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# Controlling Urban Sprawl with Integrated Approach of Space-Transport Development Strategies

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**Abstract**

Urban sprawl phenomenon has been a huge issue since 20th century characterized by a rapid and unbalanced settlement development with transportation network particularly in a suburban area. The improvement of public transport system is a major requirement to minimize urban sprawl. Academic researchers have explained the linkage strategy between transportation network and urban planning. However, insufficient empirical verification has been made to control this phenomenon by using the integrated approach of space-transport development. This paper focuses on analyzing the improvement of public transport supply incorporated with settlement development. The improvement of public transport (PT) is designed by planning Mass Rapid Transit (MRT), Light Rapid Transit (LRT), and Bus Rapid Transit (BRT) systems. The impact of PT improvement has affected on the settlement development. Setting balance between employment and population density is designed as alternative of urban spatial strategy. These approaches are necessary in order to analyze and evaluate the many alternatives to overcome this situation. The result reveals that the requirement to integrate the space-transport development strategy in order to control the settlement development in the suburb has to be done to reduce 10% of travel time and to increase double the usage possibility to public transport mode. The strategies should be done in the further research with considering on impact assessment and the residents preferences intended to determine the preferred and strategic option for them.


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*Keywords*: Public transport; Spatial strategy;Space-transport development; Controlling urban sprawl; Settlement development

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## 1. Introduction

Regarding to urban development, the city expands to the outskirt of urban area. This phenomenon has occurred in Europe and over the world. This phenomenon contributed serious problems since 20th particularly in most cities of Indonesia. Urban sprawl has several features which impact on a low density zone, dependence on automobile, spatial mismatch and job sprawling (Duncan, 1989). Several efforts to minimize the impacts of this phenomenon have been conducted as well for the previous researches. Discussion has existed on how to overcome this phenomenon by integrating activities into high density areas and land-use mixes in order to reduce vehicular travel (Banister, 1996), by considering the transportation role in combating the problems related to urban sprawl (FHWA, 1999), by considering the provision of public transport system at the suburban destinations and effective integration of land and transport policy in order to increase the dispersed employment and residential location for Greater Dublin Area (GDA) (Vega and Reynolds-Feighan, 2009).

According to Gennaio et al. (2009), the urban containment strategies are one of the best-known planning instruments for managing urban sprawl such as greenbelt and urban growth boundaries as well as applied in Switzerland since 1970. The strategies particularly the boundary has restricted development to build zones and has promoted increased building density. The study has specific consideration on urban strategy to minimize the urban sprawl.

The other researchers have paid attention on relationship between employment suburbanization and the growth of reversed commuting in the weekday travel behavior of working residents in the Paris (Aguiléra et al., 2009). The findings of the research have confirmed that the choice of transport mode depends on the workplace, and the gentrification of the municipality of Paris which was linked to its capacity to attract high qualified jobs and to its proximity to sub-centres. If public transport quality remains insufficient, the high-income residents have been greater access to car. The research recommended that public authorities should be aware of this spatial mismatch which has negative environmental and social consequences.

Another research related to urban development strategy such as a compact development approach is employed to control urban sprawl by developing different scenarios in Istanbul. The result presented that urban sprawl can be reduced by up to 62 % through setting the certain spatial strategies (Terzi and Bolen, 2012).

Little empirical research has been conducted to control urban sprawl related to public transport facilitated with consideration of urban strategy and environment impacts of these developments and the commuting travel behavior. This paper will present a strategic option with considering the effort to integrate the spatial and transport plan to control settlement in the suburb particularly in poorly planned cities in developing countries. Since the sprawling settlement has occurred in cities of developing countries since the 1980s.

This research will investigate the phenomena of transport mode choice with the simulation of improvement of public transport and spatial strategy such as balance between employment and population density and their consequences in travel behavior of residents in the suburban areas. The research will be analyzed by application of JSM (Java Spatial Model) and OmniTRANS model by using micro video data to estimate passenger car unit (PCU) value for motorcycle, travel survey by distributing questioners to the residents to estimate the distribution parameters of travel behavior and value of time (VOT), employment and inhabitant data from National Census 2010.

The first issue related to accessibility of resident in the suburban areas with improvement of public transport. The previous research has been conducted to find out the current accessibility of the residents' trip in Surabaya City (Herijanto et al, 2006). Hence, the improvement will effect on the distance and time traveled for each purpose of each trip in each zone.

The second problems concern the influence of space-transport strategy on the overall travel behavior of residents particularly living on the suburban areas. The second consequence should concern on the change of accessibility and modal spilt.

The findings of this research are expected to assist government in planning the housing development concerning transport network facilitated surrounding the development by proposing structured process of conducting potential alternatives. The further research is expected to explain the impact assessment of the integrated development, the need of involvement of public preference into measurement of public transport performance in term of satisfaction level, willingness to pay and all impacts assessment due to housing development.

The organization of paper is described as follows: data collection and explanation of methodology is explained in second section. The third section explains estimation of parameters for four-step transport model from observation data. The fourth section discusses the assessment and comparison of settlement development in the suburb under three scenarios: current trend in 2030, improvement of public transport and balance of employment and population density. The final section presents conclusion and recommendation for further analysis.

## 2. Data and Methods

This section describes the data collection, study case area and the process for conducting this research, this comprises data needed for input in the JSM and OmniTRANS model, the current situation about study case area, and the steps to analyze the alternatives proposed with the JSM and OmniTRANS model.

### *2.1. Data Collection*

In this paper, three scenarios have been applied for Surabaya City to identify the alternative development with linkage of urban-transport development. This alternative is expected as the basis for urban planner decision in delivering a more sustainable development for Surabaya City. The alternatives include an urban settlement development such as employment and population balance in density, and improvement of public transport to facilitate resident mobility in that area. The alternatives are set analyzed by applying application of JSM (Java Spatial Model) and OmniTRANS model.

