Development of Public Transport System Strategies to Control Urban Sprawl

L. Ambarwati, R. Verhaeghe, A. J. Pel, and B. Van Arem

***Abstract*—The phenomenon of urban sprawl has been a huge issue since the beginning of 20th century and is characterized by rapid and unbalanced settlement development, with transportation network, particularly in the suburban areas. Academic researches have explained the linkage strategy between transportation network and urban planning. However, insufficient empirical verification has been carried out to reduce this phenomenon by using the integrated approach of space-transport development. This paper focuses on analyzing the improvement of public transport (PT)system strategies. The research is analyzed by using microscopic data and by distributing questionnaires in order to assess the impact of settlement development in the suburbs. The impact of PT improvement has an effect on the settlement. The conclusions reveal that the requirement to improve PT-system should be facilitated together with the expanding settlement development. The combination of PT-system has to be involved to reduce 35% in travel time and to increase doubling of the use of public transport.**

***Index Terms*—Public transport, urban sprawl, settlement development, suburban area.**

I. Introduction

Regarding urban development, a city expands to the outskirts of an urban area. This phenomenon has occurred in Europe and over the world. Most cities in Indonesia, it has created broad serious problems since the beginning of 20th. Urban sprawl has several features which impact on a low density zone, dependence on the automobile, spatial mismatch and job sprawling [1]. Several efforts to minimize the impact of this phenomenon have been conducted based on the previous researches. Discussion has been carried out on how to overcome this phenomenon by integrating activities into high density areas and land-use mixes in order to reduce vehicular travel [2], by considering the transportation role in combating the problems related to urban sprawl [3], by considering the provision of a public transport system at the suburban destinations for Greater Dublin Area (GDA) [4].

According to [5], the urban containment strategies are some of the best-known planning instruments for managing urban sprawl. These include greenbelt and urban growth boundaries as applied in Switzerland since 1970. The strategies, particularly the boundary, have restricted development to building zones and have promoted the increase of building density. Other research related to urban development strategy such as a compact city approach employed in Istanbul to control urban sprawl by developing different scenarios. The result demonstrated that urban sprawl can be reduced by up to 62 % through implementing certain spatial strategies [6]. The studies specifically concentrated on an urban strategy to minimize urban sprawl.

Other researchers have paid attention to the relationship between employment suburbanization and the growth of reversed commuting in the weekday travel behavior of working residents in Paris [7]. The findings of the research confirmed that the choice of transport depends on the workplace, and the gentrification of the municipality of Paris linked to its capacity to attract high-qualified jobs and to its proximity to sub-centers. If quality of public transport remains insufficient, high-income residents resort to use their car greater extend. The research recommended that public authorities should be aware of the spatial mismatch which has negative environmental and social consequences.

Little empirical research has been conducted on the control of urban sprawl related to public transport network, taking into consideration of urban strategy and environmental impact of these developments and the commuter travel behavior. This paper will present a strategic option concentrated on the effort to integrate the spatial and transport plan to control settlement in the suburbs, particularly in poorly planned cities in developing countries. Sprawling settlement has grown in cities of developing countries since the 1980s.

This research will investigate the phenomena of transport mode choice, offering comparison for improvement of public transport by applying OmniTRANS model based on micro video data to estimate PCU (passenger car unit) value for motorcycle, travel survey by distributing questionnaires to the residents in order to estimate the distribution parameters of travel behavior and value of time (VOT), employment and population data from National Census 2010.

The issue relates to improve public transport accessibility to residents in suburban areas. Previous research was conducted to find out the current situation relating to the residents' journey in Surabaya City [8]. Consequently, the improvement will affect a change of accessibility and modal spilt.

The findings of this research are expected to assist government authority in planning housing development in relation to transport network surrounding them, by proposing a structured process of employing potential alternatives. Further research is intended to detail the impact assessment of integrated development, the need to include public preference into measurement of public transport performance in terms of satisfaction level, willingness to pay and impact assessment based on housing development.

Manuscript received December 9, 2013; revised March 11, 2014.

Lasmini Ambarwati is with the Department of Transport and Planning, TU Delft, Netherlands; Department of Civil Engineering, Brawijaya University, Indonesia (e-mail: L.Ambarwati@tudelft.nl).

