Investigating Travelers' Stated Mode Choice Preferences Considering the Influences of Choice Contexts on BRT System in Surabaya City

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ABSTRACT

This study evaluates BRT system in Surabaya, Indonesia considering various mode choice contexts based on choice context SP design. Mode choice models of multinomial logit type have widely been developed based on stated preference survey considering some future hypothetical scenario where access mode, main mode and egress mode availability differs from one trip makers to another. The model used in this study analyzes commuters' main mode and access mode choice behavior for work trips in respect to individual characteristics, socio economic variables, mode attributes, mode availability, vehicle ownership etc using data from the Surabaya City. The analysis implies that important deterministic variables for the individuals travel decision include household monthly income, age, job status, travel time and access mode choice was found conditional to main mode preference. This study reveals commuters' hidden preferences for modes that are not in existence, in particular

the bus rapid transit System in the Surabaya City due to be fully implemented in 2012. The developed models were then used to express complex travel behavior and forecasting travel demand for new transport services by simulation analysis. Changes in mode choice probabilities in response to changes in travel fare under various mode choice contexts were determined in proposed bus rapid transit system. Finally, policy recommendations are made for effective use of existing transportation modes in Surabaya city for successful implementation of BRT.

1. INTRODUCTION

Cities around the world are grappling with the many consequences of rising motorization and traffic congestion.In particular, the whole urban transportation systems in developing cities are changing rapidly due to economic development. The negative externalities such as lost time and productivity, vehicular accidents, greenhouse gas emissions and associated health hazards has been caused much more prompt and serious than the adjustments of residents' behavior and attitude.

To curb personal motor vehicle activity and its impacts on Environment it is very important that public transit service is maintained and enhanced in developing cities. Many transportation measures exist that could lead to significant improvements in commuters' exposure by reducing both in-vehicle air pollution and commuting times. Among these measures, Bus Rapid Transit (BRT) systems are being implemented in cities around the world as an efficient, sustainable, and low-cost alternative to underground or elevated public transit system.BRT systems provide a more rapid, metro-like service to commuters by including such features as separated bus ways, high capacity vehicles, and fixed stations and off bus fare collection. Such improvements to city's bus systems can potentially lead to significant environmental benefits by reducing the number of vehicles on the road, controlling the number of high-polluting starts and stops and replacing old buses with new generation public transport vehicles with improved technologies (Henry et al 2008). This paper explores the factors that contribute to improve the public transportation system based on an analysis of the operational performance of BRT in Surabaya City which is not yet existing but likely to be implemented in near future.

2. STUDY AREA AND PROPOSED BUS RAPID TRANSIT SYSTEM:

Surabaya City has been selected as study area (figure 1). Surabaya, the capital of east Java province is the second largest city in Indonesia. Surabaya is a tropical city and located at coastal and lowland area. The altitude varies from 3 to 10 m above sea level. Population of Surabaya (In 2008) was approximately 3 million in 2900.443 square km of area having a population density of 8394 per sq km. The city is divided into 31 Districts and 163 sub districts (Anwar et al, 2010).

While current urban bus transit takes an important role to meet rapidly growing mass mobility needs, and curbing personal motor vehicle activity and its impacts at low cost, the state of Surabaya's urban bus transport systems unfortunately leaves much to be desired, in terms of outcomes for users. The city's transport sector has been adversely affected by the rapid urbanization and the economic development of the country.

Surabaya city has relied predominantly on motorcycle and private vehicles for years. On the other hand public bus transit service is inadequate and decreasing day by day

Table-1. Year wise number of vehicles in Surabaya City

Types of vehicles	2005 (unit)	2006 (unit)	2007 (unit)
Motorcycle	883838	928686	972645
Private Car	217428	228195	232888
Pickup	82116	84371	86671
Public Bus	1353	1077	804
Angkot	13878	12010	9822

Source: Transportation Department of Surabaya, 2009

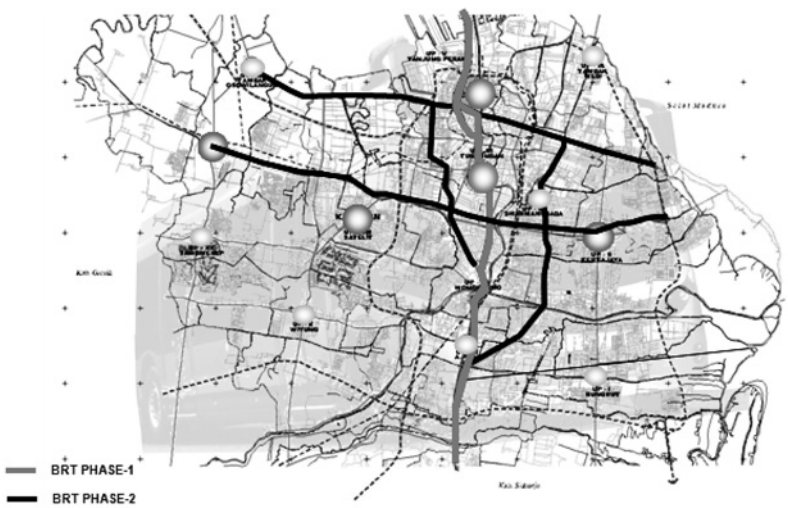


Fig-1. Study Area and proposed BRT Network

(Table-1). This rapid growth of motor vehicle activity in Surabaya city has brought in its wake a range of adverse impacts. Traffic congestion is increasing rapidly, causing significant time and productivity losses. Air quality has been poor in these centers since the late 1990s. Surveys have shown daily average suspended particulate levels, which are strongly correlated with respiratory and cardiovascular diseases, exceeding World Health Organization (WHO) guideline limits almost daily in Surabaya. Moreover, Surabaya's road accident record, already a concern, is deteriorating steadily, with the average death toll of two persons per day(Police Department, Surabaya).

In Surabaya, from 2009 it has been decided bythe city authority to celebrate "car free day" on Sunday and the time duration of celebration is from 6 AM to 10 AM. One important street (Raya Darmo Street) has been designated for car free day program and during this particular time no car or motorcycle is allowed to move through this street. Even, other motorized vehicles like city bus, angkot (public transport) etc are not allowed to go through this road. Beside road block for motorized vehicles, the celebration also consists of some other components like local ambient air quality monitoring and air quality improvement campaign etc.

Use of plastic bags in Surabaya has been enormous which cause thousands of marine animal deaths every year and manufacture of plastic bags add stones of carbon emissions into the air annually. To make more and more people around the city becoming aware of the environmental issues surrounding plastic bags, Surabaya City authority also launch "No plastic bag campaign" on regular basis .Beautiful bags made from cloths and papers are distributed or sold to the people on various occasions (also in car free day) by different non-government organizations (NGO) who describes the adverse effect of using plastic bags and encourages people to avoid it.