To apply these application models, the data set is collected for each village (called "*Desa*") within urbanized area of Surabaya City on 2010. The 2010 Census data have been used to analyze the change of population, employment, attractiveness variables and land-use for each village by applying JSM. The data set includes six variables which have been collected for all the 163 villages within the city. The variables are population, population growth, employment, employment growth, student, and population density. The other data for assessing the distribution and assignment (BPR) parameters are estimated from empirical data which is collected from the questionnaires. The questionnaires are distributed to 163 villages proportionally to population size of each village. The questions consist of five parts which are socio economic background, trip characteristic, transport mode choice, satisfaction of residents to public transport and living condition. The minimum number of sample that is necessary to be collected is 554 respondents.

Surabaya City as the capital city of East Java Province comprises 31districts and 163 villages, has a total area of 327 km², is located at an altitude of 3-6 m above mean sea level, has a population of about 2.8 million, and a high density of more than 10,000 persons per km$^2$ which can be indicated as a highly urbanized area as seen in Fig. 1 (Department of Planning and Development of Surabaya City, 2007).

Traffic congestion in Surabaya city has occurred increasing rapidly due to predominantly on motorcycles and private cars since the late 1990s. The residents have used transport mode with private car (30%), motorcycle (62%), and the others (8%, mostly minibuses as public transport). Travel time was investigated 29.7 minutes (by motorcycle) and 34.5 minutes (by car), and 39.9 minutes (by public transport) (Purwadi et al, 1998). 38% of Surabaya's population live in the suburban area of the city and those who have a trip every day back and forth to work in the central urban area (Statistic Bureau of Surabaya City, 2009).

The public transport which is served by public bus and paratransit (minibus) services is inadequate and declines gradually. The provision of rapid and efficient public transport networks is designed to combat the impact of this traffic congestion. The improvement of public transport service is expected as an alternative for private car and motorcycle to shift transport mode. The research has observed the average vehicular speed declining from 2007 to 2010. The average vehicular speed has fallen from 24 km/h to 21 km/h in that period (Permana Wandani and Yoshida, 2013). One of the many reasons for the high amount of motorized transport particularly motorcycle is 60% of the roads having no usable sidewalk. This is one of the causes why trips less than 3 kilometers were made for 60% by motorized transport resulting in more traffic congestion and economic inefficiencies (Replogle and Hughes, 2012).

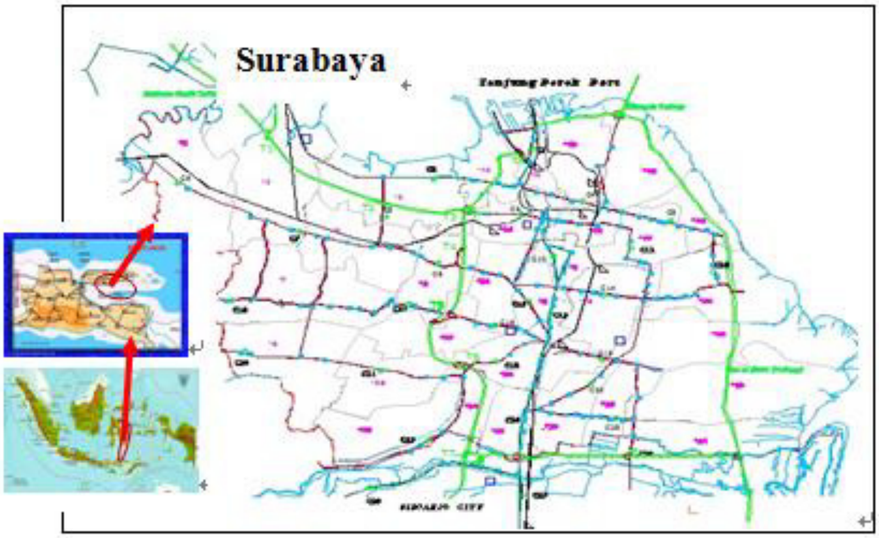



Fig. 1. Location of study area (Surabaya City) in East Java Province, Indonesia

To solve the problems, improved accessibility of these zones will be necessary for a sufficient transport system. In addition, the improvement of urban transportation plan should be connected with settlement development. As conducted in EU, suggestion to implement transport system with public transport access obligation, mandatory sustainable transport plans, emissions trading for parking have been adopted in EU to limit urban sprawl (Bart, 2010).

### *2.2. Models*

The models employed in this research are Java Spatial Model (JSM) and OmniTRANS. The main point of this research is the optimization of the transport network by simulating the performance of improvement of public transport in combination with the change of settlement strategy and considering the assessment of their impacts.

The conceptual framework of this research is intended to develop integrated plan to minimize the urban sprawl phenomenon is described in six steps as explained in Fig. 2.

The *first step* is to set up spatial settlement model based on JSM (Java Spatial Model) analysis with the input of the number of population and employment for 2010 census, socio economic data and initial situation of land-use. The output of JSM (projection of population, employment, and housing area) will be used to generate the traffic demand in 2010 and 2030 by OmniTRANS. There are some alternatives proposed for the existing and the future condition. Assessment of socio economic data and spatial allocation data of Surabaya City in 2030 is based on forecasting economic growth in 2010. A detailed description of JSM can be seen in Fig. 3.

The *second step* is analysis employing OmniTRANS to set up transport model. The transport model uses the four-step model for modelling trips between zones. In OmniTRANS model, the choice of making a trip was employed in the first step, with zonal data, such as number of residents or employments, as input. In this step, trip frequency parameters are used to determine trip productions and attractions to work, to go school, to go the other activities per zone.

