control. Before calculating floor area of land use maximum, we calculate the maximum traffic volume (Vmax) of the four roads. Table-3 shows the results.
Table 3. V max of roads in Bandung City

| No | Road Name       | VCR Plan | C Existing | V max  |
|----|----------------|----------|------------|--------|
| 1  | Jl. AH Nasution | 0.75     | 4236.96    | 3177.72|
| 2  | Jl. Ahmad Yani  | 0.75     | 4236.96    | 3177.72|
| 3  | Jl. Raya Kopo   | 0.75     | 4236.96    | 3177.72|
| 4  | Jl. Wastukencana| 0.75     | 3643.2     | 2732.4 |

Once the Vmax is determined, the maximum land use area can be calculated. The following section shows maximum floor area that can be developed in Bandung city based on Vmax for each road. Land Use proportion can be determined by the government plan. In this paper proportion of land use is determined by sample of land use area existing that is next to the road.

Table 4 Maximum Land Use Area

| No | Land Use | Vmax | Land Use Proportion | Trip Generate Max | Trip Rate | Maximum Land Use Area (m²) |
|----|----------|------|---------------------|-------------------|-----------|---------------------------|
|    |          |      |                     |                   |           |                           |
| Jl. A.H. Nasution | | | | | | |
| 1  | Commercial | 3177.72 | 29.16% | 926.54 | 0.012* | 77212.21 |
| 2  | Industry   | 3177.72 | 40.65% | 1291.80 | 0.118*** | 10947.46 |
| 3  | Office     | 3177.72 | 14.10% | 447.91 | 0.01* | 44791.65 |
| 4  | Education  | 3177.72 | 0.28% | 8.77 | 0.0237** | 370.06 |
| 5  | Residential| 3177.72 | 15.82% | 502.68 | 0.0037* | 135861.003 |

| Jl. Ahmad Yani | | | | | | |
| 1  | Commercial | 3177.72 | 80.24% | 2549.73 | 0.012* | 212477.13 |
| 2  | Office     | 3177.72 | 8.52% | 270.86 | 0.01* | 27085.55 |
| 3  | Worship    | 3177.72 | 1.32% | 41.81 | 0.0193** | 2166.17 |
| 4  | Education  | 3177.72 | 9.92% | 315.33 | 0.0237** | 13305.14 |

| Jl. Raya Kopo | | | | | | |
| 1  | Commercial | 1906.632 | 78.54% | 2495.63 | 0.012* | 207969.06 |
| 2  | Industry   | 1906.632 | 19.84% | 630.45 | 0.118*** | 5342.76 |
| 3  | Residential| 1906.632 | 0.72% | 22.99 | 0.0037* | 6214.29 |
| 4  | Office     | 1906.632 | 0.90% | 28.65 | 0.01* | 2865.21 |

| Jl. Wastukencana | | | | | | |
| 1  | Commercial | 2732.4 | 9.85% | 269.25 | 0.012* | 22437.91 |
| 2  | Residential| 2732.4 | 2.45% | 67.02 | 0.0037* | 18112.99 |
| 3  | Perkantoran| 2732.4 | 78.41% | 2142.42 | 0.01* | 214242.51 |
| 4  | Worship    | 2732.4 | 5.68% | 155.075 | 0.0193** | 8034.98 |
| 5  | Education  | 2732.4 | 3.61% | 98.62 | 0.0237** | 4161.46 |

Description:

a) Trip Rate CBD DKI Jakarta, 1990
b) Trip Rate Country Sandiego, 2003
c) Trip Rate Kota Cirebon and Semarang, 2000

Table 4 shows the results of the estimated maximum land use area, which can be used as a guideline for land use development control in each areas. Given the fact that maybe the existing land
use level has exceeded these “normal level”, public transport development approach could be introduced as alternative control mechanism.

3.1.2 Traffic Volume Reduction by Private to Public Transport Shift

Firstly, we need to know the composition of vehicles. In this research, the scenario is to shift some of the private vehicles (motorcycles and private car) passengers to public transport (angkot). The following is the vehicle composition in four roads in Bandung City.

