Road Network – Land Use Interaction Model: Failure of Mixed Use Development in Indonesian Case

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Abstract
Urban population in Indonesia is significantly increasing from 44% of total population in 2002 to approximately 60% in 2015. Rapid population growth has resulted urban problems related to rapid urban land use changes. The problems become more complicated since the changes created mixed-land use development along the main urban corridors that resulted in higher trip generations and trip attractions. On the supply side, urban land is very limited. Thus, road widening and creation of new roads are less possible. This has led to an accumulation of movement, worse road’s level of service and congestion in the main urban corridors. The aims of the research were: to analyse trip generations/attractions of the mixed-land uses of the main corridors in Malang City – Indonesia (a city with 1 million population in 2015); and to formulate transport – land use interaction model in the case of Malang. The selected corridor was the main road in the west district of Malang City. Correlational method (Pearson Product Moment) and regression method (stepwise, anova for land use’s trip generation/attraction), and analysis of road’s level of service (LOS), using Indonesian Road Capacity Manual, were employed in this research. The research formulated the interaction model as:

\[
V_{total} = \sum V_{internal} + \sum V_{external}
\]

where

\[
\sum V_{internal} = e_{residential}V_{residential} + e_{schools}V_{schools} + e_{units}V_{units} +
\]

\[
e_{offices}V_{offices} + e_{hospital}V_{hospital} + e_{chemists}V_{chemists} +
\]

\[
e_{commercial}V_{commercial} + e_{market}V_{market} + e_{fuel station}V_{fuel station} +
\]

\[
e_{bus station}V_{bus station}
\]

and

\[
\sum V_{external} = V_{local roads} + V_{continuous traffic flow}
\]

The research showed that \(V_{total} = 23,033\) car unit/day (internal) + 32,746 car unit/day (external) = 55,779 car unit/day. The trip was higher than the road’s capacity (C) which was 40,695 car unit/day. The level of services of road’s segments were dominantly F (congested). The simulation of the model showed that traffic engineering can be used to increase road’s capacity while land use changes (reduction of the variety of mixed land uses), particularly mix land uses at frontage area, can improve level of services (from F to C).

Keywords: land uses, road’s level of services, trip generation/attraction

1. Introduction
Most of recent literature of urban land use in the last two decades, such as Cervero (1988) (1996) promoted mixed uses development (MXD) to increase compactness of the city and therefore reduce trip generation of the whole city. However, compactness is claimed to be negative for several aspects of urban life, related to transport, is likely to reduce level of walking and cycling (Burton, 2000) and to increase congestion (Breheny, 1995). In the field of transportation planning, it is also recognized that
research and actions in pure transport management and/or pure demand management are ineffective to mitigate congestion (Xiaosu & Lo, 2012). Congestion should be solved through integration of land use and transport system. Recent authors, such as Bravo et.al. (2010) and Colonna, Berloco & Circella (2012) promoted models that integrated those two systems.

Recent research has analysed the influence of major land use, such as metro station, on transport system (Roukouni, Basbas S, & Kokkalis, 2012). Such study revealed that metro station had strong impacts on transport system and encouraged only local transport that passing by the metro station. As proposed by recent urban planners, mixed land use development is recommended as an effective way to solve urban transportation problem, mainly congestion, in the developed countries. However, the characteristics of the mixed land uses, such as what types land uses can be mixed, and the ‘level’ of mixture within the block or street corridor which work to reduce urban congestion, have not been clarified.

Mixed land uses are common characteristic of urban development in Indonesia. In most cases, mixed land uses are flourishened in the main road of big cities and they tend to convert housing to commercial uses (Waloejo, Surjono, & Sulistio, 2012). In the case of Malang City, East Java Province, this changes was even legitimated by the Local Government which approved commercial uses along the main corridors in its Evaluation of Malang City Spatial Plan (Bappeda, 2009).

Especially in the field of transport planning and infrastructure provision the so called four-stage models were applied. These models consist of a sequential algorithm, which includes the estimation of transport demand, transport distribution, modal split and assignment (Ortuzar, 1994) These models were mainly applied to identify bottlenecks in existing road networks and based on that, a new additional infrastructure was justified. But these models do not include all means of transport nor long term effects on land use caused by this additional supply and so wrong decisions were made. Newer developments in the domain of transport planning realised this shortcoming of four-stage models and took a more holistic approach. They combined land use models with transport models to display the interaction of urban transport systems and land use development over time in a combined model. An overview of existing Land Use Transport Interaction (LUTI) model. An advantage of this approach is, that the exogenous input data which are needed e.g. the transport model can be calculated in the land use part and vice versa (Gunter Emberger, 2003).

