

# **The Effects of Improving Public Transport System Linkage to Spatial Strategy on Controlling Urban Sprawl: Evidence from Surabaya City, Indonesia**

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## **Abstract**

The improvement of public transport system is a major requirement to minimize urban sprawl. Urban sprawl phenomenon has been a huge issue since 20<sup>th</sup> century characterized by a rapid and unbalanced settlement development with transportation network particularly in a suburban area. Academic researches 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 alternative strategies 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), and feeder system. The impact of PT improvement has affected on the settlement development. Alternative related to urban strategies are established by setting balance between employment and population density. These approaches are necessary in order to analyze and evaluate the many alternatives to overcome this situation. The result reveals that the requirement to linkage the improvement of public transport supply and urban strategy in order to control settlement development in the suburb has to be done 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 alternative for them.

## **Keywords**

public transport, spatial strategy, space-transport development, controlling urban sprawl, settlement development

# 1. Introduction

Regarding to urban development, the city expands to the outskirts of urban area. This phenomenon has occurred in Europe and over the world (Hammer et al, 2004; Siedentop, 2005). 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 et al, 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, A, and Reynolds-Feighan, A., 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 (Anne A. 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 (Fatih, 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. The sprawling settlement has occurred in cities of developing countries since the 1980s.

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.

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 PCU (passenger car unit) value for motorcycle, travel survey by distributing questioners to the residents to estimate the distribution parameters of travel behavior, 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 (Harijanto, 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 air pollution impacts.

This research attempts to demonstrate the possibilities of how new development in suburban area can be effectively for residents having high mobility and which strategic option of new development of settlement can be chosen with consideration of increasing accessibility of residents. The future research will exhibit the impact assessment of the integrated development and the alternatives of how new development can feasibly be shifted from the suburban area to the central areas,

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 alternative or improvement of public transport strategy. The further research is expected to explain 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. Background information about public transport and urban spatial development of Surabaya City is described in the third section. The fourth section explains estimation of parameters for four-step transport model from observation data. The fifth 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**

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 three parts which are socio economic background, trip characteristic, transport mode choice, satisfaction of residents to public transport and living condition.

The design of survey should be considered before collecting data from the study area selected. Sample is defined as “a collection of units which has been especially selected to represent a larger population with certain attributes of interest”. The sample size depends on three main factors as suggested by Ortuzar and Willumsen (1990): variability of the parameters in the population under study, degree of accuracy required for each, and population size. The sample size can be determined as follow:

$$n = \frac{[Z^2_{\alpha} + CV^2]}{\bar{X}^2} \quad (1)$$

where  $n$  is the total number of sampling (sample size),  $CV$  is coefficient of variation of the interested variable =  $(S / X)$ ,  $Z_{\alpha}$  is the value of standard normal variety for the required confidence (Population parameter),  $X$  is the sample mean of the interested variable (population parameter)

The number of sample size can be determined as well as indicated. The minimum number of sample that is necessary to be collected is 554 respondents,

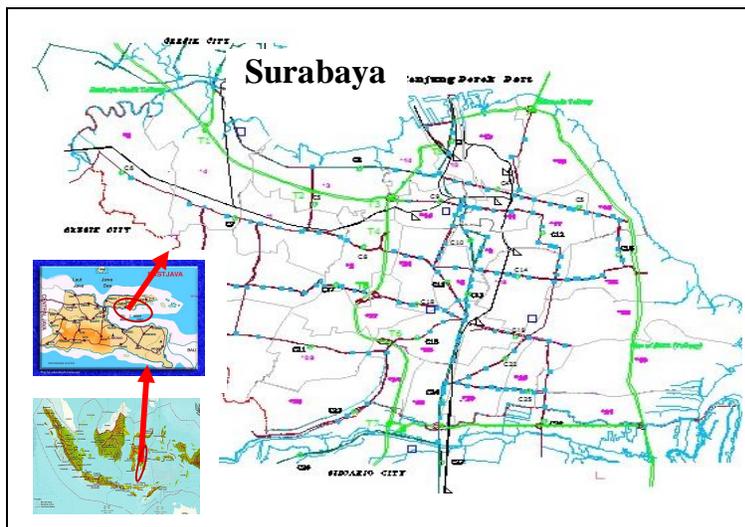
## 2.2. Study area

Surabaya City as the capital city of East Java Province comprises 31 districts and 163 villages, has a total area of 327 km<sup>2</sup>, 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<sup>2</sup> which can be indicated as a highly urbanized area as seen in Figure 1 (Department of Planning and Development of Surabaya, 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%), motor cycle (62%), and the others (8%, mostly minibuses as public transport). Travel time was investigated 29.7 minutes (by motor cycle) and 34.5 minutes (by car), and 39.9 minutes (by public transport) (Purwadi, 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). Based on travel time, the residents in particularly western Surabaya City have the lowest accessibility to the other zones and to the central urban area. The

travel time was needed more than 90 minutes for travelling by motor cycle or car, up to 110 minutes by public transportation (Herijanto et al, 2006). With the huge traffic flow in these areas, the level of service of each highway was declining into E or F (unstable condition) on the off peak hour particularly in highway network in the suburb. This situation impacts on significant time, cost and productivity loses, and an increase of air quality nowadays.

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 showed that 25% of reduction in the public transport travel time and travel cost can be double the usage probability of this public transport by residents. The change in travel fare under various mode choices has been determined in proposed bus rapid transit system (Rahman et al, 2012). The other 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 & 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 & Hughes, 2012).



**Figure 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, I.L, 2010).

### 2.3. 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 Figure 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 Figure 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 modeling 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 Figure 4.