The result of trip frequency choice is input for the next step. OmniTRANS models the second and third steps are applied simultaneously by employing travel resistances and distribution functions per mode. The travel resistances are calculated by OmniTRANS, in a process called 'Skim Generation', by using the networks of each mode as an input. The outputs of the combined second and third step are OD-matrices for every mode. These OD-matrices are used in the last step together with the travel resistances, where all the OD-pairs are assigned on the network for every transport mode by modelling route choice. This can influence the travel resistances since these will increase congestion occurs. Therefore, the traffic assignment becomes an iterative procedure. It is also possible to expand this feedback loop in OmniTRANS to include the second and third step. The resulting outputs of OmniTRANS are link loads, travel times, travel distances and travel costs. The four-step model of transport model is explained in Fig. 4.

Generally, the input of OmniTRANS consists of zonal data, transport networks and user behaviour. The zonal data was imported from JSM and the network was imported from the GIS application program. The user behaviour consists of; trip production and attraction parameters, distribution functions and BPR-functions. The parameters of the different functions need to be estimated. In this research, estimation of PCU value for motorcycle employed the microscopic empirical data by using the result of analysis of porous flow model (Ambarwati et al., 2013), and using the result of questionnaires to calculate the parameters of distribution function for each transport mode (car, motorcycle, public transport, and bicycle) and assessment of the parameter for volume delay function for each transport mode per road type is based on IHCM (Indonesian Highway Capacity Manual).

The *third step* will be done by observing the air quality in each road type, assessment of economic, social and environmental due to all alternatives designed. Assessment module is conducted by distribution of questionnaires for analysis residents' preference to accept the impact of integrated development.

The *fourth step* was undertaken to assess and evaluate the technical performance of the different alternatives. Comparative analysis of the set of scenarios and alternatives for the case study will be used to formulate strategic options for transport development as part of overall urban development suitable with the residents (user) preferences. Comparative analysis becomes the *fifth step*. The analysis consists of three alternatives of integrated approach development which will be assessed to obtain the best transport and spatial plan for Surabaya City. There are 5 alternatives set up in this assessment which consist of scenarios for 2010-the existing condition, scenario of 2030 with current trend, scenario of 2030 with design of BRT grid structure, scenario of 2030 with improvement of public transport and scenario of 2030 with build a development area by considering balance between employment and population density.

The *sixth step* is conducted to formulate the strategic option based on simulation of all alternatives with assessing the performance of the integrated plan which considers on space-transport development model and impact assessment module. The integrated plan contains simulation of transport performance, settlement and integration of transport and settlement situation of the existing, the future and possible alternatives which is considered as an optimal design.