There had been several such efforts for environmental management in Surabaya City like the soft policies stated above and the recent effort is reduction of emission from vehicular emission. A particularly important measure that combats many of the impacts of traffic is the provision of rapid and efficient public transport networks as an alternative to private cars. BRT systems have been identified as an inexpensive, efficient and increasingly popular public transportation option. Considering this fact, Surabaya City Government has decided to implement BRT in Surabaya in several phases.

Surabaya Transportation Department expect the total capacity of BRT to carry 3868 person/hour/way in the peak period and 1627 person/hour/way in the off-peak period respectively. The capacity is 85 persons per bus. In the first phase the BRT line will be implemented in the North South Direction and will gradually extend the route in West-East direction in the second phase as can be seen in fig 1. In order to maintain a good level of service 54 bus unit is planned to operate in a departure length of 19.8 km and return length of 20.9 km. Estimated travel time will be 39.6 minutes and 41.2 minutes for departure and return. Headway in the peak period is 1.31 minute and 3.14 minute in the off-peak period. Fare for BRT has been decided to keep fixed for travelling any distance and it will be in between Rp2500 and Rp 3500.

3. BACKGROUND

As the people in Surabaya City have not experienced the proposed BRT, it is impossible to use only observed/recorded diary data about actual travel behavior to represent people's future preferences. It is necessary to examine the feasibility of SP approach. On the other hand, this paper focuses on analyzing the influence of the individual-specific context coming from changes in availability of different transport mode on mode choice behavior, while also incorporating the influence of the alternative-specific context coming from changes in level-of-service variables. Yet, it should be kept in mind that there might be some behavioral differences while conducting home based trips and non-home based trips. Here, the home based trips are dealt with, and non-home based trip is left as a future research issue.

This study investigates complex travel behavior after the introduction of BRT system. Besides, the system is not familiar to the public; socio-economic conditions will dramatically grow in future and the existing various kinds of para transit should be used alternatively as access mode in Surabaya. Moreover, the local government trusts the changes in the public attitude as an effect of the above-mentioned soft policies (i.e. car free day and no plastic campaigns). To argue such a dramatic change in the society, a stated preference survey has been applied in this study.

The SP approach, originating in the mathematical psychology, has been widely used in transportation because it can measure how people choose not-yet-existing travel modes or how people take actions in case of introducing new policies (e.g., road pricing, introduction of new/intelligent transport systems). This approach examines the individual response to a series of experimentally designed choice alternatives, which are typically described in terms of combinations of attributes with several predefined levels. In addition to the ability to directly measure the demand/response under not-yet-existing conditions, the SP approach has other advantages over the RP approach, which is based on the observed choice in real situations. These advantages include the ability to control statistical problems such as multicollinearity and lack of variance in explanatory

variables, the increased possibility of including subjective or qualitative factors as explanatory variables and cost-efficiency to develop models from a relatively small size of samples.

In recent years, there are some limited applications of the related SP applications in developing countries. Fillione et al. (2007) developed ordinal and nested logit models in the context of transport mode choice models in Metro Manilla based on a questionnaire survey to determine what type and characteristics of modes are used by the individual and what modes were considered in his/her reduced choice set.Zhang et al. (2008) made an effort to capture travelers' stated mode choice preferences under the influence of income levels in Yangon city, Myanmar. Bhattacharjee et al. (1997) developed a model based on stated preference survey to assess commuters' attitudes towards travel demand management in Bangkok. Ortuzaret al. (2000) studied on demand estimation for a cycle-way network in Chile.Dissanayake and Morikawa (2010) did transport policy analysis for developing countries using a nested logit model of vehicle usage, mode choice and trip chain case study in Bangkok metropolitan region. Sjafruddin et al. (2010) conducted demand rate and elasticity of the urban taxi service based on the stated preference data case study in Bandung, Indonesia. Furthermore, Park et al. (2003) made a feasibility study on the newtransit system implementation to the congested area in Seoul. It is obvious that the SP applications are getting popular in many developing cities.

In many previous studies in developing countries, it has been assumed that all the alternatives (including both access/egress and line haul modes) are available to all individuals. On contrary, this paper assumes that not all the modes are necessary available to all the commuters which have been reflected in SP design. For example, in Surabaya becak is not allowable to operate on some certain roads results in its non-availability as an access mode to different users. The city also experienced Car Free Day (Anwar et al, 2010) where neither car nor motorcycle is allowed to operate in some major routes of the city in some specific days resulting non-availability of cars and motorcycle on some particular route. Even long distance to the nearest station or unavailability of some access mode makes it difficult to avail some certain line haul modes to some users. Charisma and Annesha (2010) introduced a probabilistic choice set of modes to account for the absence ofactual mode choice set data in Dhaka and developed a model to predict the choice set probabilistically for the choice context of Dhaka using socio-economic characteristics, origin-destination and trip purpose.

In case of developed countries the network data provides a reasonable basis for predicting the choice sets for mode selection. But, in case of developing countries like Indonesia the transport network data is not well-structured. Para transits (and even in some cases traditional transits like buses) operate beyond their permitted routes which make it almost impossible to predict the accessibility of different modes into different zones. Moreover, in developing countries the affordability of people plays a vital role in determining the choice set, both for business and non-business trips.

Passengers per car is generally very high and car ownership alone is often not a suitable proxy for car availability. For instance, if there are five members and a single car in the household, some household members may get priority over others for the car usage (e.g. school going children, elderly people, etc.) Or, for a same person who is using car in one day of the week may not be avail that car in another day for the same purpose. So, it's necessary to investigate attitude of the commuters in response to the availability of different modes in future. On the other hand choice of access mode is strongly dependent on the availability of main mode and egress mode. This is necessary to determine the most preferred combinations of access and egress mode with the main mode for efficiently manage the future demand.

4. DATA COLLECTION

(1) Stated Preference Survey in Surabaya City

The new consideration here in this paper is that the stated preference survey design considered influence of travel mode availability. In order to control the number of motorcycles in congested roads, the scenario has been designed as motorcycle will not be used in the main roads and can be used as only access mode of transport which can be parked near BRT station paying a certain parking charge and can be used as an access mode. In SP experiment, availability of access, egress and main modes are assumed to be one of the attributes affecting mode choice behavior, as well as the level-of-service variables. The assumed main mode alternatives are passenger cars, buses, angkot, and BRT.