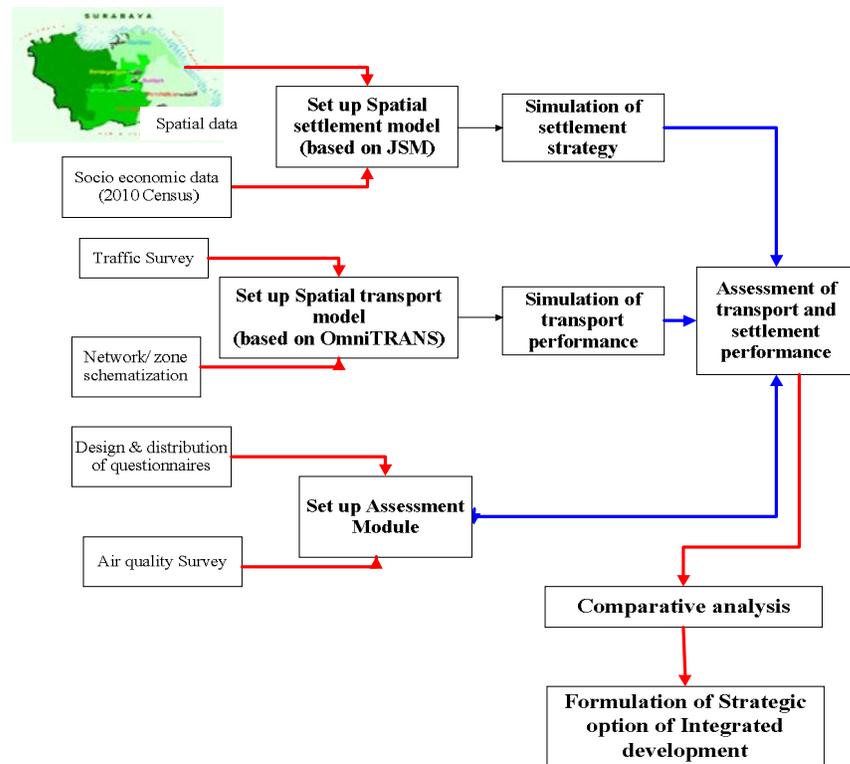
Generally, the input of OmniTRANS consists of zonal data, transport networks and user behavior. The zonal data was imported from JSM and the network was imported from the GIS application program. The user behavior consists of; trip production and attraction parameters, distribution functions and BPR-functions. 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. Hence, the MCA is executed by using the criteria such as travel time gain, speed, accessibility, and the amount of PT trips.

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 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 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.



**Figure 2: The conceptual framework of space-transport development**

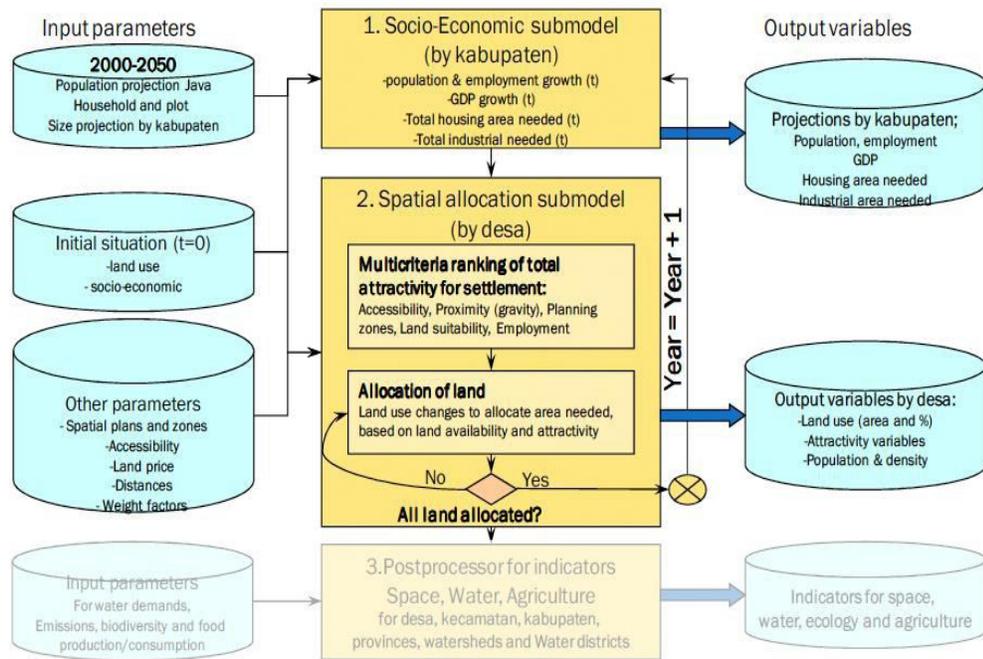


Figure 3: JSM framework 2.2 for 6Ci's project (6Ci's project, 2010)

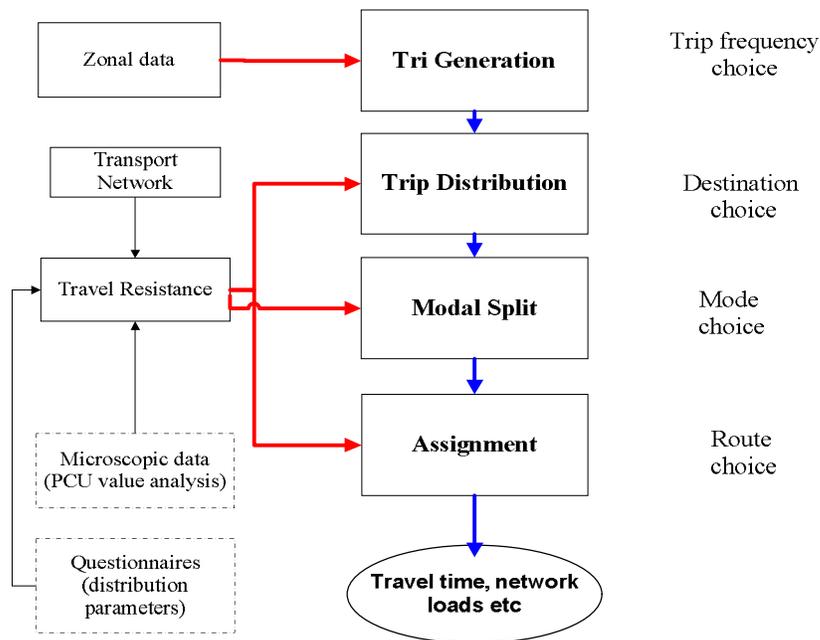


Figure 4: Four-step model (Bovy, Bliemer, Nes, 2006 and modified by author)