Table 5. Traffic Volume off Road Existing According to Vehicle Composition

| No | Road Name            | Motorcycles     | Light Vehicles - Private Car | Light Vehicles - Public transport | Heavy Vehicles | Total (pcu/hour) |
|----|----------------------|-----------------|------------------------------|-----------------------------------|----------------|-----------------|
| 1  | Jl. AH Nasution       | 2350.80         | 1094.08                      | 438.27                            | 247.51         | 4130.68         |
| 2  | Jl. Ahmad Yani       | 1530.09         | 1354.32                      | 170.1                             | 147.74         | 3202.25         |
| 3  | Jl. Raya Kopo        | 1163.61         | 2266.98                      | 343.23                            | 385.15         | 4158.99         |
| 4  | Jl. Wastukencana     | 1356.75         | 137.7                        | 351                               | 24.3           | 1869.75         |

The second step, calculate the prediction of private vehicle passengers that could be shifted to public transport. In this research the number of passenger is calculated by multiplying the number of private vehicles with load factor (LF) of each private vehicle. The LF in this research is 2.5 (for private car) and 1 (for motorcycles). It is also assumed that the probability of public transport choice is 40% (Al Faruq, 2015). The number of passengers who use public transport is divided with load factor of public transport to get public transport needs. In this research the load factor of public transport (angkot) is 12. the following table is the prediction of public transport needs in four roads in Bandung City.

Table 6. Public Transport Needs

| No | Road Name            | Existing Private Vehicle (Vehicles/hour) | Passengers of Existing Private Vehicle (Passenger/hour) | Passengers who shift to public transport (passenger/hour) | Public Transport Needs (vehicles/hour) LF= 12 |
|----|----------------------|------------------------------------------|--------------------------------------------------------|----------------------------------------------------------|----------------------------------------------|
|    |                      | Motorcycles                               | Priva te Car                                            | From Motorcycles                                         | From Motorcycles From Private Car Total     |
| 1  | Jl. AH Nasution       | 9403                                     | 1094                                                    | 2735                                                      | 3761.2                                      | 4855.2                                      | 313.43                                      | 91.16                                      | 404.6                                      |
| 2  | Jl. Ahmad Yani       | 6120                                     | 1354                                                    | 3385                                                      | 2448                                        | 3802                                        | 204                                        | 112.83                                    | 316.83                                    |
| 3  | Jl. Raya Kopo        | 4654                                     | 2267                                                    | 5667.5                                                   | 2267                                        | 4128.6                                     | 155.13                                    | 188.92                                    | 344.05                                    |
| 4  | Jl. Wastukencana     | 5427                                     | 138                                                     | 345                                                       | 2170.8                                      | 2308.8                                     | 180.9                                      | 11.5                                      | 192.4                                     |

Once the number of passengers that shift to public transport is known, the remaining passengers who use private vehicle can be known. The following is the remaining passenger who still uses private vehicles.

Table 7. The Remaining Private Vehicles
Lastly, the number of traffic volume change can be calculated. The number of private vehicle traffic will be decreasing and the number of public transport will be increasing. The calculation of traffic volume when the private vehicle users shift to public transport is as follow.

Table 8. The Changes of Traffic Volume According to Vehicle Composition

| No | Road Name            | Motorcycles | From Private Car | Light Vehicles – Public Transport | Light Vehicles – Private Car | Heavy Vehicles | Total (pcu/hour) |
|----|----------------------|-------------|-----------------|-------------------------------|-----------------------------|----------------|-----------------|
| 1  | Jl. AH Nasution       | 1410.45     | 656.4           | 842.86                        | 656.4                       | 247.51         | 3157.23         |
| 2  | Jl. Ahmad Yani       | 918.00      | 812.4           | 486.93                        | 812.4                       | 147.74         | 2365.07         |
| 3  | Jl. Raya Kopo        | 698.1       | 1360.2          | 687.28                        | 1360.2                      | 385.15         | 3130.74         |
| 4  | Jl. Wastukencana     | 814.05      | 82.8            | 543.4                         | 82.8                        | 24.3           | 1464.55         |

As a result, the LOS (level of service) of Bandung City roads are now better. Jl. A.H Nasution VCR changes from 0.97 to 0.75, Jl. Ahmad Yani, VCR changes from 0.76 to 0.56. Jl. Raya Kopo VCR changes from 0.98 to 0.74. Meanwhile, Jl. Wastukencana VCR changes from 0.51 to 0.4. The following tables shows the comparison between road existing condition with “after public transport”condition.

Table 9. The comparison of road existing condition and road condition after using public transport

| No | Road Name            | VCR Existing | LOS Existing | VCR (After Encourage Public Transport Used) | LOS (After Encourage Public Transport Used) | Description                  |
|----|----------------------|--------------|--------------|---------------------------------------------|---------------------------------------------|------------------------------|
| 1  | Jl. AH Nasution      | 0.97         | E            | 0.75                                        | C                                          | VCR reduced, LOS increased   |
| 2  | Jl. Ahmad Yani       | 0.76         | C            | 0.56                                        | C                                          | VCR reduced, VCR reduced, LOS increased |
| 3  | Jl. Raya Kopo        | 0.98         | E            | 0.74                                        | C                                          | VCR reduced, LOS increased   |
| 4  | Jl. Wastukencana     | 0.51         | C            | 0.40                                        | B                                          | VCR reduced, LOS increased   |
3.2 Cilegon City
Similar with Bandung City. The density of Cilegon City is also quite crowded. It would be very difficult to build new roads. Transport demand management would be more sensible.