Robert Verhaeghe, Adam J. Pel, and Bar Van Arem are with Department of Transport and Planning, TU Delft, Netherlands (e-mail: R.J.Vehaeghe@tudelft.nl).

DOI: 10.7763/IJET.2014.V6.739

The organization of paper is described as follows: Data collection and explanation of methodology is explained in the second section. Background information about public transport of Surabaya City is described in the third section. The fourth section comprises an estimation of parameters for four-step transport model from observation data. The fifth section discusses several alternatives to improve PT-systems in order to increase residents' accessibility. The final section presents conclusions and recommendations for further analysis.

II. Data and Methods

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

A. Data Collection

In this paper, three alternatives have been applied for Surabaya City to identify an effect on residents' accessibility. The alternatives consist of improvement of Bus Rapid Transit (BRT), Mass Rapid Transit (MRT) and Light Rapid Transit (LRT), integrated PT-system consisting of MRT, LRT, BRT, and feeder systems.

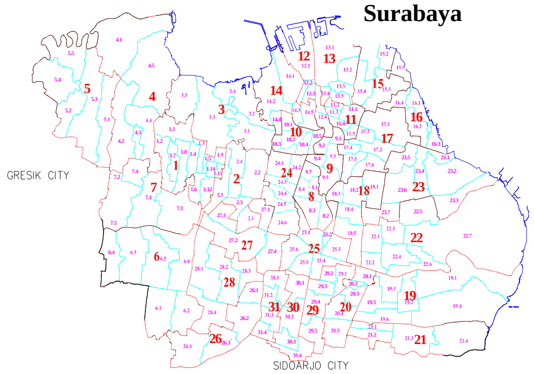


Fig. 1. Location of study area (Surabaya city) in east java province, Indonesia.

To apply the models, the data was collected for each village (called "*Desa*") within urbanized area of Surabaya City. Surabaya City as the capital city of East Java Province comprises 31districts and 163 villages with the total area of 327 km², and location at an altitude of 3-6 m above mean sea level. The city has a population of approximately 2.8 million, with 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 [9].

The data was collected by 2010 Census data and by distributing questionnaires to 163 villages (approximately 554 respondents). The questions consisted of three parts: socio-economic background, trip characteristic, and transport mode choice.

B. Models

The model employed in this research is OmniTRANS to set up a transport model. The transport model uses the four-step transport model for modeling trips between zones. The main point of this research is to achieve optimization of the transport network by proposing he alternatives for the performance of improvement of public transport combined with a settlement development in suburbs, particularly in west side of the city.

In OmniTRANS model, the choices involved in making trip are included 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, journey to school, or other activities per zone.

The result of trip frequency choice is input for the next step. In 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 steps are OD-matrices for each 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 to each transport mode by modeling route choice. This can influence the travel resistances since these will increase congestion. Therefore, the traffic assignment becomes an iterative process. It is also possible to expand this feedback loop in OmniTRANS to include the second and third steps. The resulting outputs of OmniTRANS are link loads, travel times, travel distances and travel costs. The four-step model of a transport model is explained in Fig. 2.

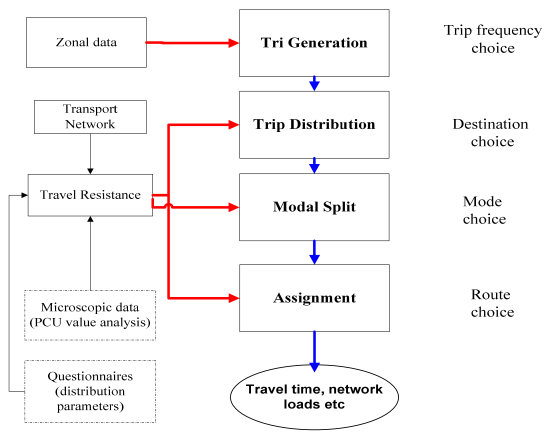


Fig. 2. Four-step model ([10] and modified by author).