### 3. Public Transport Performance and Development of Settlement in The Suburb

#### 3.1. Identifying the current public transport

The performance of public transport is based on the current transport system in the study area. Using this performance, the accessibility level of citizens of subsistence activities (working, business/shopping and school) using the existing public transport (bus and minibus/paratransit) will be found. The performance such as capacity, quality, and efficiency is measured on board survey for bus and paratransit. This performance is used as input in setting public transport network using OmniTRANS model.

The public transport network of Surabaya currently consists of minibus/paratransit, busses, and trains. There are 68 available paratransit routes, 22 bus routes as shown in Figure 5, and 1 train route within Surabaya. The most bus routes pass on national/provincial roads and toll road in the middle area of city, the other areas are served by paratransit (minibus accommodates passengers within 8-12 seats). The paratransit routes have no fixed time schedule or frequency. Bus and paratransit during the day are driven more than during the night.



Figure 5: Routes of paratransit (5.a) and bus (5.b) of Surabaya city

Table 1: Public transport characteristic for Surabaya City

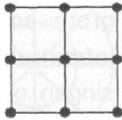
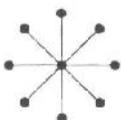
<i>Characteristics</i>	<i>Bus</i>	<i>Paratransit</i>	<i>Train</i>
Line spacing (km)	0-15	0-10	30
Stop spacing (km)	0.5-2	0.5-1	3
Average speed	40	20	25
Network level	Urban: express-service	Urban: urban	Urban: agglomeration
Network structure	Grid 	Radial 	Linier 

Table 1 explains an overview of the characteristic of different public transport service in Surabaya. Each public transport is served or different companies. Paratransit is initiated by personal and private company who think their maximum benefit and insufficient consideration on service quality to the passengers. Bus is managed by local government particularly department of transportation (called as DAMRI).

For design the different alternatives, it is required to explain the different stakeholder objectives because each stakeholder has a different interest and preference for the public transport network. The traveler (inhabitant of Surabaya) is the one using the public transport. The passenger wants to have the least travel time at a low price. If the travel time or price is too high, the chance to use public transport is less which means traveler will decide to take the private vehicle if available. Public transport needs to be attractive for travelers to be chosen, at the moment the public transport in Surabaya is not attractive for the traveler due to influenced factors such as frequency and comfort. The operator who provides the public transport will consider on cost efficient and make as much profit as possible with the lowest costs. The operator needs to make a balance between providing affordable public transport and maximizing their own profit. In some cases it is possible for operators to keep the fare prices low because of subsidies offered by the government. The authority (local government) is responsible to decide on the public transport, where a new line is build and how much they are subsidized to realize the complete project. The government surely expects to have the least costs and minimize subsidy.

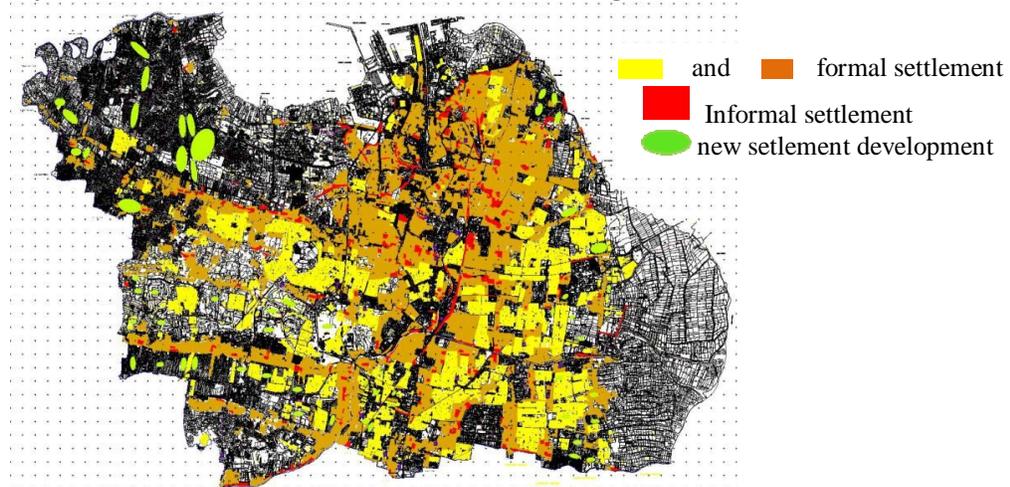
### **3.2. Settlement development and its impacts**

The population of Surabaya City is counted over 3.024 millions in 2011 (Statistical Bureau of Surabaya, 2010). There are about 16 sub districts out of 31 sub districts which have high density more than 11,000 persons per km<sup>2</sup>. With the high density of population, this city has one of the main problems such as settlement development for residents. Since the central urban areas have been dense density (45% is built area) as a consequence, this condition impacts on informal settlement area in several areas in the central urban areas. Since 1980s, the settlement development expanded to the periphery of urban areas particularly on west and east side of the city due to less than 15% built area. About 135,000 households (17% of the total of inhabitants) have lived in the suburban area. In which each family consists of 3-4 persons on average.