The level-of-service attributes include travel time and cost for all the alternatives. The level for each attribute is assumed as follows: (a) The travel cost of BRT is higher than that of buses but lower than that of passenger car, (b) travel time of BRT is shorter than that of buses, Based on the orthogonal fractional SP design method, a total of 24 scenarios are set up with respect to the combinations of the assumed travel mode availability and the level-of-service attributes with two levels. 16 contexts (16 subsets as described in Table 2) are based on home based trips and remaining 8 are about non-home based trips.

In the questionnaire, to reduce respondents' burden, the 24 contexts were grouped into four balanced blocks. Each

Table-2. The contexts of the universal choice set in SP

Context	Access Mode	Main Mode	Egress Mode	Trip Purpos	Trip Distanc
1	Becak, Walk	Car, Bus, BRT, Angkot	Walk	Shopping	20 km
2	MC, Angkot, Walk	Car, Bus, BRT	Angkot, Walk	Shopping	8 km
3	Angkot, Walk	Car, Bus, BRT, Angkot	Walk	Work/School	8 km
4	Angkot, Walk	Car, Bus, BRT, Angkot	Angkot, Walk	Work/ Schoo	20 km
5	MC, Angkot, Walk	Car, Bus, BRT	Walk	Work/School	8 km
6	MC, Becak, Walk	Car, Bus, BRT	Walk	Shopping	20 km
7	Angkot, Becak, Walk	Bus, BRT	Angkot, Walk	Work/School	20 km
8	Becak, Walk	Car, Bus, BRT, Angkot	Angkot, Walk	Work/School	20 km
9	Angkot, Becak, Walk	Bus, BRT	Walk	Work/School	8 km
10	MC, Angkot, Becak, Walk	Bus, BRT, Angkot	Angkot, Walk	Shopping	8 km
11	MC, Angkot, Becak, Walk	Bus, BRT, Angkot	Walk	Shopping	8 km
12	MC, Becak, Walk	Car, Bus, BRT	Angkot, Walk	Shopping	8 km
13	Walk	Bus, BRT	Angkot, Walk	Work/School	20 km
14	MC, Walk	Bus, BRT, Angkot	Angkot, Walk	Shopping	20 km
15	MC, Walk	Bus, BRT, Angkot	Walk	Work/School	8 km
16	Walk	Bus, BRT	Walk	Shopping	20 m

respondent received only one block with six subsets and is asked to choose the most preferred alternative. From the four predefined travel modes with respect to various trip purposes, considering the tradeoffs among the assumed attributes. In addition to that the respondents are also asked to report their socio-economic attributes, trip frequency to the city center, main travel mode, trip purpose, current level-of-service including travel time, and access time to and egress time from the nearest bus stop, railway station, etc.

(2) Survey implementation

With the cooperation of Environmental Agency of Surabaya City Government, the SP survey was conducted to the randomly selected 350 residents in March 2010. To the best of the authors' knowledge, this is the first attempt of an SP survey in Surabaya. Owing to the cooperation of township officers and residents' high interests in the survey, 270 valid questionnaires were successfully collected with a high response rate of more than 77% .