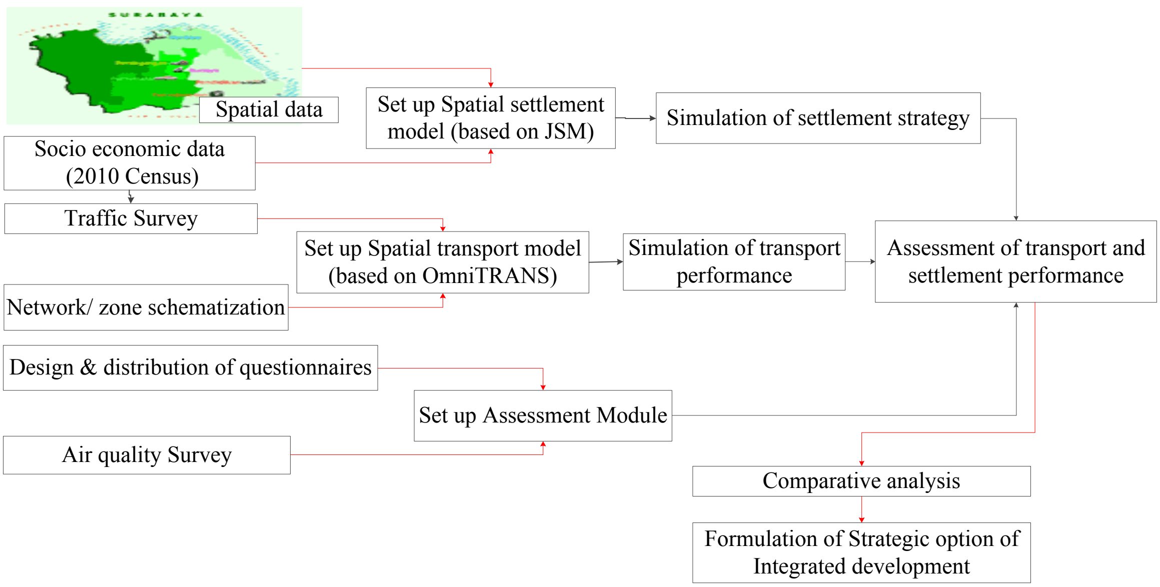



Fig. 2. The conceptual framework of space-transport development

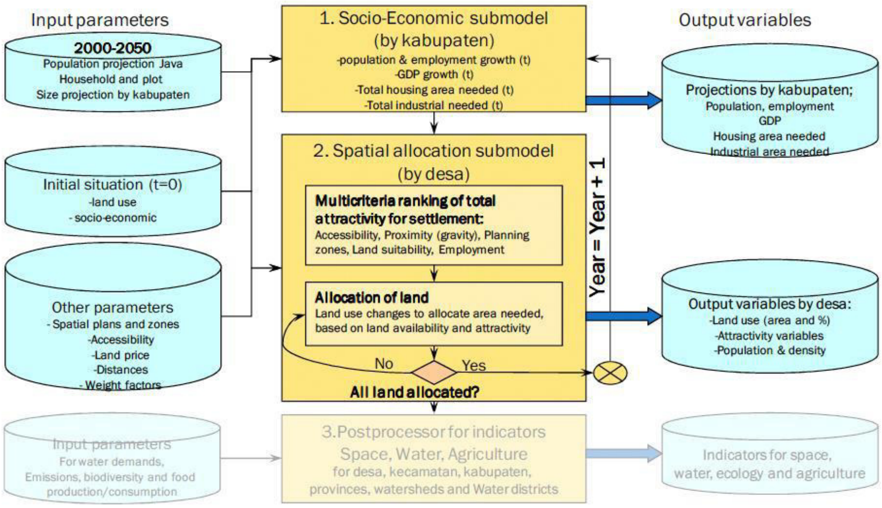



Fig. 3. JSM framework 2.2 for 6Ci's project (Grashoff and Zondag, 2010)

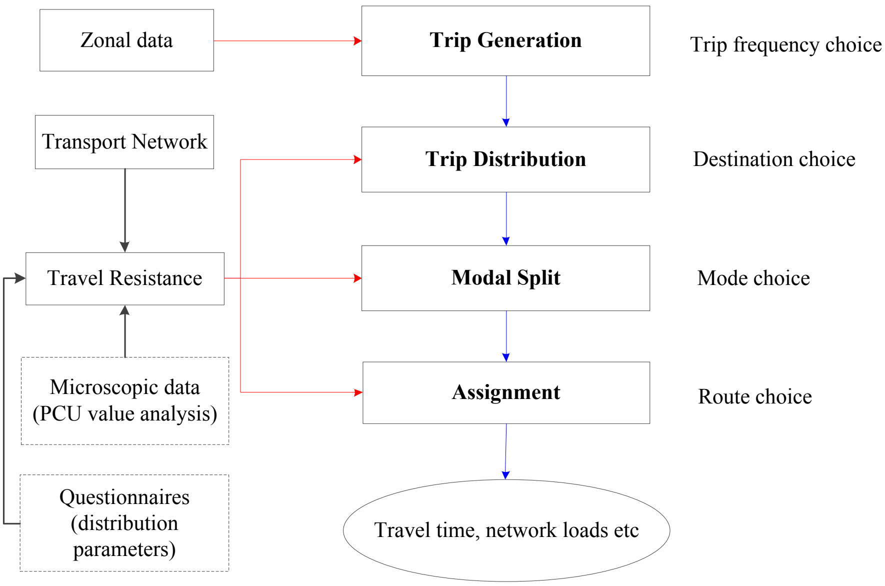



Fig. 4 Four-step model (Bovy et al, 2006 and modified by author)

## 3. Estimation Parameters for Four-step Transport Model

User behaviour function is needed as input in OmniTRANS. The parameters of these functions are necessary to be estimated, the result of empirical analysis of porous flow model (Ambarwati et al., 2013) for assessing PCU value of motorcycle, distribution parameter (using the top lognormal distribution) and value of time parameter from data which have been obtained from distributing questionnaires, parameters for BPR function and the crowding function in public transport from literature.

### 3.1. Distribution parameters

In distribution step of OmniTRANS, trip distribution gives the relative willingness to make a trip as a function of the generalized travel costs $c_{ij}$. To determine the trip distribution, the model uses a top lognormal distribution function. This model used a doubly constrained gravity model which ignored the restriction that the distribution function has to be monotonously decreasing. Using an iterative approach (Furness), it balances the trips between each zone according to the travel cost while considering as much as possible the original constraints as imposed by the Productions and Attractions. The doubly constrained gravity model is explained as follows:

$$T_{ij} = a_i\, b_j\, P_i\, A_j\, f(c_{ij}) \tag{1}$$

where $T_{ij}$ is the number of trips from zone $i$ to zone $j$, $a_i$ is balancing factor for trips from zone $i$, $b_j$ is balancing factor for trips to zone $j$, $P_i$ is number of trips departing at zone $i$, $A_j$ is the number of trips arriving at zone $j$, $f(c_{ij})$: accessibility of zone $j$ from zone $i$ (distribution or deterrence function), $c_{ij}$ is travel resistance or impedance (in this case generalized cost).

The top-lognormal function is presented as follows:

$$\mathrm{F}(c_{ij}) = \alpha\, c_{ij}^{\gamma} \exp(\beta \ln^2 (c_{ij}+1)) \tag{2}$$

where $c_{ij}$ is travel impedance (generalized travel cost based on distance and time), $\alpha$, $\beta$, and $\gamma$ are coefficients.

The different (standard) values have been used for all transport modes (car, motorcycle, bicycle, public transport). Estimation of top-log normal parameters has been assessed from the result of questionnaires distributed on September 2012. This model is used to obtain $\alpha$, $\beta$, $\gamma$ as coefficients in travel impedance for each transport mode that is set up in job description of Omnitrans. The result of calibration of distribution function parameters for every transport mode is shown in Table 1. Motorcycle is generally more attractive than the other transport modes. The result of distribution function is a function of travel time.

Table 1. Parameters of top-log normal distribution function per mode

| Transport mode | α | β | γ |
|---|---|---|---|
| car | 31.696 | -0.0554 | 1.7603 |
| motorcycle | 38.99 | -0.0388 | 1.6564 |
| Public transport | 8.848 | -0.0937 | 1.631 |
| bicycle | 5.45 | -0.025 | 0.85 |

### 3.2. PCU value for motorcycle

The quantification of the vehicular interactions, in terms of Passenger Car Unit (PCU) under heterogeneous traffic is estimated by using the result of empirical analysis employing the porous flow model (Ambarwati et al., 2013). The values of different vehicle while moving in the heterogeneous traffic flow are provided a set of basic PCU value of different types of vehicles. In this research, the PCU value for motorcycle is estimated due to the specific motorcycle behaviour as a major component in heterogeneous traffic flow.