The most common house type in the suburb is a single-family house with 45-70 m<sup>2</sup> built area within the total of land about 100-200 square meters in size. The settlement areas have an average number of 500-1,000 unit houses. Each family has on average 2 vehicles: a motor cycle and a car. This provides high mobility for households in the suburbs, as a consequence, there are huge traffic volumes generating from these settlements.

New settlement areas are far away from the central urban areas (central business district (CBD)) and far away from the working places, thus local government will still have difficulties to provide the transport network. Therefore, the apartment has been introduced in the central urban area, whereas this type is unfamiliar for the residents of

Surabaya City. The new settlement developments are located on west and east side particularly zones 2-7, 19, 21, 22 and 23 as shown in Figure 6.



**Figure 6: Settlement developments in Surabaya**

As seen in Figure 7, central urban areas are located in sub districts 8, 9, 10, and 11. The centers attract a lot of citizens doing subsistence activities such as working, business/shopping and school. These areas are located in the city which is expected to be accessible. The improvement of public transport network in these areas will lead to change in modal split.

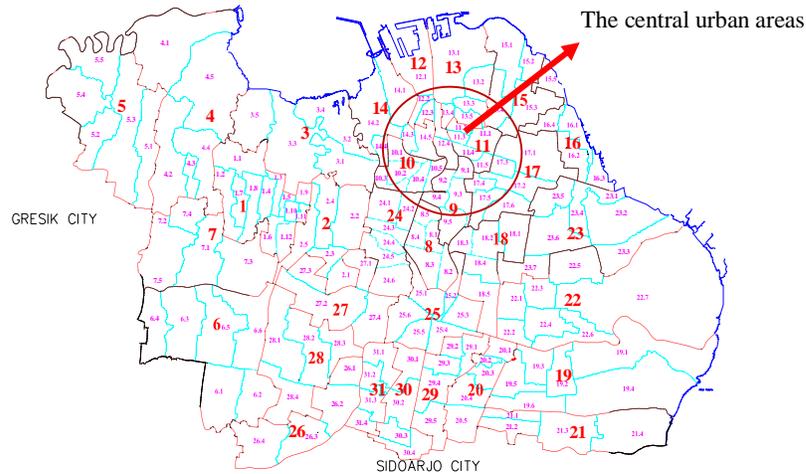
Industry in Surabaya City is mainly based on manufacturing, financial services, and trade. The medium and big scale industries are on sub districts 1, 3, 4, 13, 19, 20, and 26. Several zones are functioned as warehouse which is located close to the industry places and Tanjung Perak Port in the north side of city. The west, south and east sides near city boundaries (sub districts 1-7, 26, 21, 26 and 29) have opportunity as residential and shopping areas. The other sub districts (18, 22, and 23) are developed as education center such as the big hospital which is also found in those sub districts.

Although several trade and industries have been developed on west and south side, the residents frequently commute to the city center which is indicated by huge traffic volume with mostly car and motor cycle loading the roads as gateway to the city center. The most economic activities such as business and shopping take place in the city center. This situation causes huge production and attraction from or to settlement area in the suburban areas generating approximately 6,000 vehicles during peak hour.

Based on the urban growth regions in Surabaya City, the specific sub districts have huge attractiveness for the employees particularly the sub districts where the shopping center, business office, industrial areas, port, and education center are located. There are particularly 43 villages, where the economic centers are assigned (Korthof et al, 2013). These villages will generate 71.14% of total employment growth for the city as explained in Table 2.

**Table 2: Yearly employment growth for economic and non-economic centres**

Assessment	Villages level		Percentage of total employment growth		
	amount	percentage	JSM (%)	strategy (%)	Total (%)
Economic centre	43	26.38	50.64	+20.5	71.14
Non-economic centre	120	73.62	49.36	-20.5	28.86



**Figure 7: Surabaya city regions (31 sub districts and 163 villages)**

## 4. Estimation parameters for four-step transport model

User behavior 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.

### 4.1. 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:

$$T_{ij} = a_i b_j P_i A_j f(c_{ij}) \quad (2)$$

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).

Based on (2), the number of trips is produced by zone  $i$  and attracted to zone  $j$  ( $=T_{ij}$ ) and proportional to:

- The forecast number of trips produced by zone  $i$
- The forecast number of trips attracted to zone  $j$
- The impedance between zone  $i$  and zone  $j$ .

The top-lognormal function is presented as follows:

$$F(c_{ij}) = \alpha \cdot c_{ij}^{-\gamma} \cdot \exp(\beta \cdot \ln^2(c_{ij} + 1)) \quad (3)$$

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 3. Motor cycle is generally more attractive than the other transport modes. The result of distribution function is a function of travel time.

**Table 3: Parameters of top-log normal distribution function per mode**

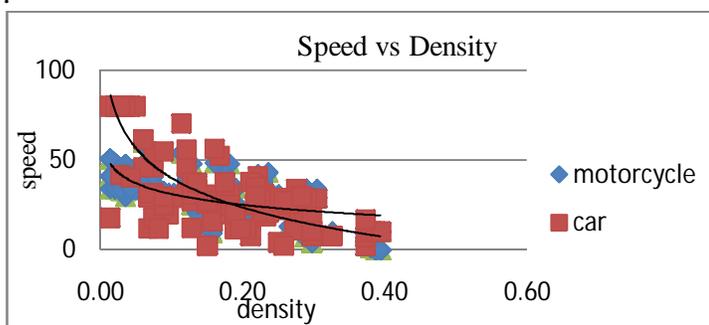
<i>Transport mode</i>	$\alpha$	$\beta$	$\gamma$
car	31.696	-0.0554	1.7603
motorcycle	38.99	-0.0388	1.6564
Public transport	8.848	-0.0937	1.131
bicycle	5.45	-0.025	0.85

## 4.2. 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 behavior 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 Figure 8, the analysis of PCU value is determined. By using the similar average speed for car and motorcycle, the PCU value 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.