3.2.1 Maximum Floor Area Development Allowed
Four roads are analysed: Jl. Tirtayasa, Jl. Lingkar Selatan, Jl. Bojonegara, and Jl. K.H Wasyid. The following table shows existing condition of roads in peak hour in Cilegon City. There are two ways of TDM to be analysed: controlling maximum floor area of development and developing public transport.

| No | Road Name         | Type of Road          | C   | V (pcu/hour) | VCR | LOS |
|----|-------------------|-----------------------|-----|--------------|-----|-----|
| 1  | Jl. Tirtayasa     | Primary arterial road | 5702.4 | 3699.78     | 0.65 | C   |
| 2  | Jl. Lingkar Selatan | Secondary arterial road | 5702.4 | 1022.88     | 0.18  | A  |
| 3  | Jl. Bojonegara    | Primary collector road | 2453.4 | 1071.23     | 0.44  | B  |
| 4  | Jl. K.H. Wasyid   | Secondary collector road | 2134.5 | 1393.40     | 0.65  | C  |

If value of level of service (LOS) is compared with VCR plan, there are no roads that do not meet the requirement of VCR plan. The following table shows a comparison between LOS on existing condition and VCR plan. VCR plan which used in this research is 0.75 which is the limit of degree of saturation (MKJI, 1997)[8]

| No | Road Name        | VCR Existing | LOS Existing | VCR Plan | LOS Plan | Land Use Development Permit |
|----|------------------|--------------|--------------|----------|----------|-----------------------------|
| 1  | Jl. Tirtayasa    | 0.65         | C            | 0.75     | C        | Allowed, but Limited        |
| 2  | Jl. Lingkar Selatan | 0.18       | A            | 0.75     | C        | Allowed                     |
| 3  | Jl. Bojonegara   | 0.44         | B            | 0.75     | C        | Allowed                     |
| 4  | Jl. K.H. Wasyid  | 0.65         | C            | 0.75     | C        | Allowed, but Limited        |

Based on the analyses results, all roads that still meet the requirement of VCR plan. However, the land use development control is needed to manage level of service in Cilegon City in good performance. Giving land use development permit is allowed. However, the limit of land use development is still needed to control trip generation that is provided by land use. So, land use development control will be exercised. Firstly, Volume Traffic Max of the four roads are calculated.

| No | Road Name     | VCR Plan | C Existing | V max |
|----|---------------|----------|------------|-------|
| 1  | Jl. Tirtayasa | 0.75     | 5702.4     | 4276.8|
| 2  | Jl. Lingkar Selatan | 0.75     | 5702.4     | 4276.8|
| 3  | Jl. Bojonegara | 0.75     | 2453.4     | 1840.05|
| 4  | Jl. K.H. Wasyid | 0.75     | 2134.5     | 1600.875|
Once Vmax is determined, the maximum land use area can be calculate. The following table shows maximum floor area that can be developed in Cilegon city based on Vmax for each Road. Land Use proportion can be determined by the government plan. In this exercise, proportion of land use is based on land use area existing next to the road.

### Table 13. Maximum Land Use Area

| No | Land Use       | Vmax | Land Use Proportion | Trip Generate Max | Trip Rate | Maximum Land Use Area (m²) |
|----|----------------|------|---------------------|-------------------|-----------|----------------------------|
|    | Tirtayasa Street |      |                      |                   |           |                            |
| 1  | Commercial     | 4276.8 | 46.7%               | 1,997.68          | 0.012*    | 166,473.24                 |
| 2  | Public Facilities | 4276.8 | 50.3%               | 2,153.27          | 0.0193**  | 111,568.37                 |
| 3  | Green area     | 4276.8 | 0.0%                | -                 | 0*        |                            |
| 4  | Office         | 4276.8 | 2.7%                | 115.51            | 0.01*     | 11,550.76                  |
| 5  | Residential    | 4276.8 | 0.2%                | 10.34             | 0.0037*   | 2,795.67                   |
|    | Lingkar Selatan Street |      |                      |                   |           |                            |
| 1  | Commercial     | 4276.8 | 14.8%               | 634.41            | 0.012*    | 52,867.52                  |
| 2  | Industry       | 4276.8 | 69.8%               | 2,986.10          | 0.118***  | 25,305.96                  |
| 3  | Residential    | 4276.8 | 15.3%               | 656.29            | 0.0037*   | 177,374.71                 |
|    | Bojonegara Street |      |                      |                   |           |                            |
| 1  | Commercial     | 1840.05 | 78.7%              | 1,447.74          | 0.012*    | 120,644.87                 |
| 2  | Public Facilities | 1840.05 | 0.6%               | 10.90             | 0.0193**  | 564.64                     |
| 3  | Residential    | 1840.05 | 20.7%              | 381.41            | 0.0037*   | 103,084.86                 |
|    | K.H. Wasyid Street |      |                      |                   |           |                            |
| 1  | Commercial     | 1600.875 | 100%              | 1600.87.6         | 0.012*    | 133,406.25                 |

