Road network – land use interaction model: Malang City 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 in rapid urban land use changes. The problems became more complicated since the changes created mixed use development along the main urban corridors that resulted in higher trip generation and attraction while urban land very limited that made road widening and creation of new road less possible. This led to an accumulation of movement, worse road’s level of service and congestion in the main urban corridor. The aims of the research are to analyse trip generation/attraction of the mixed-land uses of the main corridors Malang City; and to formulate road network – land use interaction model in the case of Malang (a nearly 1 million population city in 2015). The selected corridors in Malang City a main road in the west district of Malang City - Indonesia. 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, are employed in this research. The research formulated the interaction model as:

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

Where

\[ \sum V_{\text{internal}} = e_{\text{residential}}Y_{\text{residential}} + e_{\text{schoo}l}Y_{\text{schoo}l} + e_{\text{unis}}Y_{\text{unis}} + e_{\text{offices}}Y_{\text{offices}} + e_{\text{hospital}}Y_{\text{hospital}} + e_{\text{chemists}}Y_{\text{chemists}} + e_{\text{commercials}}Y_{\text{commercials}} + e_{\text{market}}Y_{\text{market}} + e_{\text{fuelsation}}Y_{\text{fuelsation}} + e_{\text{busstation}}Y_{\text{busstation}} \]

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

The research showed that \( V_{\text{total}} = 23,033 \) car unit/day (internal) + 32,746 car unit/day (external) = 55,779 car unit/day. The trip higher than the road’s capacity (C) which 40.695 car unit/day. The levels of services of road’s segments 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).

1. Introduction
Most of recent literature of urban land use in the last two decades, such as Cervero [1] [2] 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 [3] and to increase congestion [4]. Mixed land uses are common characteristic of urban development in Indonesia. In most cases, mixed land uses are flourished in the main road of big cities and they tend to convert housing to commercial
uses [5]. In the case of Malang City, East Java Province, this change was even legitimated by the Local Government which approved commercial uses along the main corridors in its Evaluation of Malang City Spatial Plan.

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 [6]. These models mainly applied to identify bottlenecks in existing road networks and based on that new, additional infrastructure is 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 are 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 [7].

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 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 researh is a mix of qualitative and quantitative research. Qualitative approach used to describe the condition of the study area. The study area 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 qualitatively explored. Quantitative approach used to formulate regression model of the interaction between land uses and trip generation/attraction [8]. 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 (kinder Garten 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. Hospitals; \(X_{19}\) = 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. Commercial; \(X_{28}\) = 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 passangers.

Using Borland Delphi 7 and Microsoft Access 2010 we developed an application program (B.eswe2013) to simulate data based on the regression equation. This 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 is 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 occupied by many street vendors. The condition of the road surface. The road had about 0.5 to 1 m shoulder/curb width. The curb/shoulder occupied by many street vendors. The road in the study area

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

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

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

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

4. Offices
   Most (57%) of the origin of movement 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 only 16 veh/day for each movement, then the total movement 32 veh/day. The peak for trip attraction at 8.00-9.00 am with 2.75 veh/hr, while the peak for trip generation at 1.00-2.00 pm with 2.58 veh/hr. The peak of total movement at 2.00-3.00 with 4.25 veh/hr and its e ratio at 13.28%, while the lowest at 5.00 – 6.00 pm with only 0.67 veh/hr and e ratio at 2.08%.
5. Health facilities (Hospitals and chemists)
The building varied 1 – 2 floors. Most of the movements from outside the district (53%). Popular mode of transport is motorbike (57%) which took 11-15 minutes (31%) and 15-25 minutes (69%). There one hospital and five chemists. Trip attraction and generation of the hospital 192 veh/day for each movement, thus the total movement 384 veh/day. Peak hour of total movement 68 veh/hr with e ratio 17.71% at 5.00-6.00 pm. Trip attraction for chemists 20 veh/hr equal to trip generation. The peak hour for trip generation 2.25 veh/hr at 9.00-10.00 am, 10.00-11.00 am, 5.00-6.00 pm, while the peak for trip attraction 4.75 veh/hr at 9.00-10.00 am with e ratio 11.88%.

6. Commercials
Origins of the movement from outside the neighbouring districts (54%). Similar to other land uses, the favourite mode is 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 veh/day. The peak for trip attraction 1.53 veh/hr at 12.00 am-1.00 pm. The peak for trip generation occurred at the same time with 1.51 veh/hr then the total movement at the peak hour 3 veh/hr with e ratio 10.71%.

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

7. Bus station
The bus station covered an area of 4,770 sqm which allocated for bus parking space (2,290 sqm). The terminal operated 337 minibuses, 48 buses. The terminal accommodated 150 motor bikes in its parking space. Landungsari transit station generated and attracted the highest trip with 4.381 veh/day (in + out). The peak hour is at 4.00-5.00 pm with 175 veh/hr (attraction) and 175 veh/hr (generation) then the total 350 veh/hr with e ratio at 9.86%.