**Figure 8: Speed-density diagram from the result of empirical analysis of porous flow approach**

$$PCU \text{ value of motorcycle} = \frac{\text{number of cars removed}}{\text{number of motorcycle added}} \quad (4)$$

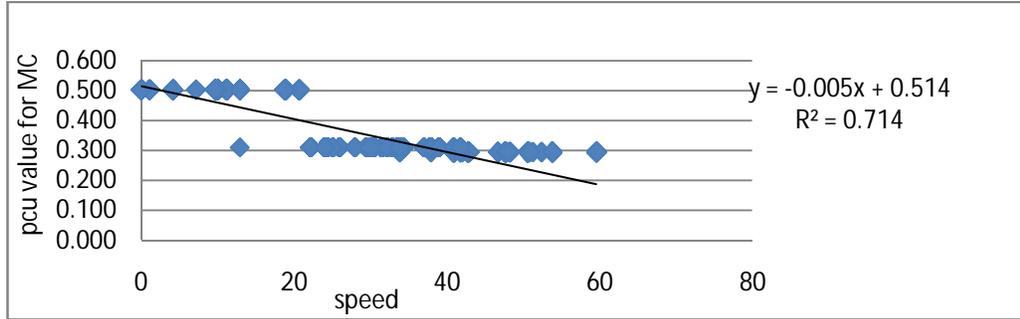
Based on (4) which is introduced by Arasan et al (2011), the PCU value is determined in each speed group by using regression-fit analysis. The parameters which are approximated to a linear model are assessed as PCU value for each speed group. The examination of the regression-fit analysis was done to estimate the goodness-of-fit of data as a linear model for each speed group. The PCU values based on the linear model analysis are explained in Table 4.

**Table 4: PCU value of each speed group**

<i>Speed group</i>	<i>PCU value</i>
40-80 km/hr	0.294
20-40 km/hr	0.309
0-20 km/hr	0.502

Three PCU value groups are plotted with the speed occur as a linear model as illustrated in Figure 9. From the PCU-speed curve corresponding to heterogeneous traffic, the variation of PCU for motorcycle is approximated to a linear model. From empirical analysis of heterogeneous traffic flow with applying the porous flow model, the average speed for motorcycle is 24.8 km/hr. 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 behavior.

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).



**Figure 9 Variation of PCU value of motorcycle (MC)**

### 4.3. 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:

$$Pq = a_1 + a_2(Cp - Cq) + a_2(Tp - Tq) \quad (5)$$

$$VOT = \lambda = \frac{a_2}{a_1} \quad (6)$$

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

### 4.4. Parameters of BPR and crowding function in PT

Deterministic user-equilibrium assignment is applied in this research due to consider on 4 modes (car, motorcycle, bicycle, and public transport). Deterministic user-equilibrium assignment assumed measurement of route choice and congestion. For study case area, congestion has to be taken into account, since this influence on route choice and congestion usually occurs.

The main assumption of this method is that travelers are fully informed about the possibilities in a network. Each traveler will choose the route which minimizes his/her travel time or travel cost. The travel times in turn depend on the link flows, while the link flows depend again on the route choice proportions. To account the congestion, every link type has been assigned with a so called BPR function. The link performance function in term of V/C ratio into travel time, OmniTRANS uses the BPR (Bureau of Public Roads) function as explained as follows:

$$t_a(q_a) = t_a^0 \left( 1 + \alpha \left( \frac{q_a}{c_a} \right) \right)^\beta \quad (7)$$

where  $t_a$  is (congested) travel time on link  $a$ ,  $q_a$  is volume (flow) on link  $a$ ,  $t_a^0$  is free-flow travel time on link  $a$ ,  $C_a$  is capacity on link  $a$ ,  $\alpha$ , and  $\beta$  are parameters

Indonesian Highway Capacity Manual (IHCM or MKJI) considers other volume delay functions which present suitable results for Indonesian roads. The parameters are determined by adopting the value estimation from previous research (Irawan, Sumi, & Munawar, 2010). The volume delay function is formulated as follows and parameter of volume delay function is explained in Table 5:

$$t_a = t_a^0 \left( 1 + \alpha_1 \left( \frac{v_a}{c_a} \right)^\beta + \alpha_2 \left( \frac{v_a}{c_a} \right)^\beta \right) \quad (8)$$

**Table 5: MKJI (Indonesian Highway Capacity Manual parameters for volume delay function**

<i>parameters</i>	<i>Toll road</i>	<i>National road</i>	<i>Provincial road</i>	<i>Local road</i>
$\alpha_1$	0.10	0.14	0.18	0.58
$\alpha_2$	0.43	0.48	0.61	0.54
$\beta$	7	7.32	8.08	9.48

A crowding function is employed in OmniTRANS due to the affect of crowding in public transport perceived travel time. The default crowding function is used to estimate the parameters from OmniTRANS. This function is based on V/C ratio as follows:

$$\frac{V}{C} = \begin{cases} \frac{L}{C_{seated}} & : 0 < L < C_{seated} \\ 1.0 + \frac{L - C_{seated}}{C_{crush} - C_{seated}} & : L > C_{seated} \end{cases} \quad (9)$$

where  $L$  is load of transit line,  $C_{seated}$  is seat capacity of transit line, and  $C_{crush}$  is crush capacity of transit line.