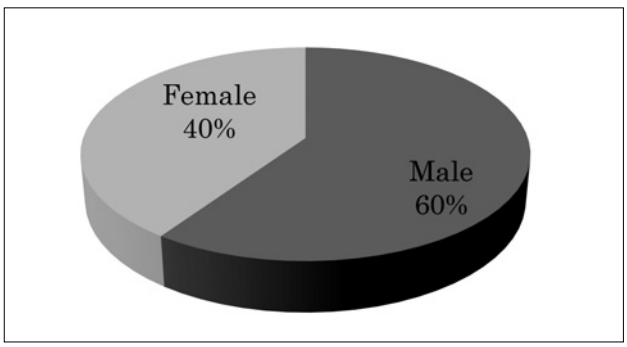


Fig. 2. Gender of the respondents

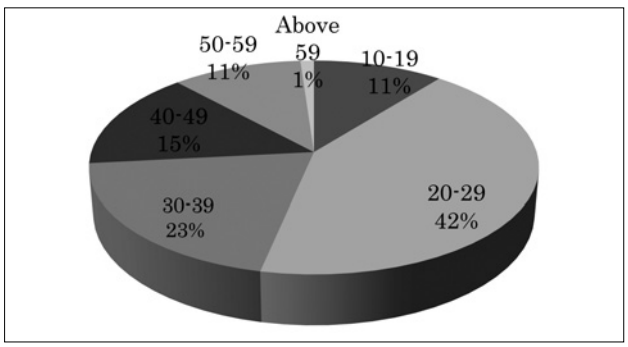


Fig.3. Respondent's age distribution

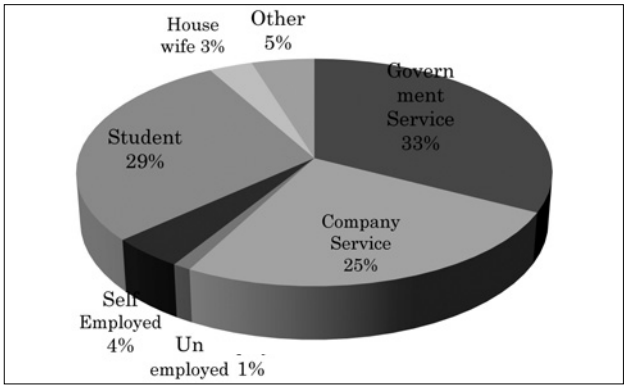


Fig 4. Occupation of the respondents

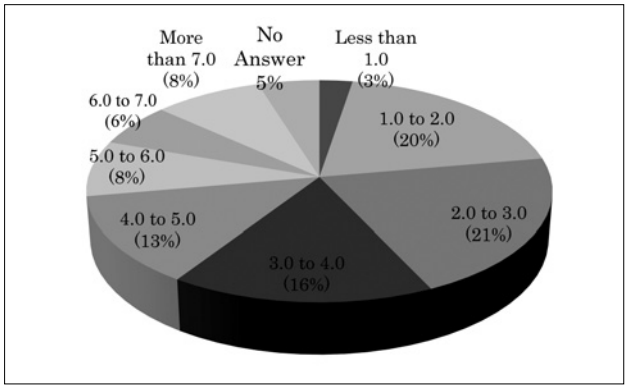


Fig. 5. Household income (million Rp) of the respondents

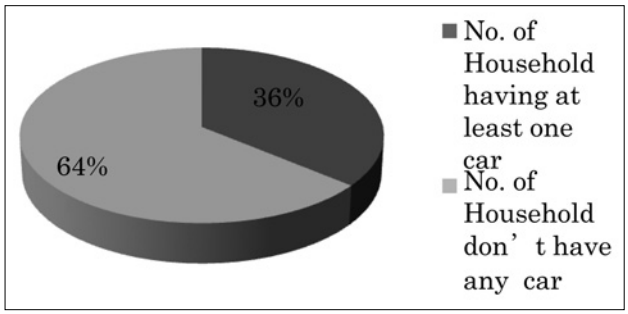


Fig-6. Car Ownership of the respondents

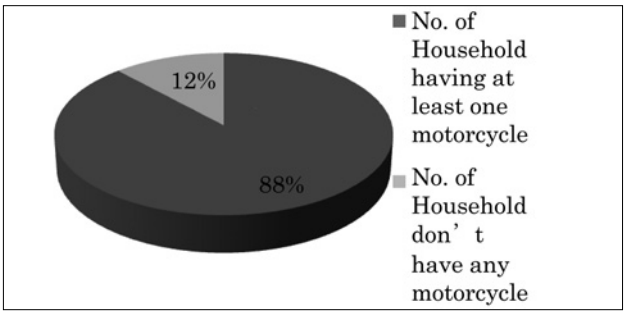


Fig-7. MC ownership of the respondents

The survey included commuters including students, employed, businessmen, and housewives of different income groups.The survey contents included commuters' individual attributes, trip attributes, and their choices to choose bus, BRT, private car and angkot. The utility information for the new traffic mode for the forecasting model was collected in a stated preference survey. Respondents' characteristics are shown in Fig-2 to Fig-8

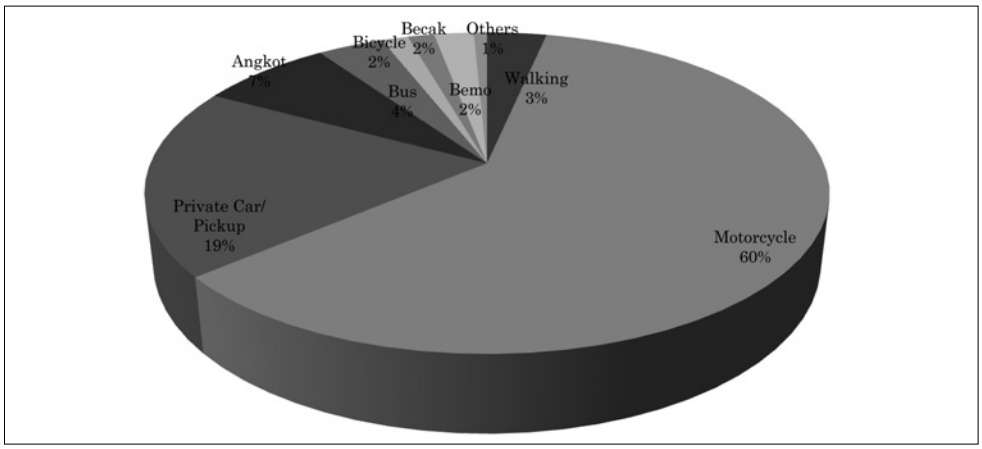


Fig- 8. Modal Share for the first trip of the day of the respondents.

Becak and angkot have been traditionally used as main and access mode in Surabaya city and hence, travelers' perception about becak and angkot has been collected in this survey and the result is shown in Fig-9 and Fig-10

Table-3 shows competitive modes in different choice context. It is found that in the entire choice context where car is present in the choice set, car and BRT are the two main competitive modes although there are are significant share of bus and angkot.

Table-3. Modal Share among the competitive modes (SP survey)

Choice context	No. of respondents	% of access mode share				% of main mode share			
		Becak	walking	Angkot	MC	Car	BRT	Bus	Angkot
1	71	11.27	59.15	–	–	29.58	43.66	14.08	12.68
2	61	–	40.98	14.75	18.03	26.23	50.82	22.95	–
3	68	–	45.59	33.82	–	20.59	57.35	13.24	8.82
4	70	–	37.14	34.29	–	28.57	52.86	10.00	8.57
5	71	–	49.30	16.90	16.90	16.90	60.56	22.54	–
6	61	3.28	52.46	–	18.03	26.23	57.38	16.39	–
7	68	13.24	50.00	36.76	–	–	82.35	17.65	–
8	70	21.43	55.71	–	–	22.86	57.14	10.00	10.00
9	71	8.45	54.93	36.62	–	–	78.87	21.13	–
10	61	8.20	55.74	11.48	24.59	–	68.85	18.03	13.11
11	68	10.29	45.59	26.47	17.65	–	80.88	10.29	8.82
12	70	7.14	47.14	–	15.71	30.00	52.86	17.14	–
13	71	–	100.00	–	–	–	76.06	23.94	–
14	61	–	59.02	–	40.98	–	75.41	11.48	13.11
15	68	–	60.29	–	39.71	–	77.94	11.76	10.29
16	70	–	100.00	–	–	–	84.29	15.71	–