Speed is the performance measurement from the empirical analysis which is employed to estimate the PCU values. Based on the relationship diagram between speed and density as shown in Fig. 5, the analysis of PCU value is determined. By using the similar average speed for car and motorcycle, the PCU value for each speed group is determined. The average speed of car and motorcycle is classified in three groups, 40-80 km/hr, 20-40 km/hr, and 0-20 km/hr.

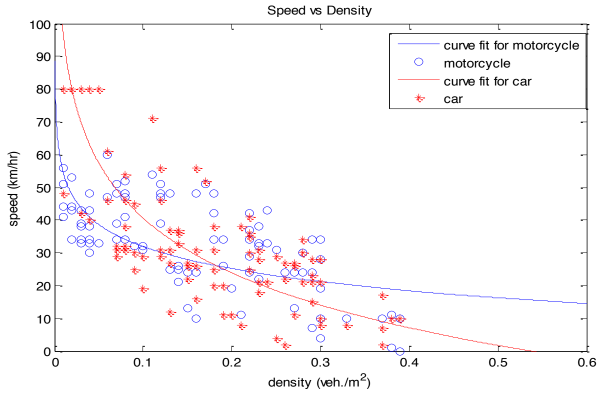



Fig. 5 Speed-density diagram from the result of empirical analysis of porous flow approach

Based on (3) which is introduced by Arasan and Arkatkar (2011), the PCU value is determined in each speed group by employing regression-fit analysis. The parameters which are approximated to linier model are assessed as PCU value for each speed group. Summary of examination of the regression-fit analysis is explained in Table 2.

$$PCU.value.of.motorcycle = \frac{number.of.cars.removed}{number.of.motorcycle.added} \quad (3)$$

Three PCU value groups are plotted with the speed occur as a linear model. From the PCU-speed curve corresponding to heterogeneous traffic, the variation of PCU for motorcycle is approximated to a linier model. From empirical analysis of heterogeneous traffic flow applying the porous flow model, the average speed for motorcycle is 24.8 km/hr (Ambarwati et al., 2013). Considering this speed and employing regression-fit analysis, the PCU value for motorcycle is 0.39. PCU value is 0.304 when average speed from spot speed survey 42 km/hr is mentioned in motorcyclist behaviour. Meanwhile, the PCU for bicycle is 0.24 which has been revealed by research about conversion factor for bicycle using field data in Shenyang, Tianjin and Shijiazhuang, China (Wanga et al., 2008).

Table 2. PCU value of each speed group

| Speed group | PCU value |
|---|---|
| 40-80 km/hr | 0.294 |
| 20-40 km/hr | 0.309 |
| 0-20 km/hr | 0.502 |

### 3.3. Value of time

The value of time (VOT) is input in OmniTRANS would be used for translating fare into time related to socio-economic background of residents in study area. The VOT is estimated from distributing questionnaires through revealed preference survey by mode choice approach as explained as follows:

$$P_q = a_1 + a_2\left(C_p - C_q\right) + a_2\left(T_p - T_q\right) \quad (4)$$

$$VOT = \lambda = \frac{a_2}{a_1} \quad (5)$$

where $P_q$ is transport mode choice of $q$ (%), $C_p$ is travel cost for mode $p$ (IDR), $C_q$ is travel cost for mode $q$ (IDR ), $T_p$ is travel time for mode $p$ (minute), $T_q$ is travel time for mode $q$ (minute), $\lambda$ is value of time, $a_1$, $a_2$ are parameters.

Based on Eq. (5) and Eq. (6), the VOT for motorized vehicle is 32,837 IDR/hr while VOT for public transport passenger is 23,448 IDR/hr.

## 4. Alternatives and Strategies Related to Space-transport Development

In setting up a strategic plan for urban development particularly suburban area, a simulation of performance of the space-transport plan will be done to get the potential alternatives for Surabaya City and to develop a successful settlement development. The proposed spatial measures are based on demand of transport network and residents preference. The effects of the spatial measures on transport network will be assessed to obtain the best spatial plan for Surabaya City. There are 4 alternatives set up in this assessment which consist of scenarios for 2010-the existing condition, scenario of 2030 with current trend, scenario of 2030 with improvement of public transport, scenario of 2030 with considering on improvement of public transport, balance between population and employment density.

For the analysis of scenario trend using the JSM software, an overview of the different socio-economic variables and spatial planning strategy is explained. The socio economic variables as input in JSM are GDP (5% for 2010 and 7% for 2030 respectively), employment growth (1% (2010) and 3% (2030)), population growth in Indonesia1% a year (The World Bank, 2013), household size and land-use per household projection using 0.5% a year based on the JSM standard input.

Three strategies are set up to affect on the distribution of population and job in the city. The strategies consist of economic center which considers the significant higher employment growth in the economic centers, good government which means increase of consistency of land-use plan, and setting the ratio of employment and inhabitant 30-40% in the certain area (economic centers).

For running the JSM, zone is set based on the lowest administrative level (village or "*Desa*" level). The data of population and employment is also input in this level. Surabaya city has 163 *Desa*'s over the 5 regions (central, north, south, west and east regions) as shown in Fig. 6.