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

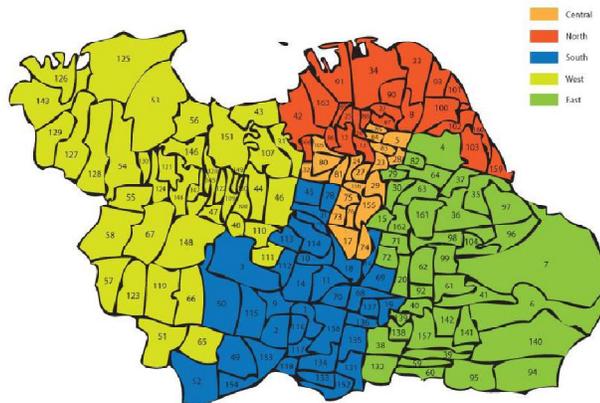
In setting up a strategic plan for urban development particularly suburban area, a simulation of performance of the space-transport plan will be done to get the potential alternatives for Surabaya City and to develop a successful settlement development. The proposed spatial measures are based on demand 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 Indonesia 1% 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 Figure 10.



**Figure 10: ID for the “Desa” level and regions of Surabaya City**

### **5.1. 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.

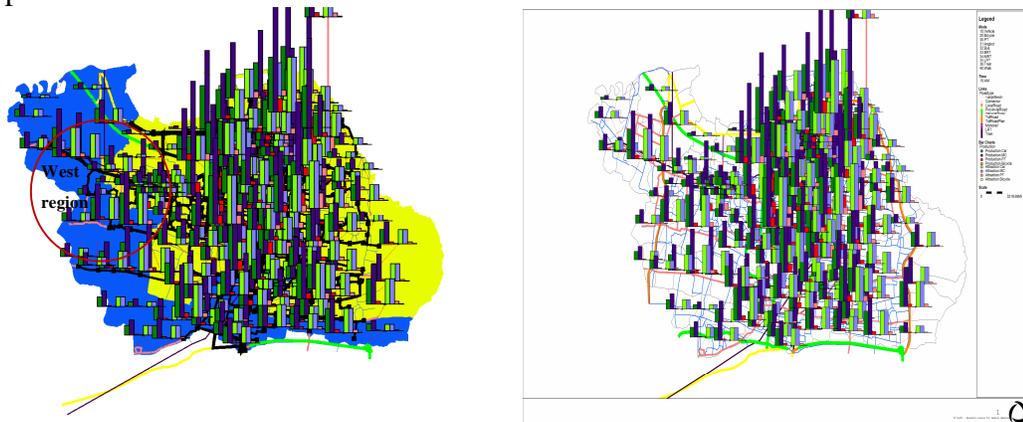
The current 2010 scenario consists of two scenarios with regarding the PCU value of motorcycle as explained in sub-section 4.2. The PCU values of motorcycle are 0.39 (for the average speed 24.8 km/hr) and 0.304 (for the average speed 42 km/hr) which are employed as input in assignment step of transport 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 motorcycle in the current case of 2010 with PCU 0.39 and 0.304 are 59.4% and 58.73% 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 6.

**Table 6: Modal split for 2010 scenarios**

<i>Transport mode</i>	<i>Modal split 2010 using PCU = 0.39 (%)</i>	<i>Modal split 2010 using PCU = 0.304 (%)</i>	<i>Modal split from traffic counting survey</i>
Public transport	5.8	5.82	5
Motorcycle	59.4	58.73	58.5
Car	34.25	34.88	35.9
Bicycle	0.53	0.57	0.6

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.

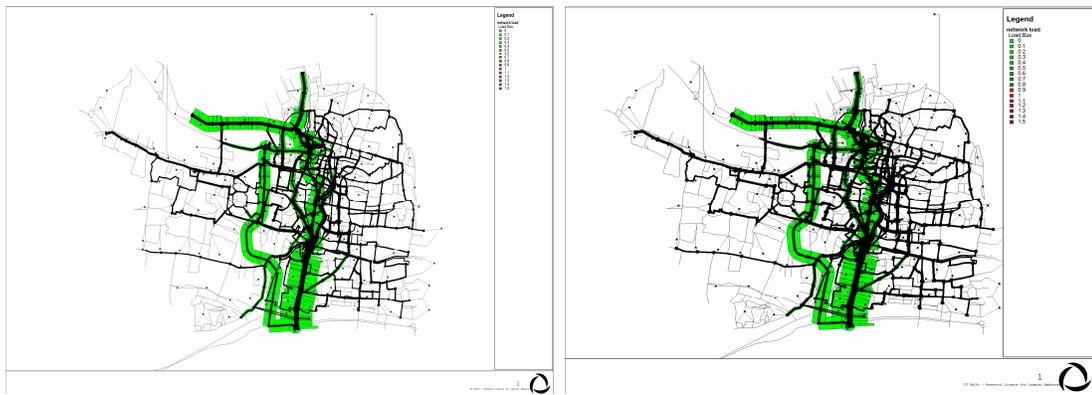


**Figure 11: Production and Attraction per transport mode in 2010 (11a) and 2030 (11b)**

The result of production and attraction per transport mode choice for current trend in 2010 and 2030 step is shown in Figure 11. 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 (sub districts 8, 9, 10, and 11), 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, Figure 11 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.

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 Figure 12 and 13, 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 which is indicated by slightly increase of the volume capacity ratio mentioned for the current trend in 2010 and 2030. VCR of paratransit increased particularly in west and south regions due to development of the regions as residential areas. Meanwhile usage of bus is relatively similar for 2010 and 2030.



**Figure 12: Volume/capacity ratio (VCR) of bus in base case 2010 (12a) and 2030 (12b)**



**Figure 13 volume/capacity ratio (VCR) of paratransit (minibus) in base case 2010 (13a) and 2030 (13b)**

Modal split indicates the percentage of trip for each transport mode. From Table 7, 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 in 2010 and 2030.