An important step to this quest is to examine to what extent the mixed land-uses can be developed on urban corridor area based on the maximum capacity of road’s network within the area. The hypothesis was if the traffic volume indicates to reach the capacity threshold of the road, then land uses should be controlled by, e.g. preventing conversion of low trip to high trip generator/attractor land uses through zoning ordinance. Therefore it is significance to examine the character/type of each land use. Therefore, land use planning for areas along the urban main corridor and its correlation to transportation in Indonesian city, which also representing most cities in South East Asia, is relevant to explore to formulate a more well-planned and efficient regional transportation system. Promotion of a model of interaction between land-uses and capacity of the road is intended to measure the desired threshold of the capacity of the land-uses and their interaction to road’s service.

2. Research Method

The approach of the research is a mix of qualitative and quantitative research. Qualitative approach was used to describe the condition of the study are. The study area was located on areas of a main road in the west district of Malang City i.e. a main road that connects Malang to Batu City, a tourist destination city in the Province of East Java. The characteristics of trip attraction and generation along the main road
were qualitatively explored. Quantitative approach was used to formulate regression model of the interaction between land uses and trip generation/attraction (Torrens, 2000). The analyses included stepwise method, correlation, ANOVA, road capacity, and road’s level of services.

Based on trip attraction and generation, we proposed a mathematical model using correlation between response variable (the sum of trip generation/attraction) and independent variables. We proposed 10 (ten) independent variables as follows:

1. Residential: \(X_1=\) building area, \(X_2=\) number of bedrooms, \(X_3=\) number of household’s members, \(X_4=\) number of motorized vehicles possessed by the family, \(X_5=\) family income.
2. Schools (kindergarten to high school): \(X_6=\) number of students, \(X_7=\) number of teachers/employees, \(X_8=\) number of classrooms, \(X_9=\) land area, \(X_{10}=\) building area.
3. Universities; \(X_{11}=\) building area, \(X_{12}=\) number of students, \(X_{13}=\) number of lecturers/employee, \(X_{14}=\) number of courses.
4. Offices; \(X_{15}=\) number of employees, \(X_{16}=\) number of visitors/guests, \(X_{17}=\) land area, \(X_{18}=\) building area.
5. Hospital; \(X_{19}=\) number of doctors, \(X_{20}=\) number of daily patients, \(X_{21}=\) number of rooms, \(X_{22}=\) parking area, \(X_{23}=\) building area.
6. Chemists; \(X_{24}=\) number of employees, \(X_{25}=\) number of customers, \(X_{26}=\) building area, \(X_{27}=\) parking area.
7. Commercials; \(X_{28}=\) parking area, \(X_{29}=\) building area, \(X_{30}=\) number of employee, \(X_{31}=\) number of visitors.
8. Market; \(X_{32}=\) number of sellers, \(X_{33}=\) floor area for meat and fish, \(X_{34}=\) floor area for food and beverage, \(X_{35}=\) floor area for daily basic need, \(X_{36}=\) floor area for fruits, \(X_{37}=\) floor area for vegetables, \(X_{38}=\) floor area for clothing/fashion, \(X_{39}=\) floor area for other goods.
9. Fuel station; \(X_{40}=\) number of employees, \(X_{41}=\) built up area.
10. Bus station; \(X_{42}=\) land area, \(X_{43}=\) number of buses/minibuses, \(X_{44}=\) number of employee and passengers.

Using Borland Delphi 7 and Microsoft Access 2010 software we developed an application program (B.eswe2013) to simulate data based on the regression equation. These software can be used to recommend the extent of mixed land use that can be accommodated in the area based on the capacity of the road.

3. Result and Discussion

The road in the study area was a two way road, un-separated, with 8 m pavement width of hot mix asphalt surface. The road had about 0.5 to 1 m shoulder/curb width. The curb/shoulder were occupied by many street vendors. The condition of the road was as follows: \(C_0 = 2,900\) car unit/h; \(F_{NW} = 1.14\), \(F_{SP} = 0.97\); \(F_{SF} = 0.90\), and \(F_{CS} = 0.94\), so the actual capacity of the road was 2,712.97 car unit/h. Continuous movement during the weekdays was 27,523 car unit/day, higher than local movement (10,763 car unit/day).

3.1. The characteristic of mixed land use in the study area:

Residential

Most the buildings (60%) were single story, consisted of maximum four rooms with 3 persons per household in the average. The majority of the residents were employees with the destination to city centre riding motorbike (50%). This land use generated 75 car unit/day and attracted 75 car unit/day, so the total was 150 car unit/day. Highest trip generation (30 car unit/hr) was from 7.00 to 8.00 am while the highest trip
attraction was from 4.00 – 5.00 pm. The ratio (e) was 20%. The lowest movement was at 10.00 – 11.00 am (6 car unit/hr) with ratio (e) at 4%.