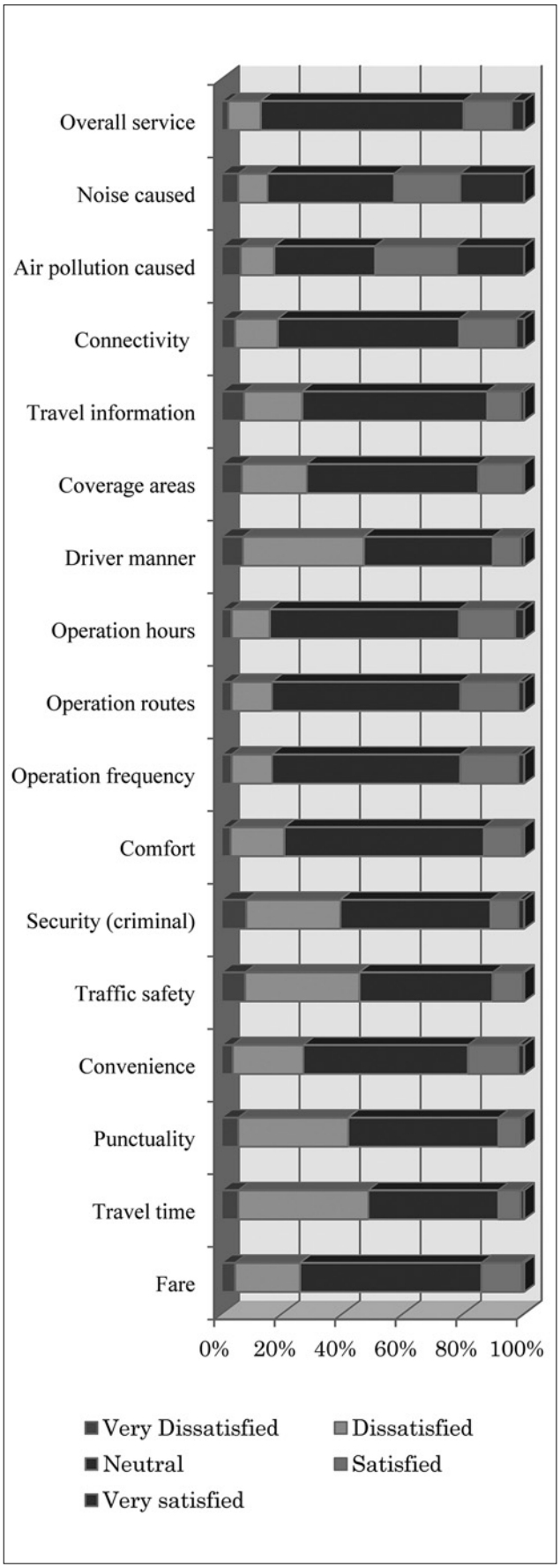


Fig-9. Travelers' Perception about becak

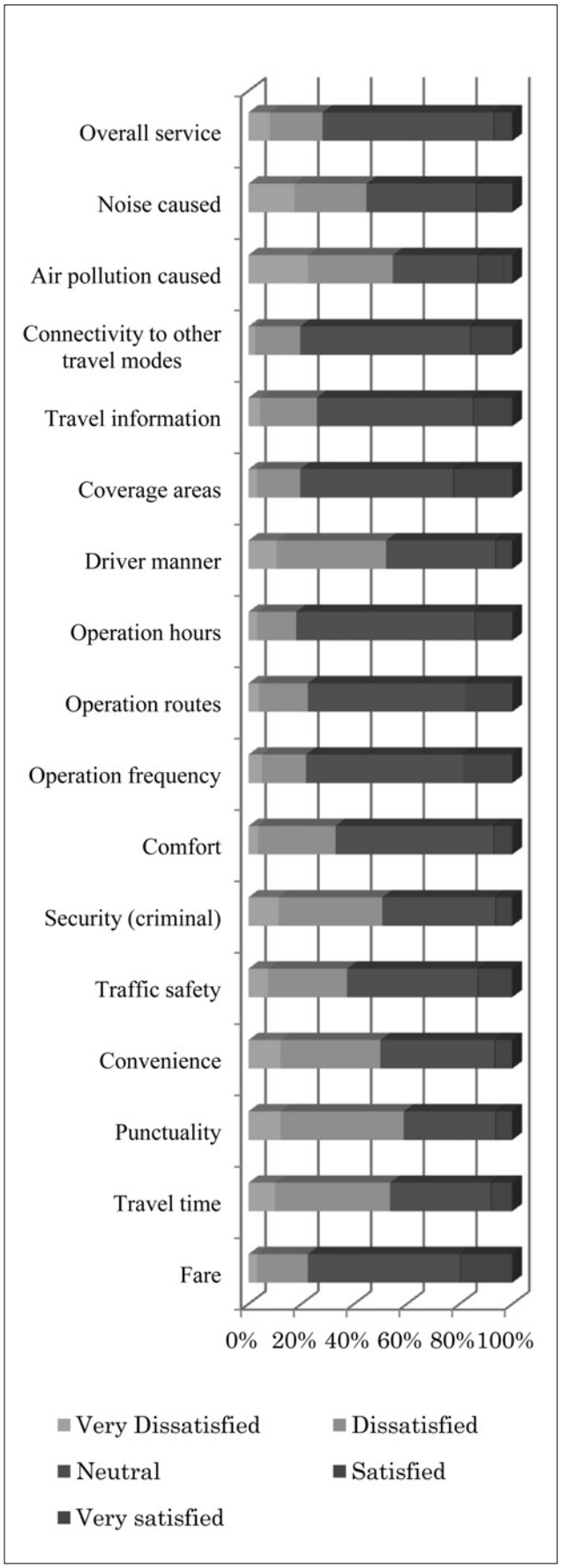


Fig-10. Travelers Perception about angkot

5. Model Structure

The mode choice by an individual during the morning home-to-work trip couldinvolve complex decision making processes which are context-dependent, where the context can be classified into individual-specific context, alternative-specific context and circumstantial context. The first type refers to individuals' and their households' attributes such as income level, car ownership, occupation, education level and residential locations. The second includes the number of alternatives and their attributes, the correlation structure of attributes, and the availability of alternatives. The last refers to circumstantial factors that are common to decision makers, such as economic conditions and tax levels in the purchase of passenger cars. Here in this model only the first two types of contexts are considered.

The most common model for mode choice of an individual is Multinomial Logit model (MNLM) which is used in this study to ascertain individuals' mode choice preference under various mode availability options. Considering limitations of data size obtained from choice context SP design survey result this simple MNL model is considered here.

Utility Equation of an individual for choosing a particular mode k can be expressed as

$$U_{ki} = V_{ki} + \varepsilon_{ki} \quad (1)$$

Where,
$$V_k = \sum \alpha_{mk} X_{mk} + \sum \beta_{nk} X_{nk} + \sum \delta_{\omega k} X_{\omega k} \quad (2)$$

Here, V_k is a deterministic term of the kth main mode option with mth mode attributes (X_{mk}) and nth individual characteristics (X_{nk}) and ω access/main mode options ($X_{\omega k}$). The deterministic term V_k is assumed to be a linear-in-parameters specification.

(ε_k) is a disturbance component hidden or unobservable to the modeler.

Now, choice probability of mode i for individual n can be written as

$$P_{ni} = \frac{\lambda_{ni} \exp(V_{ni})}{\sum_i \lambda_{ni} \exp(V_{ni})} \quad (3)$$

Where, λ_{ni} =1, if mode i is available in the choice set of individual n, =0, otherwise.