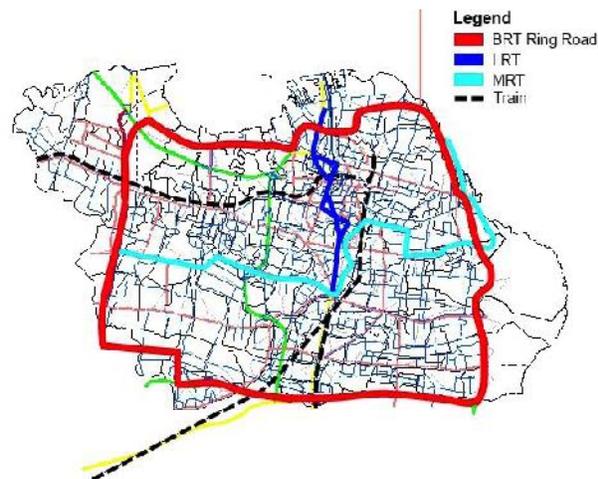
**Table 7: Modal split for 2010 and 2030 scenarios**

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

## 5.2. Improvement of Public Transport System

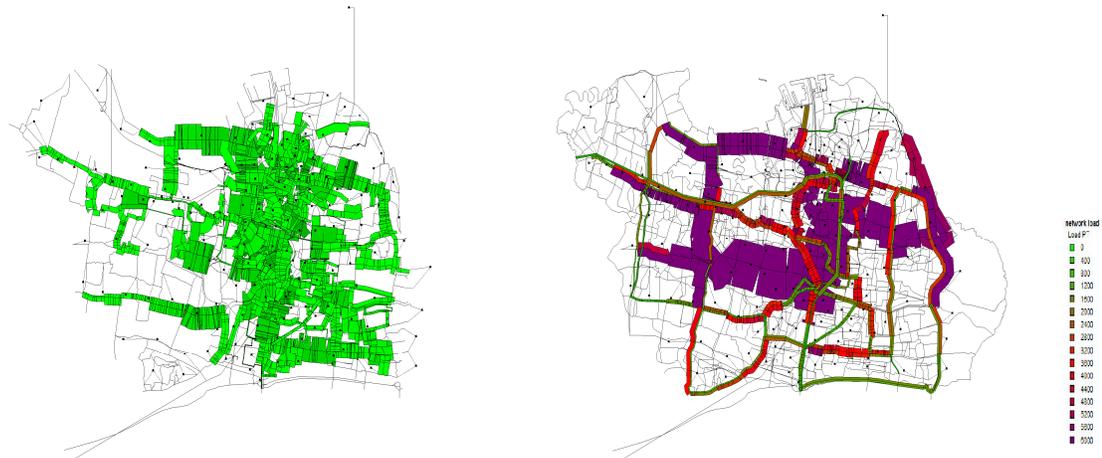
The alternative to improve public transport network is planned to increase the accessibility of residents of Surabaya City. Based on design of the public transport network (Dept. of Transport of Surabaya City, 2013), this research considers the improvement of public transport by designing an alternative with propose of MRT (monorail), LRT (tram line), BRT (bus rapid transit), regional train, feeder and trunk network as seen in Figure 14. Even though the previous research about improvement of public transport system 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. This alternative is basis of the criteria such as travel time gain, speed, accessibility and amount of public transport trips for the citizens of Surabaya City.

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.



**Figure 14: Public transport networks in the future for Surabaya City (Dept. of Transport of Surabaya City, 2013)**

One effort to evaluate the performance of public transport improvement is conducted by considering the loads of public transport system for the alternative given compare to the current base 2030. Figure 15 illustrates the loads of public transport system in the base case 2030 and in the alternative. 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 alternative for public transport systems particularly usage of MRT and BRT systems.



**Figure 15 Load public transport networks in the current trend 2030 and in the alternative**

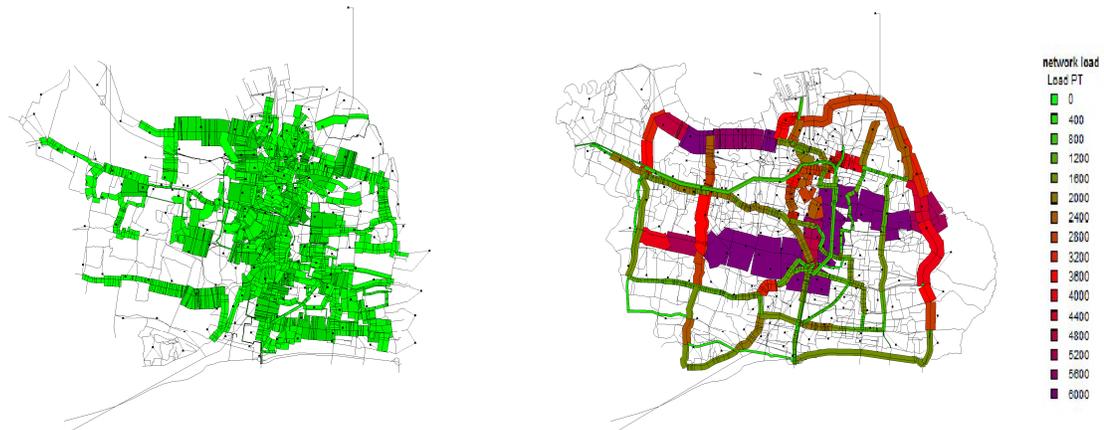
### **5.3. Impact urban strategy on the accessibility of residents**

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, J.K, 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. Since according to

Loo and Chow (2010), the new growth areas further away from CBD linkage with providing good public transport become good interactions among different new growth areas and reduce their dependency on the urban core areas.