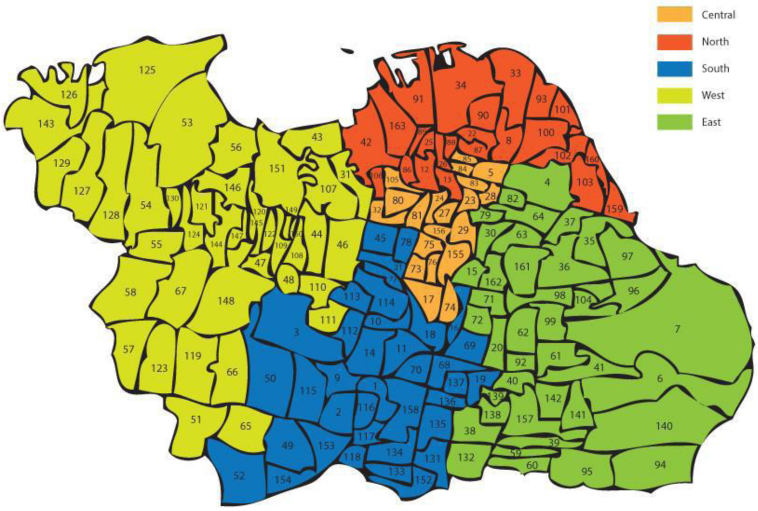



Fig. 6. ID for the "*Desa*" level and regions of Surabaya City

### 4.1. Current Trend

This scenario presents an analysis of the present (2010) and 2030 situation with considering transportation aspects and spatial allocation aspects. The current 2010 scenario explains insight in the network and spatial performance of the Surabaya City in the current situation. 5% of GDP, and employment growth 1% will be applied in this scenario. This scenario also notes the total of production and attraction into assessment of interzonal production and attraction. Which place has high percentage of interzonal trips, contributes high load in the network.

The current 2010 scenario consists of two scenarios with regarding the PCU value of motorcycle as explained in sub-section 4.2. The PCU values of motorcycle are 0.39 (for the average speed 24.8 km/hr) and 0.304 (for the average speed 42 km/hr) which are employed as input in assignment step of transport model in order to calculate loads of each transport mode.

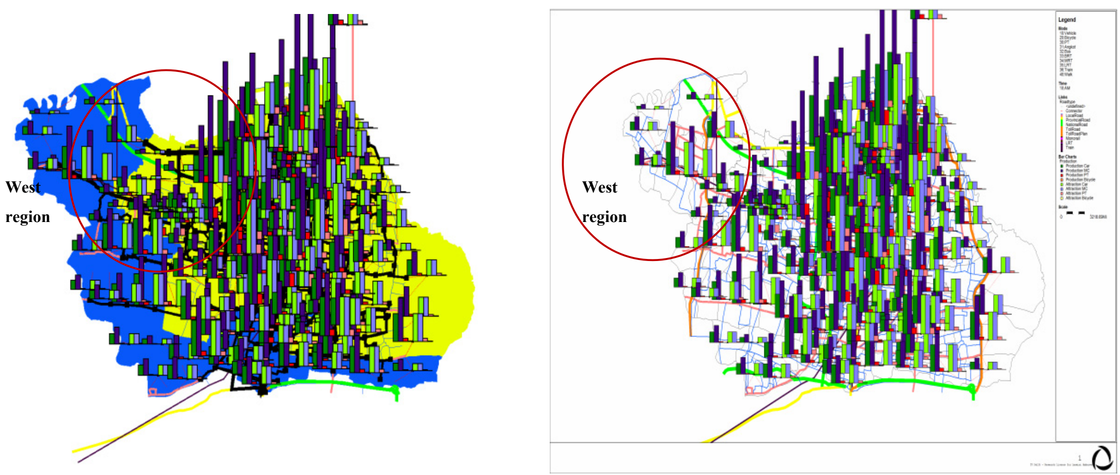
Two scenarios give a significant result in modal split which indicates the percentage of trips for each transport mode type. The modal split of public transport in the current case of 2010 with PCU 0.39 and 0.304 are 6.91% and 6.82% respectively. By using 0,304 for PCU value of motorcycle, the further analysis will be done due to equivalence with the traffic counting survey conducted in September 2012 as explained in Table 3.

The current trend 2030 scenario used 5% of GDP and 2% of employment growth, while the change of socio economic and transport policy (such as local government planning for expansion of transport network with the extension of eastern ring road, and development of new collector and local roads) will be considered in the analysis. The projection of the demand of land-use which is needed for housing development, job places etc without any improvements of public transportation and urban strategy approach.

The result of production and attraction per mode choice for current trend in 2010 and 2030 step is shown in Fig. 7. The production bar chart explains the amount of trips that are produced in each village/*desa* which means the traveller having origin from this *desa*. Citizens attract to the central urban area, even though a lot of people are living around the centre of Surabaya particularly in northeast of Surabaya. The amount of trips produced per village/*desa* in 2030 is relatively increasing. This situation means increase of population growth and significant difference of growth rate in population for each *desa*. The trip attraction is related to amount of employment. *Desa* which has high amount of employment results in high trip attraction. The current trend 2030 of trip production and attraction is significant different with the production and attraction of the current trend 2010 particularly in several zones of west side. Briefly, Fig. 7 explains that there are several *Desas* locating in suburban areas particularly in the west side having similar in production and attraction value with *Desas* in urban area.