In this paper, four competitive main modes (i.e. bus, BRT, angkot and car) have been considered whether all the modes may or may not be available in the choice set for any individual i, then the probability equation for individual i can be written as

$$\Pr(bus) = \frac{e^{V_{bus}}}{e^{V_{bus}} + e^{V_{brt}} + \lambda_{car} e^{V_{car}} + \lambda_{ang} e^{V_{ang}}} \quad (4)$$

$$\Pr(brt) = \frac{e^{V_{brt}}}{e^{V_{bus}} + e^{V_{brt}} + \lambda_{car} e^{V_{car}} + \lambda_{ang} e^{V_{ang}}} \quad (5)$$

$$\Pr(ang) = \frac{\lambda_{ang} e^{V_{ang}}}{e^{V_{bus}} + e^{V_{brt}} + \lambda_{car} e^{V_{car}} + \lambda_{ang} e^{V_{ang}}} \quad (6)$$

$$\Pr(car) = \frac{\lambda_{car} e^{V_{car}}}{e^{V_{bus}} + e^{V_{brt}} + \lambda_{car} e^{V_{car}} + \lambda_{ang} e^{V_{ang}}} \quad (7)$$

Where, λ_{ang} =1, if angkot is available in the choice set of individual i, =0, otherwise. λ_{car} =1, if car is available in the choice set, =0, otherwise. Probability of access modes were also estimated based on the similar types of equation

6. Model Estimation and Discussions

Here, two different mode choice models were developed; one for main mode choice and another access mode choice. The utility equations are expressed in terms of the significant deterministic variables which include the alternative specific constant for each mode, alternative specific socio-economic variables of the traveler and also some interaction variables like age*gender etc. The significant deterministic variables for main mode choice and access mode choice are shown in table-4 and table -5 respectively.

(1) Choice of main mode

It has been found that age and household income have strong effects on main mode choice in Surabaya. The sign indicates that aging people have more utility on choosing public transit such as bus, BRT and angkot, while younger generation tends to use car in future. Household income has significant positive correlation with the utility of car for all trip makers as well as that of BRT for employed persons. Other than that increases in household income has negative effect on the utility of all other modes. Level of education has significant negative effect on Bus choice. Travel makers having educational background of at least graduation have less utility to choose bus . This may be due to the feeling of status of the travel makers. The utility of all the main modes have negative relationship with total travel cost with high level of significance.

Table-4. Estimation results of the models for main mode choice

Variables	Specific mode	Parameter	t- statistics
Education*gender (=1, if higher education and male)	Angkot	-0.423	-2.48 **
Student	Car	-1.958	-4.763**
Employment (=1, if employed in service)	BRT	0.571	2.813**
Employed as Company Service (=1, if company service)	Bus	0.649	2.957**
Age	Car	-0.020	-1.799*
Age	BRT	0.037	5.901**
Age*gender (=1, if, male)	Bus	0.012	1.965*
Age*occupation (=1, if employed as company service)	Angkot	0.045	4.172**
Household income (Rp)	Car	0.171E-06	2.50 **
Household income (Rp)	Angkot	-0.224E-06	-2.46 **
Household income (Rp)	BRT	0.120E-06	2.204**
Household income (Rp)	Bus	-0.770E-06	-1.15
Household income (Rp)*occupation*education(=1, if employed as company service and higher education)	BRT	-0.144E-06	-3.193**
Car Ownership	To Car	0.671	4.046**
Car Ownership*Gender (=1,if male)	To BRT	-0.324	-1.999*
Total Travel Cost (Rp)	All mode	-0.508E-06	-9.102**
Total Travel Time (minute)	All mode	-0.303E-03	-1.11
Travel Distance (km)	Car	0.377	8.863**
Travel Distance*Occupation (=1 if employed as Govt Service)	BRT	0.020	1.692*
Travel Distance*Occupation (=1 If Student)	Bus	-0.082	-5.12 **
Travel Distance*Occupation*Gender (=1 If male Student)	Angkot	0.039	1.6205
Log likelihood at Zero	-1153.234		
Log-Likelihood at convergence	- 788.764		
McFadden's Rho Square	0.31603		
Adjusted Mcfadden's Rho Square	0.29728		
No of cases	1080		

*Significance at $\alpha = 0.1$ **Significance at $\alpha = 0.05$

Despite the parameter of travel time is not significant, the negative sign of the parameters is quite reasonable in the context of development city like Surabaya. The sign of the parameter quite reasonably point out that faster travel mode is better for all trip makers in Surabaya. Parameters from the above model result show that students are disinclined to use car as main mode with very high level of significance. Travel distance has positive influence on mode choice of all user of car, BRT for government service holder and angkot for male student. On the other hand for student longer travel distance gives less utility to use bus significantly.

Company service holders are more apt to use bus with high level of significance whereas for employed persons BRT is the mode which gives more utility. Although in the present situation motorcycle ownership is increasing day by day but motorcycle ownership was not found significant while choosing the mode but car ownership level has significant and positive impact on choosing car and negative impact on choosing BRT for males. Besides, age has significant negative effect on car mode choice. The younger people are more attracted to car for work trip which clearly defines that car will be having more utility to the future generation in Surabaya City. Like all the developing cities it has been found that higher household income will significantly increase the utility of faster mode of transport like BRT and private car. Value of parameters for income shows that household income increase will increase the utility of private cars more than BRT which has been shown in the subsequent figures in details.

Table-5. Estimation result for access mode choice

Variables	Specific Mode	Parameter	t- statistics
Alternative Specific Constant	Car	1.679	3.595**
Student (=1if Student, 0 otherwise)	Walk	−0.574	−2.846**
Employed as Government Service (=1 if government service 0=otherwise)	Walk	−0.358	−1.889*
Age	Becak	0.059	7.022**
	Motorcycle	−0.037	−3.484**
Household Income (HIC) (Rp)	Becak	0.112E−06	1.657*
	Car	0.269E−06	2.271 **
Car Ownership	Car	0.356	1.639*
Motorcycle Ownership	Motorcycle	0.232	2.004**
Gender (=1 if Male, 0 otherwise)	Angkot	0.813	2.452**
	Motorcycle	0.732	2.190**
	Walk	0.519	1.987*
Trip Distance (km)	Motorcycle	0.072	3.015**
	Walk	0.055	2.996**
BRT as Main Mode (=1, If main mode choice is BRT, 0 otherwise)	Angkot	3.360	9.314**
	Motorcycle	3.778	8.684**
	Walk	4.256	12.074**
BUS as Main Mode (=1, If main mode choice is BUS, 0 otherwise)	Angkot	2.462	3.878**
	Motorcycle	2.773	4.258**
	Walk	4.383	8.672**
Log likelihood at Zero	−1153.234		
Log-Likelihood at convergence	− 662.73		
McFadden's Rho Square	0.42533		
Adjusted Mcfadden's Rho Square	0.40799		
No of cases	1080		