**Figure 16: The load of PT system for base case 2030 and the scenario (compact city)**

The loads of all public transport systems for base case 2030 and the scenario (compact city) can be seen in Figure 16. The significant differences with the scenario current trend can be found in the loads of the all PT systems 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 all PT system than the loads of scenario with only improvement of PT system.

**Table 8: Modal split for 2030 and the alternatives**

Transport mode	Modal split 2030 (%)	Improvement of PT in 2030 (%)	Space-transport development in 2030 (%)
Public transport	5.62	8.51	9.23
Motorcycle	63.39	59.8	60.3
Car	30.23	26.58	25.39
Bicycle	0.75	5.04	5.09

Table 8 indicates the modal split of 2030 current trend with the alternatives such as improvement of PT system and space-transport development. The increase of public transport passengers is 60%, meanwhile 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.

## 6. 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 choice of transport mode 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. 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. 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 behavior 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.

## References

- Aguiléra A., Sandrine Wenglenski, Laurent Proulhac 2009. Employment Suburbanization, Reverse Commuting and Travel Behavior by Residents of the Central City in the Paris Metropolitan Area, *Transportation Research Part A* 43 (2009), 685-691.
- Ambarwati, L., Pel, A.J., Arem. B.V, Verhaeghe, R. 2013. Empirical Analysis of Heterogeneous Traffic Flow. *Proceedings of the Eastern Asia Society for Transportation Studies, Vol.9.*
- Arasan, V.T., Arkatkar, S.S., 2011. Micro simulation study of vehicular interactions on heterogeneous traffic flow on intercity roads. *European Transport*. 48 : 60-86.

- Bart, I.L., 2010, Urban Sprawl and climate change: A Statistical Exploration of Cause and effect, with policy options for the EU, *Land Use Policy* 27 (2010), 283-292.
- Bovy, P., Bliemer, M., & Nes, R. v. (2006). *Transportation Modeling*. Delft: Delft University of Technology
- Bruckner, J. K., 2011, *Lectures on Urban Economics*, Massachusetts Institute of Technology, USA.
- Burchell et al (1997) *a National Perspective on Land use policy Alternative and Consequent*, Rutgers University, Center for Urban Policy Research.
- Department of Planning and Development of Surabaya, 2007. *Master plan of Surabaya City*, Technical Report Surabaya, Indonesia.
- Departement of Transport of Surabaya City, 2013. *Surabaya MRT: Surabaya Mass Rapid Transportation (SMART)*. Technical Report Surabaya, Indonesia.
- Duncan et al, 1989. *The Search for Efficient Urban Growth Patterns: A Study of the Fiscal Impacts of Development in Florida*, Tallahassee: Florida Department of Community Affairs.
- Dupuy, G., 2008, *Urban Networks - Network Urbanism*. Amsterdam: Techne Press.
- Fatih T., Fulin B., 2012. *The Potential Effects of Spatial Strategies on Urban Sprawl in Istanbul*. *Urban Studies* 49(6) 1229-1250.
- FHWA, 1999. *An Overview Land Use and Economic Development in Statewide Transportation*, Center for Urban Transportation Studies, University of Wisconsin Milwaukee, In Cooperation with Wisconsin Department of Transportation
- Gennaio M.P., Hersperger A. M., Burgi, M., 2009. *Containing urban sprawl-Evaluating effectiveness of urban growth boundaries set by the Swiss Land Use Plan*. *Land Use Policy* 26 (2009) 224–232.
- Herijanto et al, 2006, *Accessibility of settlement area in Surabaya City (in Indonesian)*, Simposium IX FSTPT, Brawijaya University Malang, 17-18 November 2006.
- Irawan, M. Z., Sumi, T., & Munawar, A. (2010). *Implementation of the 1997 Indonesian Highway Capacity Manual (MKJI)*. *Journal of the Eastern Asia Society for Transportation Studies*.
- Korthof, E., Saase, M.V., Swierstra, A., Wong, J., 2013. *Improvement of Public Transport Systems in Surabaya*. Thesis Report. TU Delft. Netherlands
- L.Buys, E. Miller, 2011. *Conceptualising Convenience: Transportation Practices and Perceptions of Inner-Urban High Density Residents in Brisbane, Australia*, *Transport Policy* 18 (2011), 289-297.
- Loo, B. P.Y., Chow, A.S.Y., 2010. *Jobs-housing balance in an era of population decentralization: An analytical framework and a case study*. *Journal of Transport Geography*
- Permana Wandani, F., Yoshida, Y. 2013. *Automobile and Motorcycle Traffic on Indonesian National Roads: Is It Local or Beyond the City Boundary*. Tokyo, Japan: National Graduate Institute for Policy Studies.

Purwadi D., Wahyu H., dan Hera W., 1998, Distribution of Travel pattern for Citizen of Surabaya City based on Transport Mode and Trip Purposes, *1'st Symposium FSTPT*, Institute of Technology Bandung 3 December 1998.

Rahman, S., Fujiwara, A., Zhang, J., Nughoro, S., & Silaban, T. 2012. Investigating Travelers' Stated Mode Choice Preferences Considering the Influences of Choice Contexts on BRT System in Surabaya City. *Journal of International Development and Cooperation* , 1-16.

Statistic Bureau of Surabaya City. 2009. Surabaya City in Figures (in Indonesian), Surabaya.

Vega, A., Reynolds-Feighan, 2009. A Methodological Framework for the Study of Residential Location and Travel-to-Work Mode Choice Under Central and Suburban Employment Destination Patterns, *Transport Research part A* 43 (2009) 401-419.

Wanga, D., Feng, T., Liang, C., 2008. Research on bicycle conversion factors. *Transportation Research Part A* 42 (2008) 1129–1139.

Zhao, P., Lu, B., Roo, G. D., 2011. Impact of the jobs-housing balance on urban commuting in Beijing in the transformation era. *Journal of Transport Geography* 19, 59–69.