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):

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

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 of trip at 12.00 am – 1.00 pm with 2,040 veh/hr while
the capacity of the street 2,713 veh/hr, therefore the influence 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.

| Time         | Vehicle volume (veh/hr) | Road capacity | The influence (%) |
|--------------|-------------------------|---------------|-------------------|
| 06.00-07.00  | 608.67                  | 2,712.97      | 22.44             |
| 07.00-08.00  | 1,377.47                | 2,712.97      | 50.77             |
| 08.00-09.00  | 1,758.03                | 2,712.97      | 64.80             |
| 09.00-10.00  | 1,710.22                | 2,712.97      | 63.04             |
| 10.00-11.00  | 1,775.22                | 2,712.97      | 65.43             |
| 11.00-12.00  | 1,853.70                | 2,712.97      | 68.33             |
| 12.00-13.00  | 2,040.34                | 2,712.97      | 75.21             |
| 13.00-14.00  | 1,885.56                | 2,712.97      | 69.50             |
| 14.00-15.00  | 1,757.06                | 2,712.97      | 64.77             |
| 15.00-16.00  | 1,840.05                | 2,712.97      | 67.82             |
| 16.00-17.00  | 1,871.90                | 2,712.97      | 69.00             |
| 17.00-18.00  | 1,583.31                | 2,712.97      | 58.36             |
| 18.00-19.00  | 1,169.54                | 2,712.97      | 43.11             |
| 19.00-20.00  | 1,091.66                | 2,712.97      | 40.24             |
| 20.00-21.00  | 710.15                  | 2,712.97      | 26.18             |
| **Total**    | **23,032.90**           |               |                   |

Figure 1. Comparison between the road capacity and trip volume contributed by the mixed land use at the corridor.

The total volume of vehicle trip interacted with road capacity to provide road’s performance or level of service. The road performance is based on the following formula:

\[
VCR = \frac{V_{total}}{C}
\]
\[
VCR = \frac{\sum V_i + \sum V_{\text{external}}}{C}
\]  
\[
\sum V_{\text{land uses}} = 23,033 \text{ veh/day}
\]  
\[
\sum V_{\text{external}} = V_{\text{local roads}} + V_{\text{continuous trip}} = 32,746 \text{ veh/day}
\]  
\[
\sum V_{\text{Total}} = 23,033 \text{ veh/day} + 32,746 \text{ veh/day} = 55,779 \text{ veh/day}
\]

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.

| Time     | Trip volume resulted from land uses (veh/hr) | Trip volume resulted from local road heading to/from the corridor + continuous trip (veh/hr) | Total trip volume (veh/hr) | Road capacity | Ratio V/C | LOS |
|----------|---------------------------------------------|------------------------------------------------------------------------------------------|----------------------------|---------------|----------|-----|
| 06-08    | 608.67                                       | 1,708.90                                                                                 | 2,317.57                  | 2,712.97      | 0.85     | D   |
| 07-08    | 1,377.47                                     | 2,421.55                                                                                 | 3,799.02                  | 2,712.97      | 1.57     | F   |
| 08-09    | 1,758.03                                     | 2,427.05                                                                                 | 4,185.08                  | 2,712.97      | 1.55     | F   |
| 09-10    | 1,710.22                                     | 2,334.75                                                                                 | 4,044.97                  | 2,712.97      | 1.51     | F   |
| 10-11    | 1,775.22                                     | 2,295.45                                                                                 | 4,070.67                  | 2,712.97      | 1.49     | F   |
| 11-12    | 1,853.70                                     | 2,300.40                                                                                 | 4,154.10                  | 2,712.97      | 1.54     | F   |
| 12-13    | 2,040.34                                     | 2,371.05                                                                                 | 4,411.39                  | 2,712.97      | 1.65     | F   |
| 13-14    | 1,885.56                                     | 2,434.90                                                                                 | 4,320.46                  | 2,712.97      | 1.61     | F   |
| 14-15    | 1,757.06                                     | 2,346.05                                                                                 | 4,103.11                  | 2,712.97      | 1.51     | F   |
| 15-16    | 1,840.05                                     | 2,186.70                                                                                 | 4,026.75                  | 2,712.97      | 1.51     | F   |
| 16-17    | 1,871.90                                     | 2,250.60                                                                                 | 4,122.50                  | 2,712.97      | 1.52     | F   |
| 17-18    | 1,583.31                                     | 2,179.00                                                                                 | 3,762.31                  | 2,712.97      | 1.36     | F   |
| 18-19    | 1,169.54                                     | 2,126.65                                                                                 | 3,296.19                  | 2,712.97      | 1.22     | F   |
| 19-20    | 1,091.66                                     | 1,914.25                                                                                 | 3,005.91                  | 2,712.97      | 1.11     | F   |
| 20-21    | 710.15                                       | 1,448.30                                                                                 | 2,158.45                  | 2,712.97      | 0.78     | C   |
| Total    | 23,032.90                                    | 32,745.60                                                                                 | 55,778.50                 | 40,694.55     |          |     |

Table 3 shows that from 7.00 am to 8.00 pm the road’s LOS is 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).

We use the equation models to develop 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:
1. 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 e ratio for each column corresponding to each land use
   (figure 2).

   **Figure 2.** The view of program showing interaction process of
   land use and road network.

   **Figure 3.** Graph showing total trip volume and road’s capacity.
2. 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.

3. Road’s capacity
   This part executes C value by inputting CO, FCW, FCSP, FCSF, FCCS data, the values will change when the previous data is modified.

4. 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 3).

4. Conclusion
   The character of movement identified from 6.00 am to 9.00 pm. The primary observation showed that CO = 2,900 veh/hr; FCW =1.14; FCSP = 0.97; FCSF = 0.90; and FCCS = 0.94. Based on these values, the actual capacity of the corridor is 2,713 veh/hr. The continuous trip week days 27,523 veh/day while the local trip only 10,763 veh/day. The majorities (60%) of the building permanent and one storey building. 58% of trips heading to/from other districts and 50% of trip used motorbikes.

   The research promotes an interaction model between activity system (mixed land use) and road network system using a serie of equations incorporating ∑ Vinternal, ∑ Vexternal, e ratio and Y. V 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 (veh/day), provided from the trip in each land use. The Y 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 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 other, Cervero [2] [1], who stated that mixed land uses contribute to reduce trip volume, is not applicable to the study area. It also means the notion is not applicable to Indonesian Cities which are already ‘very mixed’. There is a need to measure the extent of mix use, since the typology of East Asian Countries is different to American (Western) Cities.

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