*Significance at $\alpha = 0.1$ **Significance at $\alpha = 0.05$

(2) Access Mode Choice

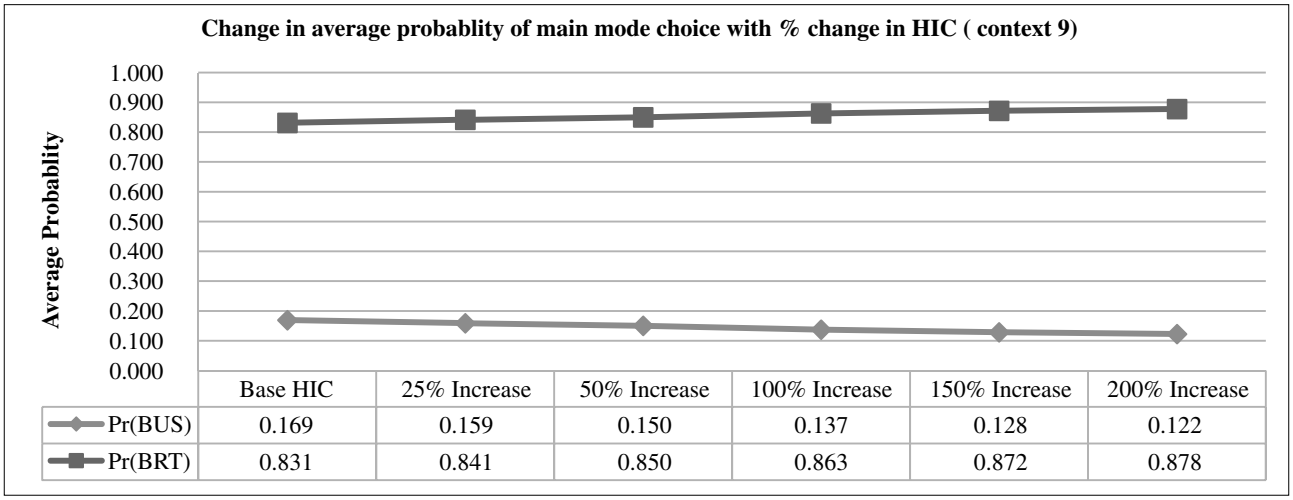
Main mode choice was found to have proof shows how utility of MC, walking and angkot depends on the mode choice of bus and BRT as main mode. By comparing the parameters of main mode choice with the access mode we can find that BRT as main mode contributes to utility on walking more than MC and angkot. Also, bus choice as main mode has significant influence on choosing walking and motorcycle as the access mode. Becak, though seems most unpopular access mode under BRT scenario with very low frequency of choice by the respondents, the model suggests that the aging people are attracted to use becak and can still be better for elderly people But, becak being a expensive mode of transport and only more household income (HIC) gives more utility to use becak .Traveler's perception about becak can be found from the Figure 4. One can find that level of satisfaction over the overall service of becak and angkot is not very impressive and drivers' manner, security from the criminals, traffic safety, punctuality of the modes and travel time are the major source of concern which can greatly influence the future limited use of angkot and becak. Becak which is becoming expensive day by day and as it is a slower mode of transport has a very low choice frequency as access mode among the SP respondents. According to the model, both students and Government employee are less likely to prefer walking with high significance level. Besides, Surabaya people have high motorcycle ownership, which has a significant positive effect on choosing motorcycle as access mode. It also indicates that people of Surabaya are gradually moving from non-motorized transports to motorized transports and Motorcycle can be successfully used as access mode for BRT and bus use.

7. SIMULATION ANALYSIS

(1) Sensitivity to increase in household income

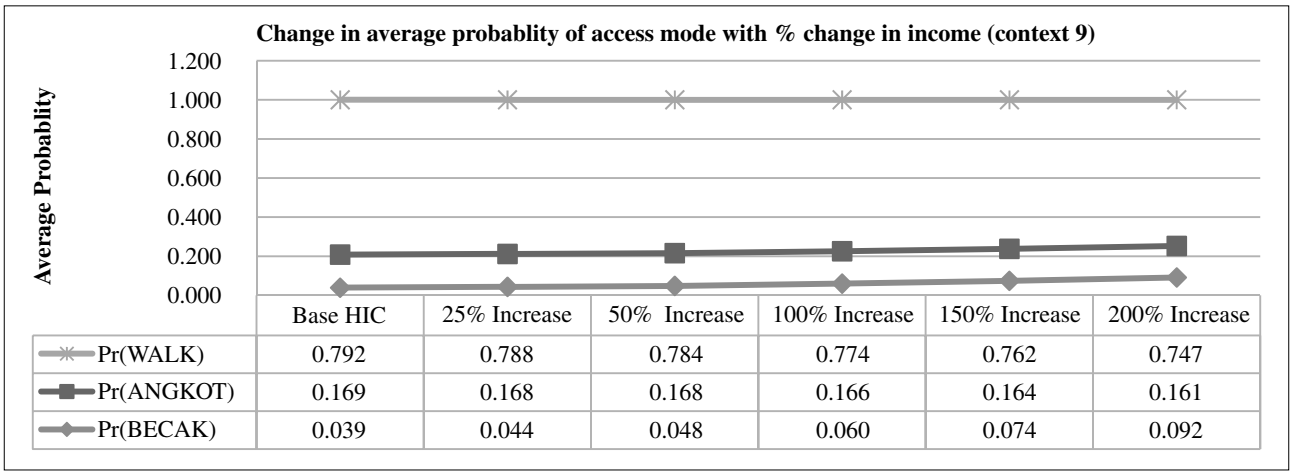
To understand people's travel mode choice behavior in the future under BRT, simulation analysis is conducted to examine the influence of future income on the modal choice Probability based on the assumptions that all the other parameters are

applicable over a long-term period. The choice probability by travel mode is calculated based on the estimated SP parameters. It is assumed that for the existing travel modes, their relevant level-of-service variables are all fixed at the current average values. The medium level assumed in SP Survey is adopted for each variable of the mode. Simulation results for each scenario of mode availability were done and typical results are shown in from Fig -11 to Fig- 20.