Schools (kindergarten – high school)
Most of the buildings were single storey, except one high school that consisted two – three storeys. Origins of the movement to these land uses were from inside the district (45%) and the rest were form other districts. Transportation modes were motorbike (47%) with travel time less than 25 minutes (74%). Total trip from and to these education facilities was 140 car unit/day. The highest trip attraction (15 car unit/hr) was at 7.00 – 8.00 am while trip generation was at 3.00 – 4.00 pm. The ratio at peak hour was 15.19% and the lowest was at 5.00 – 6.00 pm with the ratio of 2.79%.

Universities
Origins of the movement to this land use were 50% form other districts and the transportation mode was motorbike (50%), with travel time less than 5 minutes (54%). There were 3 Universities along the corridor. Average movement was 648 car unit/day, a total of 324 car unit/day trip attraction with peak hours at 12.00 am – 1.00 pm (56 car unit/hr) and 324 car unit/day trip generation with peak hour at 3.00 – 4.00 pm (44 car unit/hr). Peak of trip attraction and generation was at 12.00 am – 1.00 pm with 88 car unit/hr and e ratio at 13.50%, while the lowest movement was at 8.00 – 9.00 pm with only 4 car unit/hr and e ratio at 0.62%.

Offices
Most (57%) of the origin of movement were from other district and 56% used motorbike. Travel times varied from 10-25 minutes (65%) to 6-10 minutes (35%). Trip attraction and generation for offices was only 16 car unit/day for each movement, then the total movement was 32 car unit/day. The peak for trip attraction was at 8.00-9.00 am with 2.75 car unit/hr, while the peak for trip generation was at 1.00- 2.00 pm with 2.58 car unit/hr. The peak of total movement was at 2.00-3.00 with 4.25 car unit/hr and its e ratio at 13.28%, while the lowest was at 5.00 – 6.00 pm with only 0.67 car unit/hr and e ratio at 2.08%.

Health facilities (Hospitals and chemists)
The building varied 1 – 2 floors. Most of the movements were from outside the district (53%). Popular mode of transport was motorbike (57%) which took 11-15 minutes (31%) and 15-25 minutes (69%). There were one hospital and five chemists. Trip attraction and generation of the hospital was 192 car unit/day for each movement, thus the total movement was 384 car unit/day. Peak hour of total movement was 68 car unit/hr with e ratio 17.71% at 5.00-6.00 pm. Trip attraction for chemists was 20 car unit/hr equal to trip generation. The peak hour for trip generation was 2.25 car unit/hr at 9.00-10.00 am, 10.00-11.00 am, 5.00-6.00 pm, while the peak for trip attraction was 4.75 car unit/hr at 9.00-10.00 am with e ratio 11.88%.

Commercials
Origins of the movement were from outside the neighbouring districts (54%). Similar to other land uses, the favourite mode was motor bike (64%) with travel times varied from 6-10 minutes (33%) to 10-25 minute (67%). Land uses for commercials consisted of trades and commercial services, markets, and fuel station. Trades and commercial services generated and attracted 28 car unit/day. The peak for trip attraction was 1.53 car unit/hr at 12.00 am-1.00 pm. The peak for trip generation occured at the same time with 1.51 car unit/hr then the total movement at the peak hour was 3 car unit/hr with e ratio 10.71%.

Trip generation and attraction for Dinoyo market was 841 car unit/day, with the peak of attraction was 105 car unit/hr at 7.00 – 8.00 am and the peak of trip generation at 68 car unit/hr at 10.00-11.00 am. The peak of total movement occured at 7.00-8.00 with 145.25 car unit/hr with e ratio 17.27%.
The fuel station generated and attracted the second highest trip along the corridor with total trip 3,548 car unit/day. The peak hour was at 4.00-5.00 pm with 175 car unit/hr (attraction) and 175 car unit/hr (generation) then the total was 350 car unit/hr with e ratio at 9.86%.