Table 3. Modal split for 2010 scenarios

| Transport mode | Modal split 2010 using PCU = 0.39 (%) | Modal split 2010 using PCU = 0.304 (%) | Modal split from traffic counting survey |
|---|---|---|---|
| Public transport | 6.91 | 6.82 | 5 |
| Motorcycle | 58.51 | 57.98 | 58.5 |
| Car | 33.75 | 34.41 | 35.9 |
| Bicycle | 0.83 | 0.78 | 0.6 |




(a) (b)

Fig. 7. Production and Attraction per transport mode in 2010 (7a) and 2030 (7b)

Regarding the importance of usage of public transport, the volume /capacity ratios of public transport are determined. This ratio is assessed basis of the crush capacity and frequency of public transport service. As seen in Fig. 8 and Fig. 9, ratio between 0 and 1 (light green indicator) indicates the amount of people that use the public transport service did not reach the capacity of the public transport service. Ratio 1 or higher (darker green, red and purple indicators) means the amount of people who willingness to use the public transport service is equal or higher than the capacity of the service. These figures illustrate the potential usage of paratransit and bus which are indicated by increasing the volume capacity ratio mentioned for the current trend in 2010 and 2030. VCR of paratransit and bus increased particularly in west and south regions due to development of the regions as residential areas. The usage of paratransit is also increasing in northeast of city due to development areas surrounding the Suramadu Bridge.

(a) (b)

Fig. 8. Volume/capacity ratio (VCR) of bus in base case 2010 (11a) and 2030 (11b)

(a) (b)

Fig. 9. Volume/capacity ratio (VCR) of paratransit (minibus) in base case 2010 (12a) and 2030 (12b)

Modal split indicates the percentage of trip for each transport mode. From Table 4, increase of motorcycle and bicycle users are described from the current case of 2010 to the base case 2030, while the other transport modes are relatively fixed. It means that the motorcyclists and cyclists will increase 10% and 40% respectively without change of public transport network or similar public transport network.

Table 4. Modal split for 2010 and 2030 scenarios

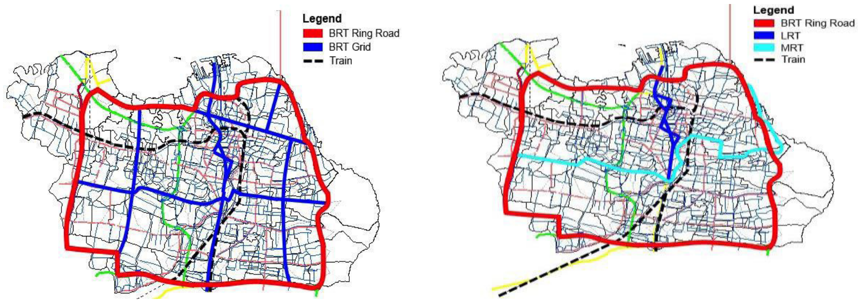
| Transport mode | Modal split 2010 (%) | Modal split 2030 (%) |
|---|---|---|
| Public transport | 5.82 | 5.62 |
| Motorcycle | 58.73 | 63.39 |
| Car | 34.88 | 30.23 |
| Bicycle | 0.57 | 0.75 |

## 4.2. *Improvement Public Transport*

The alternatives to improve public transport network are planned to increase the accessibility of residents of Surabaya City. Based on the previous research and design of the public transport network (Department of Transport of Surabaya City, 2013), this research considers the improvement of public transport by designing the alternatives with propose of MRT (monorail), LRT (tram line), BRT (Bus Rapid Transit), regional train, feeder and trunk network as seen in Fig. 10. Even though the previous research about improvement of public transport system considering 3 modes in Surabaya (Korthof et al., 2013) has presented the alternative with design of BRT system on the new ring road and on grid structure is best alternative.

In order to reach the goal of research with assessing the best alternative of space-transport development, the analysis of impact assessment and residents' preferences due to development of space-transport strategies is needed in the further research. So, the best option is expected to improve the accessibility for the residents living in the suburb, and to minimize the impact of the urban expansion phenomenon.

One effort to evaluate the performance of public transport improvement is conducted by considering the loads of public transport system for the alternatives given compare to the current base 2030. Fig. 11 illustrates the loads of public transport system in the base case 2030 and in the alternatives. The load of all public transport systems for the alternatives is significant different from the current base 2030 since the huge willingness for residents to shift transport mode to the new alternatives for public transport systems. The first alternative concerning the implementation of a BRT-system with grid structure results huge load of BRT passengers in west regions of the city. This result explains that residents in that region are more attractive than the others. The situation is also revealed with the second alternative which concerns on the implementation of new PT-system (MRT, LRT, BRT and train). The huge load of PT particularly usage of MRT and BRT systems occurs in the west and central regions of the city.




(a) (b)

Fig. 10 BRT-system with grid structure (Korthof et al., 2013) (10a) and public transport networks in the future for Surabaya City (Dept. of Transport of Surabaya City, 2013) (10b)

(a) (b) (c)

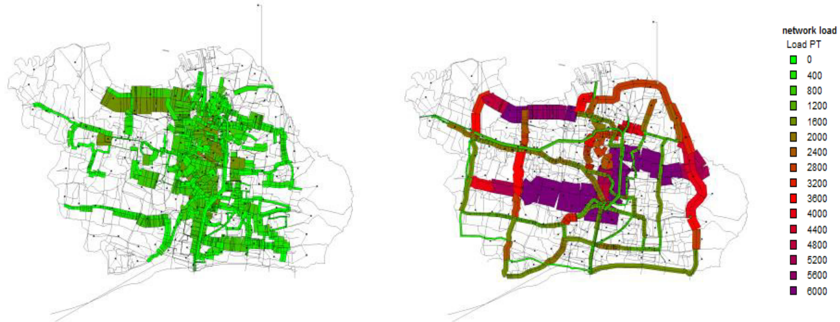
Fig. 11. Load public transport networks in the current trend 2030 (11a) and in the alternatives (BRT-grid structure (11b), and PT-system (11c))

### *4.3. Impact urban strategy on the accessibility of residents*

Urban development strategy should be implemented in order to realize high accessibility for the citizens. Such urban strategy has been implemented in Ranstand by performing the Network city concept (NCC) which has feature such as each city having own identity, separated from each other by green zones and connected with each other by as well a road network as a high quality public transport network (Dupuy, 2008). The policy with considering on land-use controls such urban growth boundaries, building-height restriction and zoning law has been applied to limit urban expansion (Brueckner, 2011).