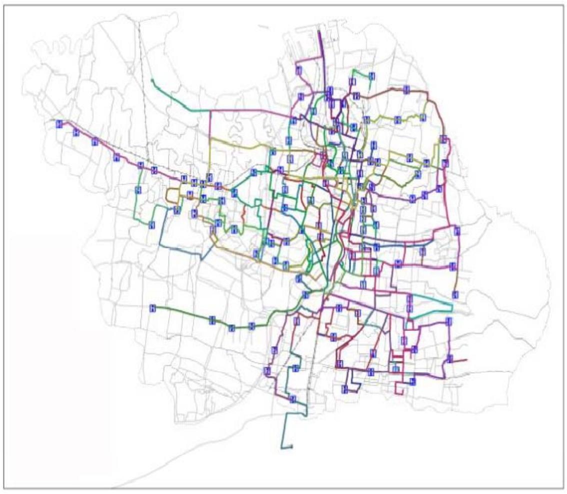
Generally, the input of OmniTRANS consists of zonal data, transport networks and user behavior. The zonal data was imported from JSM (Java Spatial Model) and the network was based on the GIS application program. The user behavior consists of: trip production and attraction parameters, distribution functions and BPR-functions. The parameters of the different functions had to be estimated. In this research, estimation of the PCU value for motorcycles employed the microscopic empirical data by using the result of analysis of porous flow model [11], and using the result of questionnaires to calculate the parameters of distribution function for each transport mode (car, motorcycle, public transport, and bicycle) and value of time (VOT). The assessment of the parameter for the volume delay function for each transport mode per road type is based on IHCM (Indonesian Highway Capacity Manual).

Comparative analysis is undertaken to assess and to evaluate the technical performance of the different alternatives. The analysis consists of three alternatives of improvement of PT-systems which is assessed to obtain the best transport for Surabaya City. There are 5 alternatives proposed in this assessment consisting of scenarios for 2010-the existing condition, scenario for 2030 with current trend, scenario for 2030 with improvement of public transport (design of BRT grid structure, combination of MRT and LRT systems, and design of MTR, LRT.BRT systems).

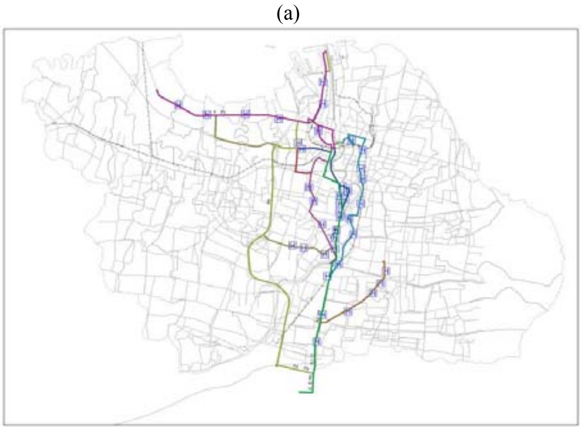
III. Identifying the Current Public Transport

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

Surabaya public transport network currently consists of minibus/paratransit, busses and trains. There are 68 available paratransit routes, 22 bus routes as shown in Fig. 3, and 1 train route within Surabaya. Most bus routes use national/provincial roads and toll roads in the middle area of city, the other areas are served by paratransit (minibus accommodates 8-12 passengers). The paratransit routes have no fixed time schedule or frequency. Bus and paratransit are driven more during the day than the night.



(a)



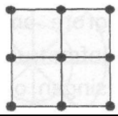
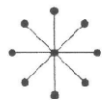
(b)

Fig. 3. Routes of paratransit (3.a) and bus (3.b) of Surabaya city.

The public transport which is served by public bus and paratransit (minibus) services is inadequate and deteriorating gradually. The provision of rapid and efficient public transport networks is designed to combat the impact of this traffic congestion. The improvement of the public transport service is regarded as an alternative for private car and motorcycle to change transport mode. The research noticed a reduction of average vehicular speed from 2007 to 2010. The average vehicular speed fell from 24 km/h to 21 km/h in that period [12]. One of the many reasons for the high proportion of motorized transport particularly motorcycles, that is 60% of the roads have no usable sidewalk. Consequently, trips of less than 3 kilometers were made for 60% by motorized transport, result in more traffic congestion and economic inefficiencies [13].

Table I 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).