Bus station
The bus station covered an area of 4,770 sqm which was allocated for bus parking space (2,290 sqm). The terminal operated 337 minibuses, 48 buses. The terminal accommodated 150 motor bike in its parking space. L andungsari transit station generated and attracted the highest trip with 4.381 car unit/day (in + out). The peak hour was at 4.00-5.00 pm with 210 car unit/hr (attraction) and 210 car unit/hr (generation). The e ratio at the peak hour was 9.59%

3.2 Formulation of the model
We used linear regression (stepwise method) for each land use. The result of each land use is as in the following table (table 1):

<table>
<thead>
<tr>
<th>No</th>
<th>Land Use</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Residential</td>
<td>$Y_{\text{residential}} = 1.012 + 0.004 (X_1) + 0.264 (X_3) + 0.251 (X_4)$</td>
</tr>
<tr>
<td>2</td>
<td>Schools</td>
<td>$Y_{\text{schools}} = 2.498 + 0.141 (X_6) + 0.024 (X_{10})$</td>
</tr>
<tr>
<td>3</td>
<td>Universities</td>
<td>$Y_{\text{unis}} = -3.555 + 0.008 (X_{11}) + 0.149 (X_{12})$</td>
</tr>
<tr>
<td>4</td>
<td>Offices</td>
<td>$Y_{\text{offices}} = 9.456 + 0.564 (X_{16}) + 0.089 (X_{18})$</td>
</tr>
<tr>
<td>5</td>
<td>Hospital</td>
<td>$Y_{\text{hospital}} = 13.715 + 0.291 (X_{20}) + 0.055 (X_{21})$</td>
</tr>
<tr>
<td>6</td>
<td>Chemists</td>
<td>$Y_{\text{chemists}} = 25.323 + 0.322 (X_{25}) + 0.084 (X_{26})$</td>
</tr>
<tr>
<td>7</td>
<td>Commercials</td>
<td>$Y_{\text{commercials}} = 4.639 + 0.180 (X_{29}) + 0.189 (X_{31})$</td>
</tr>
<tr>
<td>8</td>
<td>Market</td>
<td>$Y_{\text{market}} = 1.648 + 0.500 (X_{33}) + 0.979 (X_{35}) + 0.505 (X_{36}) + 1.127 (X_{37})$</td>
</tr>
<tr>
<td>9</td>
<td>Fuel station</td>
<td>$Y_{\text{fuel station}} = -3.255 + 12.867 (X_{41})$</td>
</tr>
<tr>
<td>10</td>
<td>Bus station</td>
<td>$Y_{\text{bus station}} = 49.435 + 8.097 (X_{43})$</td>
</tr>
</tbody>
</table>

3.3 The influence land uses to vehicle trip at the corridor
By comparing the results of land use model analyses at the corridor (Mayjen Haryono Street – Raya Tlogomas Street) we found that the peak volume was 2,040 car unit/hr (at 12.00 am – 1.00 pm), while the capacity of the street was 2,713 car unit/hr, therefore the influence was 75.21%. The influence for each hour is described in table 2 and figure 1.

Table 2. The influence of land uses to trip volume

<table>
<thead>
<tr>
<th>Time</th>
<th>Vehicle volume (car unit/hr)</th>
<th>Road capacity</th>
<th>The influence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>06.00-07.00</td>
<td>608.67</td>
<td>2,712.97</td>
<td>22.44</td>
</tr>
<tr>
<td>07.00-08.00</td>
<td>1,377.47</td>
<td>2,712.97</td>
<td>50.77</td>
</tr>
<tr>
<td>08.00-09.00</td>
<td>1,758.03</td>
<td>2,712.97</td>
<td>64.80</td>
</tr>
<tr>
<td>09.00-10.00</td>
<td>1,710.22</td>
<td>2,712.97</td>
<td>63.04</td>
</tr>
</tbody>
</table>
The total volume of vehicle trip was interacted with road capacity to provide road’s performance or level of service. The road performance is based on the following formula:

\[ VCR = \frac{V_{\text{land uses}}}{V_{\text{external}}} \]

\[ VCR = \frac{\sum V_i + \sum V_{\text{external}}}{V_{\text{external}}} \]

\[ \sum V_{\text{land uses}} = 23,033 \text{ car unit/day} \]

\[ \sum V_{\text{external}} = V_{\text{local roads}} + V_{\text{continuous trip}} = 32,746 \text{ car unit/day} \]

\[ \sum V_{\text{Total}} = 23,033 \text{ car unit/day} + 32,746 \text{ car unit/day} = 55,779 \text{ car unit/day} \]

The output of the interaction between trip generation/attraction of the mixed land use and road network system is described in Table 3.