Description:

- a Trip Rate CBD DKI Jakarta, 1990
- b Trip Rate Country Sandiego, 2003
- c Trip Rate Kota Cirebon and Semarang, 2000

### 3.2.1 Traffic Volume Reduction by Private to Public Transport Shift

The calculation and scenario are similar to Bandung City case. The following is the vehicle composition in four roads in Cilegon City.

### Table 14. Traffic Volume off Road Existing According to Vehicle Composision

| No | Road Name            | Traffic Volume (pcu/hour) | Motorcycles | Light Vehicles - Private Car | Light Vehicles - Public | Heavy Vehicles | Total (pcu/hour) |
|----|----------------------|---------------------------|-------------|-----------------------------|------------------------|----------------|-----------------|
| 1  | Jl. Tirtayasa        |                           | 1155.77     | 1725.3                      | 717.86                 | 100.84         | 3699.78         |
| 2  | Jl. Lingkar Selatan  |                           | 176.43      | 411.07                      | 4.05                   | 431.32         | 1022.87         |
| 3  | Jl. Bojonegara       |                           | 620.86      | 341.21                      | 101.25                 | 7.89           | 1071.22         |
| 4  | Jl. K.H. Wasyid      |                           | 714.42      | 442.46                      | 184.275                | 52.24          | 1393.40         |
The second step is to calculate the number of passengers shift to public transport by multiplying the number of private vehicles with load factor (LF) of each private vehicle. The LF is set 2.5 (for private car) and 1 (for motorcycles). The probability of public transport choice is set at 40% (Al Faruq, 2015)\cite{7}. And the number of passengers who use public transport is divided with load factor of public transport to get public transport needs. The public transport (angkot) load factor is 12. The following table shows the prediction of public transport needs in four roads.

### Table 15. Public Transport Needs

| No | Road Name       | Existing Private Vehicle (Vehicles/hour) | Passengers of Existing Private Vehicle (Passenger/hour) | Public Transport Shift (passenger/hour) | Public Transport Needs (vehicles/hour) |
|----|-----------------|----------------------------------------|--------------------------------------------------------|-----------------------------------------|----------------------------------------|
|    |                 | Motorcycles                             | Private Car (Load Factor = 1)                           | From Motorcycles                        | From Private Car                       | Total | From Motorcycles | From Private Car | Total |
| 1  | Jl. Tirtayasa   | 4623                                    | 1725                                                   | 4312.5                                  | 1849.2                                 | 1725  | 357              | 143.7           | 297.8 |
|    |                 |                                         | 2587.5                                                  | 282.4                                   | 1027.5                                 | 411   | 1027.5           | 246.6           | 1274  |
|    |                 |                                         |                                                         |                                         |                                        | 1035  | 2737.5           | 246.6           | 3003  |
| 2  | Jl. Lingkar Selatan | 706                                    | 411                                                   | 1027.5                                  | 282.4                                 | 1027.5 | 246.6           | 246.6           | 493.2 |
| 3  | Jl. Bojonegar a | 2483                                    | 341                                                   | 852.5                                   | 993.2                                 | 341   | 993.2            | 204.6           | 1197  |
| 4  | Jl. K.H. Wasyid | 2858                                    | 442                                                   | 1105                                    | 1143.2                                | 442   | 1143.2           | 265.2           | 1408  |

Once the number of passengers that shift to public transport is known, the remaining passengers who still use private vehicle is also known.