Job-housing balance has been conducted in Beijing by examining its impact on individual commuting time. This strategy has significant influence on workers' commuting time when the factors of transport accessibility, population density and worker's socioeconomic characteristics are controlled (Zhao et al., 2011). By employing the analytical framework, different rate and patterns of population decentralization has been significant influence on the potential commuting travel saving and environmental benefit (Loo and Chow, 2010)

For Surabaya City, the implementation of balance between job and population density (compact city) linkage with improvement PT system is examined in this research. The further analysis is expected to apply the balance of job and housing distance in order to reduce commuting time and to assess its impact on the environment.




(a) (b)

Fig. 12. The load of PT network at current trend 2030 and the scenario (compact city)

The loads of public transport network at current trend 2030 and the scenario (compact city) can be seen in Fig. 12. The significant differences with the scenario current trend can be found in the loads of the PT network particularly several zones in the west side and the northeast of city. On the other hand, the compact city scenario has quite higher loads of PT network than the loads of scenario with only improvement of PT system. This alternative is expected to accommodate residents' trips and to increase the accessibility of residents in west region which is developed as settlement areas.

Table 5. Modal split for 2030 and the alternatives

| Transport mode | Modal split 2030 (%) | Implementation of BRT-grid structure in 2030 (%) | Improvement of PT in 2030 (%) | Space-transport development in 2030 (%) |
|---|---|---|---|---|
| Public transport | 5.62 | 5.69 | 8.51 | 9.23 |
| Motorcycle | 63.39 | 60 | 59.8 | 60.3 |
| Car | 30.23 | 28.86 | 26.58 | 25.39 |
| Bicycle | 0.75 | 5.48 | 5.04 | 5.09 |

Table 5 indicates the modal split of 2030 current trend with the alternatives such as implementation of BRT-system, improvement of PT system and space-transport development. The implementation of BRT-system with grid structure does not increase the willingness of BRT passengers in entire of city. The increase of public transport passengers with concerning improvement of PT-system (MRT, LRT, and BRT, train) is 60%, while cyclist increases six times of the base case 2030. This condition means that the alternatives will increase significantly usage of public transport which should be linked with bicycle facilities. On the other hand, usage of motorcycle is insignificant affect on the alternatives. Briefly, it is needed an alternative in order to decrease usage of motorcycle.

Table 6 explains travel time per trip for residents in entire of city and in west regions of city. Average travel time is highest for the public transport passengers in base case 2010. By designing improvement of PT-systems, average travel time foe each trip declines depending on the alternative. Travel time which indicates the network performance declines with improvement of PT system. This situation affects on increase of the willingness of PT usage. The alternative concerning the linkage of space-transport development is expected to minimize average travel time for residents in west region of city. The huge amount of PT loads in those areas illustrates residents' willingness to use PT as shifting from the usage of private vehicle. Decreasing travel time for each trip in those areas also explains the performance of PT network is more attractive than the other transport mode.

Table 6. Average travel time per trip in minute

| region | Transport mode | Base case 2010 | Current trend 2030 | Implementation of BRT-grid structure in 2030 | Improvement of PT in 2030 | Space-transport development in 2030 |
|---|---|---|---|---|---|---|
| West region | Public transport | 58.5 | 150.3 | 89.8 | 67.6 | 71 |
| | Motorcycle | 35.8 | 193.6 | 91.4 | 85 | 96.3 |
| | Car | 42.1 | 265.3 | 133.4 | 121.5 | 143.7 |
| Entire of city | Public transport | 55.9 | 114 | 80.5 | 61.38 | 63.9 |
| | Motorcycle | 46 | 149.3 | 86.7 | 82.26 | 95.4 |
| | Car | 59.4 | 209.3 | 127.3 | 119.8 | 141.5 |

## 5. Conclusion and future research issues

During the last thirty years, the settlement was expanding in the suburbs. As a consequence, commuting trips by using private vehicle such as car and motorcycle increase to the central of urban areas. Briefly, the central of urban areas has kept a strong attraction for the commuter from the suburb.

Under heterogeneous traffic condition, the variation of the PCU value is estimated by using microscopic data which has been analyzed by employing porous flow approach (Ambarwati et al., 2013). The PCU value decreases with the increase of speed. Using questionnaires data, estimation of distribution parameters has been conducted by employing a top-lognormal distribution function. The similar data is used to determine the VOT which is analyzed by mode choice approach.

The finding by evaluating the alternative of space-transport development has significant difference in modal split. Firstly, the transport mode choice is very dependent on the alternatives of improvement of PT systems. If public transport system is facilitated in a sufficient quality, the willingness to shift to PT system is high due to declining average travel time per trip. Secondly, the balance between employment and population density links to the PT system affects on reducing the usage of car and increasing the shift of transport mode particularly public transport and bicycle. This result means settlement development and work place should be connected with high accessibility.

For Surabaya City, the implementation of balance between job and population density (compact city) linkage with improvement PT system is examined in this research and is revealed as an alternative to increase the residents' accessibility in the suburban areas. This alternative is expected as an effort to minimize settlement development in the suburb. The further analysis is expected to apply the balance of job and housing distance in order to reduce commuting time and to assess its impact on the environment.

To understand residents travel behaviour in the future under improvement of public transport and settlement strategy, simulation analysis is recommended to examine the influence of the values the elasticity of accessibility to city center or work place. Further research employing the space-transport development should comprise the balance of job and housing distance in order to reduce commuting time, assessment of air quality impact, and consideration of residents' preference to evaluate the PT performance and living condition.

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