TABLE I: Public Transport Characteristic for Surabaya City

Characteristics	Bus	Paratransit	Train
Line spacing (km)	0-15	0-10	30
Stop spacing (km)	0.5-2	0.5-1	3
Average speed	40	30	30
Network level	Urban: express-servic e	Urban: urban	Urban: agglomeration
Network structure	Grid 	Radial 	Linier 

IV. 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 [11] 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.

A. *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 *cij*. 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:

$$T_{ij} = a_i b_j P_i A_i f(c_{ij}) \quad (1)$$

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 to assess the accessibility from zone i to zone j is presented as follows:

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

where c_{ij} is travel impedance (generalized travel cost based on distance and time), α, β, and γ 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 α, β, γ 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 II. Motorcycle is generally more attractive than the other transport modes. The result of distribution function is a function of travel time.

TABLE II: PARAMETERS OF TOP-LOG NORMAL DISTRIBUTION FUNCTION FOR EACH 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

B. 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 [11]. 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 Fig. 4, 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.

Based on (3) which is introduced by [14], 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 III.

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

TABLE III: 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

Three PCU value groups are plotted with the speed occur as a linear model as illustrated in Fig. 5. 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. 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).

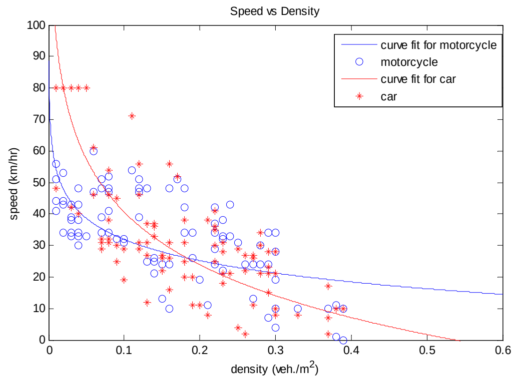


Fig. 4. Speed-density diagram from the result of empirical analysis of porous flow approach.

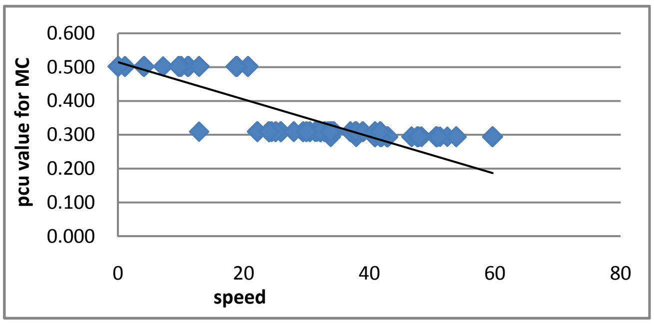


Fig. 5. Variation of PCU value of motorcycle (MC).

C. 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:

$$P_q = a_i + a_2(C_p - C_q) + a_2(T_p - T_q) \quad (4)$$

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

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), λ is value of time, a_1, a_2 are parameters.

Based on (4) and (5), the VOT for motorized vehicle is 32,837 IDR/hr while VOT for public transport passenger is 23,448 IDR/hr.

V. Alternatives Related to Improvement of PT-Systems

A. Current Trend

This scenario presents an analysis of the present (2010) and 2030 situation with considering transportation 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 IV.B. 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.

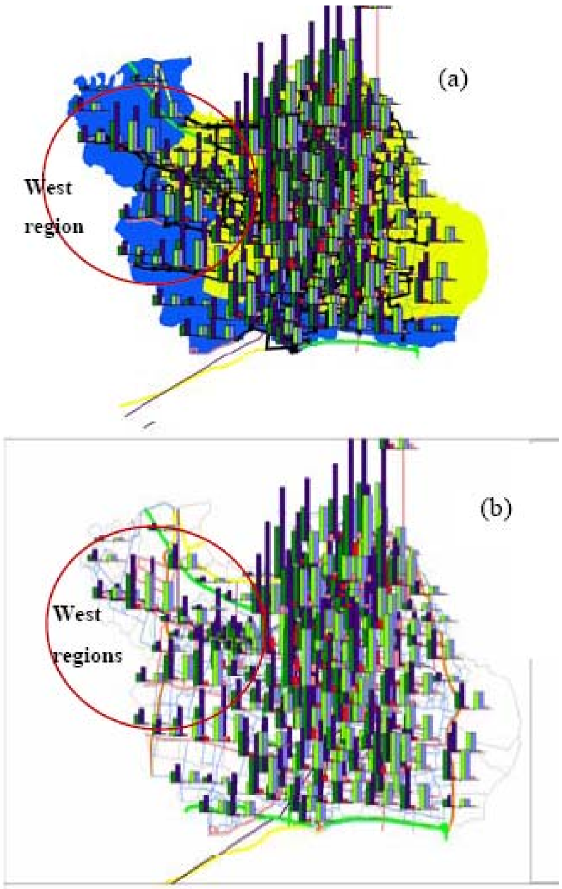
Two scenarios give a significant result in modal split which indicates the percentage of trips for each transport mode type. The modal split of public transport in the current case of 2010 with PCU 0.39 and 0.304 are 6.91% and 6.82% respectively. By using 0,304 for PCU value of motorcycle, the further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