### Table 16. The Remaining Private Vehicles

| No | Road Name       | The remaining passengers who are still in private vehicle (passengers/hour) | The Remaining of Private Vehicle (Vehicles/hour) | The Remaining Traffic Volume of private vehicles (pcu/hour) |
|----|-----------------|---------------------------------------------------------------------------|--------------------------------------------------|-------------------------------------------------------|
|    |                 | Motorcycles | Private Car | Motorcycles | Private Car | Motorcycles | Private Car |
| 1  | Jl. Tirtayasa   | 2773.8       | 2587.5       | 2773.8       | 1035        | 693.45      | 1035       |
| 2  | Jl. Lingkar Selatan | 423.6       | 616.5       | 423.6       | 246.6       | 105.9       | 246.6      |
| 3  | Jl. Bojonegar a | 1489.8       | 511.5        | 1489.8       | 204.6       | 372.45      | 204.6      |
| 4  | Jl. K.H. Wasyid | 1714.8       | 663          | 1714.8       | 265.2       | 428.7       | 265.2      |

Lastly, the number of traffic volume changing can be known. The following table shows the calculation of traffic volume when the private vehicle users shift to public transport.
Table 17. The Changes of Traffic Volume According to Vehicle Composition

| No | Road Name      | Traffic Volume (pcu/hour) | VCR (After using PT) | LOS (After using PT) | Description         |
|----|----------------|---------------------------|----------------------|----------------------|---------------------|
|    |                | Motorcycles | Light Vehicles - Private Car |                  |                     |                     |
| 1  | Jl. Tirtayasa  | 693.45      | 1035                   | 1015.71              | 975.06              | VCR Reduced         |
| 2  | Jl. Lingkar Selatan | 105.9    | 246.6                   | 61.83                | 431.325             | VCR Reduced         |
| 3  | Jl. Bojonegara | 372.45      | 204.6                   | 212.43               | 7.8975              | VCR Reduced         |
| 4  | Jl. K.H. Wasyid | 428.7      | 265.2                   | 316.38               | 52.245              | VCR Reduced         |

The results shows that the for roads LOS are getting better. In Tirtayasa street, the VCR changed from 0.65 to 0.50. In Lingkar Selatan Street, VCR changed from 0.18 to 0.15. In Bojonegara Street, VCR changed from 0.44 to 0.33. And in K.H. Wasyid street, VCR changed from 0.65 to 0.5. The following tables shows the comparison between road existing condition with “after public transport” condition.

Table 18. The comparison of road existing condition and road condition after using public transport

| No | Road Name      | VCR Existing | LOS Existing | VCR (After using PT) | LOS (After using PT) | Description         |
|----|----------------|--------------|--------------|----------------------|----------------------|---------------------|
| 1  | Jl. Tirtayasa  | 0.65         | C            | 0.50                 | C                    | VCR Reduced         |
| 2  | Jl. Lingkar Selatan | 0.18    | A            | 0.15                 | A                    | VCR Reduced         |
| 3  | Jl. Bojonegara | 0.44         | B            | 0.33                 | B                    | VCR Reduced         |
| 4  | Jl. K.H. Wasyid | 0.65         | C            | 0.50                 | C                    | VCR Reduced         |

4. Conclusions
Urban land use development control based on transport carrying capacity is very crucial to assure that urban physical development would not imply a severe transportation problem. While the concept of incorporating transport carrying capacity into urban land use development control has been previously realised, we are still facing lack of clear method to implement the concept in todays urban land use development control. This paper, among others, develop the calculation method of this concept for Indonesia city application.

Whenever road development reaches its maximum level, there is a need to control development both through supply as well as demand management. In this case, transport demand management is needed to maintain the level of service (LOS) on the road. Transport demand management approaches in this paper is land use development control. Land use development control is performed by controlling maximum land use that is allowed in each of every road classifications. Land use area will affect how much trip generation produced. Therefore, land use area should be controlled in the context of maximum capacity of the road. Meanwhile, from supply management side, this paper examines public transport development to reduce total traffic volume.

In Bandung City case, LOS in Jl. A.H. Nasution and Jl. Raya Kopo have exceeded the LOS plan. While LOS in other roads such as Jl. Ahmad Yani and Jl. Wastukencana still in accordance with LOS plan. On the road network which has exceeded LOS plan, there should be an effort to create an
alternative transport which can reduce the use of private vehicles. For the road network has not exceeded
the limit level of service then the government can make a restriction of land use area that can be
developed. The government can adopt the model that is performed in this paper for making development
permit.

In Cilegon City, the roads that are analysed have not exceeded the limit of LOS plan. However, the
effort to control urban development should be done with control land use area. This way can control trip
generation that is produced by land use development in Cilegon City. While the urban development is
controlled, other ways should be done to manage road performance in Cilegon City by promoting a
better public transport services. Public transport improvement is one of the promising strategy to
maintain a good LOS, while allowing further land use development up until a certain level of
development.

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