Table 3. The interaction between trip volume of the mixed land use and road network system

<table>
<thead>
<tr>
<th>Time</th>
<th>Trip volume resulted from land uses (car unit/hr)</th>
<th>Trip volume resulted from local road heading to/from the corridor + continuous trip (car unit/hr.)</th>
<th>Total trip volume (car unit/hr.)</th>
<th>Road capacity</th>
<th>Ratio V/C</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>06-08</td>
<td>608.67</td>
<td>1,708.90</td>
<td>2,317.57</td>
<td>2,712.97</td>
<td>0.85</td>
<td>D</td>
</tr>
<tr>
<td>07-08</td>
<td>1,377.47</td>
<td>2,421.55</td>
<td>3,799.02</td>
<td>2,712.97</td>
<td>1.57</td>
<td>F</td>
</tr>
<tr>
<td>08-09</td>
<td>1,758.03</td>
<td>2,427.05</td>
<td>4,185.08</td>
<td>2,712.97</td>
<td>1.55</td>
<td>F</td>
</tr>
<tr>
<td>09-10</td>
<td>1,710.22</td>
<td>2,334.75</td>
<td>4,044.97</td>
<td>2,712.97</td>
<td>1.51</td>
<td>F</td>
</tr>
<tr>
<td>10-11</td>
<td>1,775.22</td>
<td>2,295.45</td>
<td>4,070.67</td>
<td>2,712.97</td>
<td>1.49</td>
<td>F</td>
</tr>
</tbody>
</table>

Total 23,032.90
Table 3 shows that from 7.00 am to 8.00 pm the road’s LOS was F. This proves that the model can be used to estimate the influence of mixed land use at the corridor to road performance in Malang City. This also indicates that the level of mixed land use in Malang (we argue that this is the typical land use in most South East Asian Countries) generated/attracted vehicle trip that override road’s capacity. The interaction model, therefore, can measure the influence of mixed land use to trip generation and attraction along a main road. The model can also provide a comparison between continuous trip (regional trip) with local trip (generated/attracted by the activities of the mixed land use system and by movement from interconnected local roads to the main road).

![Figure 1](Figure 1The view of program showing interaction process of land use and road network)

We use the equation models to develop a user friendly application program software (B.eswe2013) with the help of Borland Delphi 7 and Microsoft Access 2010. This
program accelerates equation by executing the interaction of mixed land use with the road system and estimates the road performance. (The program is still developed in Indonesian language). The program consisted of four parts:

a) Data for response variable:
This part has two tables: response variable and ratio. Response variable table consisted of response variable data (read only) resulted from execution using SPSS (version 17.0) by inputting data of independent variables for each land use, thus the trip volume can be calculated. Ratio table consists of the list of each ratio of response variable from 6.00 am to 9.00 pm. This table is for inputting each ratio for each column corresponding to each land use (figure 2).

b) Factors that determine the road’s capacity
Several setting options, including type of the road, effective width, separation of two ways traffic, side load category, effective curb width, and city size can be modified in this part.

c) Road’s capacity
This part execute C value by inputting $C_O$, $C_W$, $C_{SP}$, $C_{SF}$, $C_{CS}$ data, the values will change when the previous data is modified.

d) Interaction model
Execution of the interaction model of land use and road network is calculated in this part. The value resulted from the analysis can be simulated to provide road’s performance following the interaction process.

Figure 2 Graph showing total trip volume and road’s capacity
4. Conclusion

The characteristics of trip were identified from 6.00 am to 9.00 pm. The primary observation showed that $C_O = 2,900$ car unit/hr.; $FC_W = 1.14$; $FC_{SP} = 0.97$; $FC_{SF} = 0.90$; and $FCCS = 0.94$. Based on these values, the actual capacity of the corridor was 2,713 car unit/hr. Continuous trip during weekdays was 27,523 car unit/day while the local trip was only 10,763 car unit/day. Most of the buildings (60%) were permanent and one storey buildings. 58% of trips were heading to/from other districts and 50% of trips used motorbikes.

The research promotes an interaction model between activity system (mixed-land use) and road network system using a series of equations incorporating $\sum V_{\text{internal}}$, $\sum V_{\text{external}}$, $e$ ratio and $Y$. $V$ was obtained from the observation, while $e$ ratio, which is the ratio of trip volume of each land use at particular time and the total trip volume (car unit/day), was provided from the trip in each land use. The $Y$ was obtained from the regression analyses for each land use (see Table 1). The analysis and estimation can be executed using B.eswe2013, an application that was formulated from the interaction process based on the research on the main corridor in Malang City, representing typical intermediate/big city of Indonesia (or East Asian Countries).

The notion, promoted by, among others, Cervero (1988) (1996), who stated that mixed land uses contribute to reduce trip volume, was not applicable to the study area. It means that the notion is not applicable to Indonesian Cities which are already ‘very mixed’. There is a need to measure the extent of mixed-land use, since the typologies of East Asian Countries are different to American (Western) Cities.

References