TABLE IV: 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

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. 6. The production bar chart explains the amount of trips that are produced in each village/*desa* which means the traveler 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. 6 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 the central urban area.



(b)

Fig. 6. Production and Attraction per transport mode in 2010 (6a) and 2030 (6b).

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. 7 and Fig. 8, 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.

Fig. 7. Volume/capacity ratio (VCR) of bus in base case 2010 (7a) and 2030 (7b)

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

Modal split indicates the percentage of trip for each transport mode. From Table V, 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. To solve the congestion occurs, improved accessibility of these zones will be necessary for a sufficient public transport system. In addition, settlement development should be connected with the improvement of PT-system.

TABLE V: 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

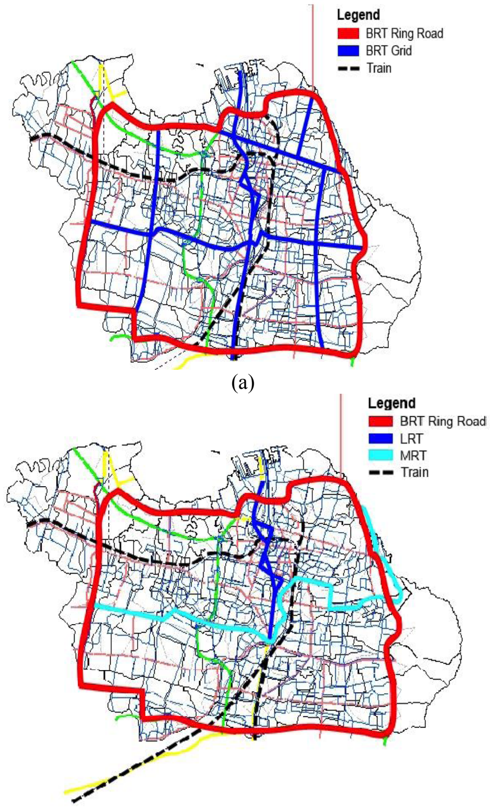


Fig. 9. BRT-system with grid structure [15] (9a) and public transport networks in the future for Surabaya City [16] (9b).

B. Improvement of Public Transport Systems

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 (Dept. of Transport of Surabaya City, 2013), this research considers the improvement of public transport by designing the alternatives with propose of BRT (Bus Rapid Transit) system with grid structure, and combination of MRT (monorail) and LRT (tram line), combination of MRT (monorail), LRT (tram line), regional train, feeder and trunk network as seen in Fig. 9(a) and Fig. 9(b). Even though the previous research about improvement of public transport system considering 3 modes in Surabaya [15] has presented the alternative with design of BRT system on the new ring road and on grid structure is best alternative.

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. 10 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 and LRT). The huge load of PT particularly usage of MRT system and feeder system occurs in the west and central regions of the city. The third alternative (improvement of MRT, LRT, BRT and train systems) also revealed the similar trend of passenger of MRT and BRT systems. The huge load of PT particularly usage of MRT and BRT systems also occurs in the west and central regions of the city. This alternative is expected to accommodate residents' trips and to increase the accessibility of residents in the west region which is developed as settlement areas.

C. The Impact of Improvement of PT-System on Residents Accessibility

Interpretation results of the alternatives are explained as indicator of accessibility of residents particularly in the west region of city. The indicators are presented in modal split, distance and travel time per trip, and quality of PT network.

(a)

(b)

(c)

(d)

Fig. 10. Load public transport networks in the current trend 2030 (10a) and in the alternatives (BRT-grid structure (10b), MRT+LRT (10c) and combination of all PT-systems (10d)).

Table VI indicates the modal split of 2030 current trend with the alternatives such as implementation of BRT-system, improvement of PT system (MRT and LRT), and improvement of all PT systems. 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 52%, 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 insignificant affects on the alternatives. Briefly, it is needed an alternative in order to decrease usage of motorcycle for example by simulation of decreasing the PT fare.

Table VII and Table VIII explain travel distance and time per trip for residents in entire of city and in west regions of city. The average distance per trip is an indicator of network performance which means illustration of the demand. Hence, a larger average travel distance in each trip also means more demand and congestion. The PT passengers in the west region have the smallest average distance than the other modes.

TABLE VI: MODAL SPLIT FOR BASE CASE 2030 AND THE ALTERNATIVES IN 2030

Transport mode	Modal split 2030 (%)	Implementation of BRT-grid structure (%)	Improvement of MRT & LRT (%)	Improvement of PT (%)
PT	5.62	5.69	7.72	8.51
MC	63.39	60	58.7	59.6
Car	30.23	28.86	28.7	26.58
Bicycle	0.75	5.48	5	5.04

TABLE VII: AVERAGE DISTANCE PER TRIP FOR ALL ALTERNATIVES

Region	Transport mode	Base case 2010	Current trend 2030	Implementation of BRT-grid structure in 2030	Improvement of MRT & LRT in 2030 (%)	Imp. of PT in 2030 (%)
West region	PT	13.2	25.34	11.27	11.59	11.65
	MC	12.22	26.71	37.57	35.78	37.41
	Car	13	19.23	13.87	13.37	17.46
Entire of city	PT	12.41	22.78	12.11	20.5	20.83
	MC	11.56	14.52	16.67	14.49	16.65
	Car	11.27	13.4	12.79	11.3	11.77

TABLE VIII: AVERAGE TRAVEL TIME PER TRIP FOR ALL ALTERNATIVES

Region	Transport mode	Base case 2010	Current trend 2030	Implementation of BRT-grid structure in 2030	Improvement of MRT & LRT in 2030 (%)	Imp. of PT in 2030 (%)
West region	PT	58.5	150.3	89.8	69.43	67.6
	MC	35.8	193.6	91.4	87.61	85
	Car	42.1	265.3	133.4	124.88	121.5
Entire of city	PT	55.9	114	80.5	61.52	61.38
	MC	46	149.3	86.7	82.17	82.26
	Car	59.4	209.3	127.3	119.07	119.8

TABLE IX: VARIOUS INDICATORS OF THE QUALITY OF PT NETWORK

Indicators		Base case 2010	Current trend 2030	Implementation of BRT-grid structure in 2030	Improvement of MRT & LRT in 2030 (%)	Imp. of PT in 2030 (%)
Distance per trip (km)	Access leg	0.64	1.53	1.32	1.26	1.21
	Egress leg	0.66	1.3	1.4	1.32	1.3
Waiting time per trip (min)	Access stop	0.52	0.91	2.43	5.06	4.38
	Transfer stop	1.16	1.42	1.84	3.75	2.68
Average per trip	Fare (IDR)	2887	3112	4559	6399	6402
	Travel per trip (#)	2.36	1.51	0.73	0.78	0.62
	Travel time (min)	55.9	114	80.5	61.52	61.38
	Distance (km)	12.41	22.78	12.11	20.5	20.83

Average travel time is highest for the public transport passengers in base case 2010. By designing improvement of PT-systems, average travel time for each trip declines depending on the alternative. Travel time which indicates the network performance declines with improvement of PT system. This situation effects on increase of the willingness of PT usage. The alternative concerning improvement of all PT-systems 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 (public transport) network is more attractive than the other transport modes.

Table IX explains several indicators of the quality of public transport network. The alternative with design of all PT-systems in term of combination of MRT, LRT, BRT and feeder systems shows better result of all indicators except waiting time and fare than the other alternatives in 2030. As mentioned in Table VI, modal split with improvement of PT-system also increase with indicated value approximately 1.5 times the usage possibility of PT-system. Travel time of this alternative is the smallest than travel time occur of the other alternatives. Briefly, this alternative performs well to decrease 40% travel time and to increase 1.5 times passenger of public transport.

VI. 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 urban areas. Briefly, the central urban areas have 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 [11], 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 improvement of PT-systems 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*, improvement of PT system affects on reducing the usage of car and increasing the shift of transport mode particularly public transport and bicycle in the west region which is designed as settlement development areas. This result means settlement development and work place should be connected with high accessibility.

For Surabaya City, the design of spatial development strategies and linkage of space-transport development strategies should be examined in this research. These strategies are expected as a strategic option to increase the residents' accessibility in the suburban areas. The alternatives are expected as an effort to minimize settlement development in the suburb. 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

[1] J. Duncan, *The Search for Efficient Urban Growth Patterns: A Study of the Fiscal Impacts of Development in Florida*, Tallahassee: Florida Department of Community Affairs, 1989.

[2] D. Banister, "Energy, quality of life and the environment: the role of transport," *Transport Reviews*, 1996. vol. 16, no. 1, pp. 23-35, 1996.

[3] FHWA, *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, 1999.

[4] A. Vega and A. R. Feighan, "A methodological framework for the study of residential location and travel-to-work mode choice under central and suburban employment destination patterns," *Transport Research Parts*, vol. 43, pp. 401-419, 2009.

[5] M. P. Gennaio, A. M. Hersperger, and M. Burgi, "Containing urban sprawl-Evaluating effectiveness of urban growth boundaries set by the Swiss Land Use Plan," *Land Use Policy*, vol. 26, pp. 224–232, 2009.

[6] F. Terzi and F. Bolen, "The potential effects of spatial strategies on urban sprawl in Istanbul," *Urban Studies*, vol. 49, no. 6, pp. 1229-1250, 2012.

[7] A. Aguiléra, S. Wenglenski, and L. Proulhac, "Employment suburbanization, reverse commuting and travel behavior by residents of the central city in the Paris Metropolitan Area, *"Transportation Research Part A: Policy and Practice*, vol. 43, pp. 685-691, 2009

[8] W. Herijanto, A. A. G. Kartika, H. Widyastuti, and C. Arif, "Accessibility of settlement area in surabaya city," *Symposium IX FSTPT*, pp. 17-18, 2006.

[9] Department of Planning and Development of Surabaya City, "Master plan of Surabaya City," Technical Report Surabaya, Indonesia, 2007.

[10] P. Bovy, M. Bliemer, and R. V. Nes, *Transportation Modeling,* Delft: Delft University of Technology, 2006.

[11] L. Ambarwati, A. J. Pel, B. V. Arem, and R. Verhaeghe, *Empirical Analysis of Heterogeneous Traffic Flow*, 2013.

[12] F. P. Wandani and Y. Yoshida, *Automobile and Motorcycle Traffic on Indonesian National Roads: Is It Local or Beyond the City Boundary?* Tokyo, Japan: National Graduate Institute for Policy Studies, 2013.

[13] M. Replogle and C. Hughes, *Moving Toward Sustainable Transport,* Worldwatch Institute, pp. 53-65, 2012.

[14] V. T. Arasan and S. S. Arkatkar, "Microsimulation study of vehicular interactions on heterogeneous traffic flow on intercity roads," *European Transport\Trasporti Europei*, vol. 48, pp. 60-86, 2011.

[15] E. Korthof, M. V. Saase, A. Swierstra, and J. Wong, "Improvement of public transport systems in surabaya," Thesis Report. TU Delft. Netherlands, 2013.

[16] Department of Transport of Surabaya City, "Surabaya MRT: Surabaya Mass Rapid Transportation (SMART)," Technical Report Surabaya, Indonesia, 2013.

Lasmini Ambarwati received the M.Sc. degree in civil engineering in 2002 from Saga University, Japan. She is currently working toward her Ph.D. degree in transport infrastructure planning. Delft University of Technology, Netherlands. Her research interest lies on integration of space-transport planning, and impact assessment.

Robert Verhaeghe is an associate professor with the same group at Delft University of Delft. His research interests cover transport infrastructure planning, transport demand management, and spatial planning.

Adam J. Pel is an assistant professor with the same group at Delft University of Delft. His background is in strategic transport model, traffic assignment, travel behavior and evacuation

Bart Van Arem is a professor with the Faculty of Civil Engineering, Delft University of Technology. His main research interests cover deriver behavior, traffic flow simulation, dynamic simulation model, and multimodal transport networks.