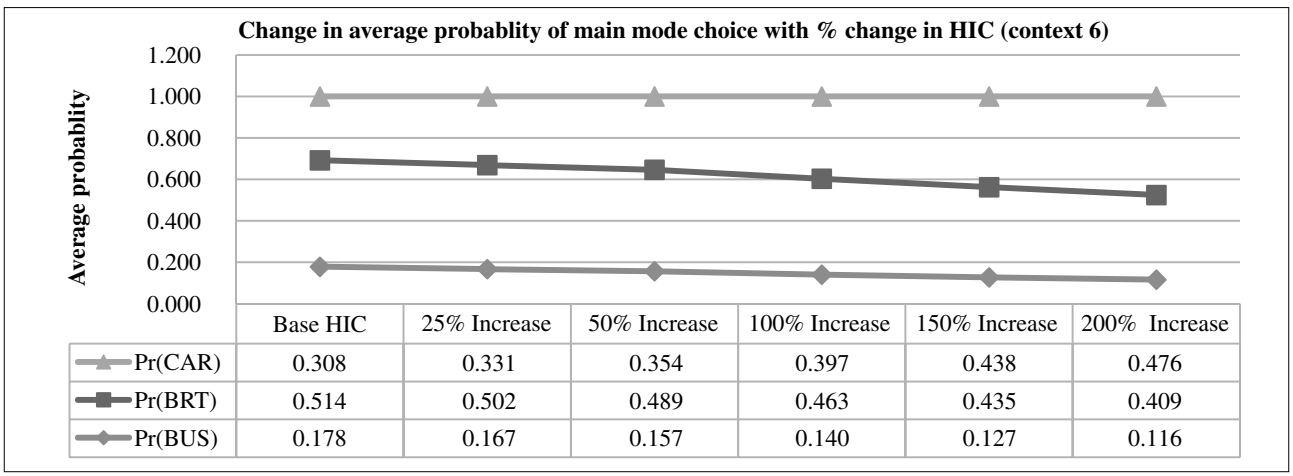
	Base HIC	25% Increase	50% Increase	100% Increase	150% Increase	200% Increase
Pr(BUS)	0.169	0.159	0.150	0.137	0.128	0.122
Pr(BRT)	0.831	0.841	0.850	0.863	0.872	0.878

Fig-11. Sensitivity to HIC change on main mode choice probability in context 9



	Base HIC	25% Increase	50% Increase	100% Increase	150% Increase	200% Increase
Pr(WALK)	0.792	0.788	0.784	0.774	0.762	0.747
Pr(ANGKOT)	0.169	0.168	0.168	0.166	0.164	0.161
Pr(BECAK)	0.039	0.044	0.048	0.060	0.074	0.092

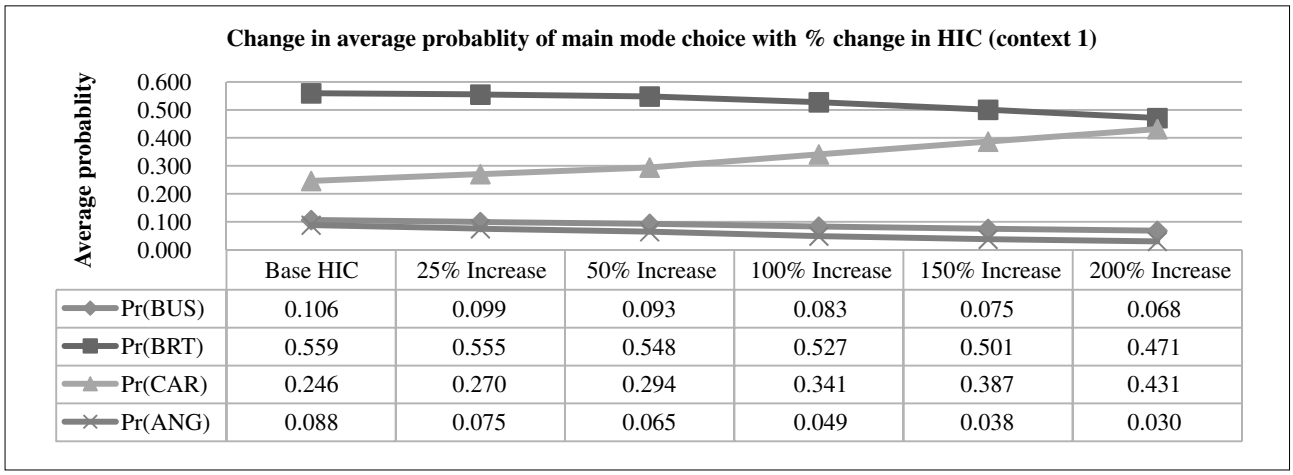
Fig-12. Sensitivity to change in HIC to access mode choice probability under subset 9



	Base HIC	25% Increase	50% Increase	100% Increase	150% Increase	200% Increase
Pr(CAR)	0.308	0.331	0.354	0.397	0.438	0.476
Pr(BRT)	0.514	0.502	0.489	0.463	0.435	0.409
Pr(BUS)	0.178	0.167	0.157	0.140	0.127	0.116

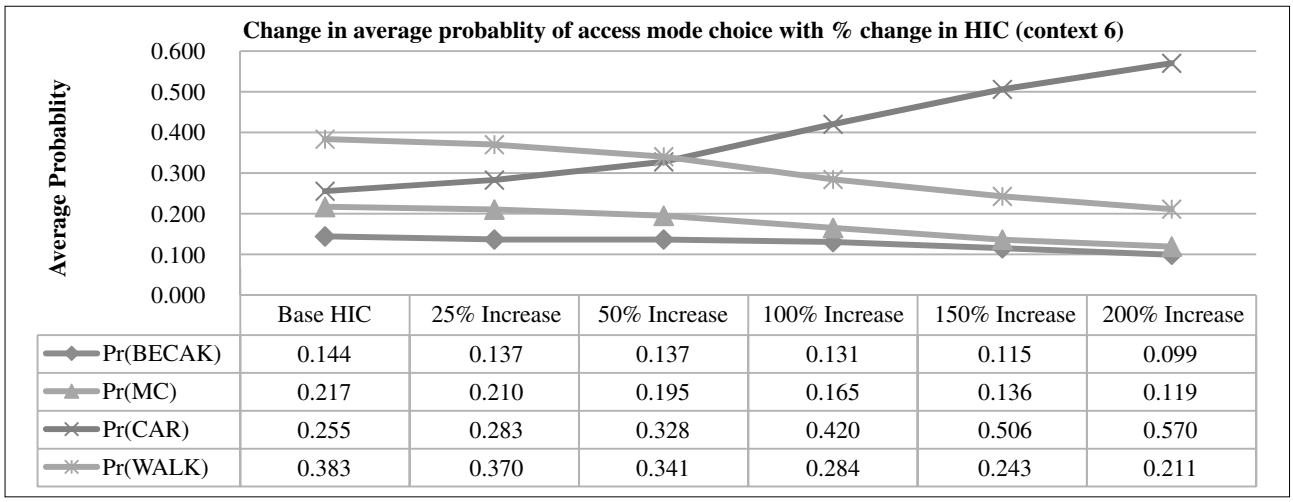
Fig-13. Sensitivity to change in HIC to main mode choice probability under context6

The subset where all the four main modes are available (Fig-14) as the main mode and becak and walking are available as access mode (Fig-16). It has been found that the average probability of only car will increase with the increase in household income. But, with the increase in income utility BRT, bus and angkot decreases. Transit systems lose their choice probability when income increases. The simulated situations assumed that, the existing transport systems are maintained unchanged and the standard version of a bus rapid transit prevail, at a base scenario, BRT use gives the higher average probability utility than



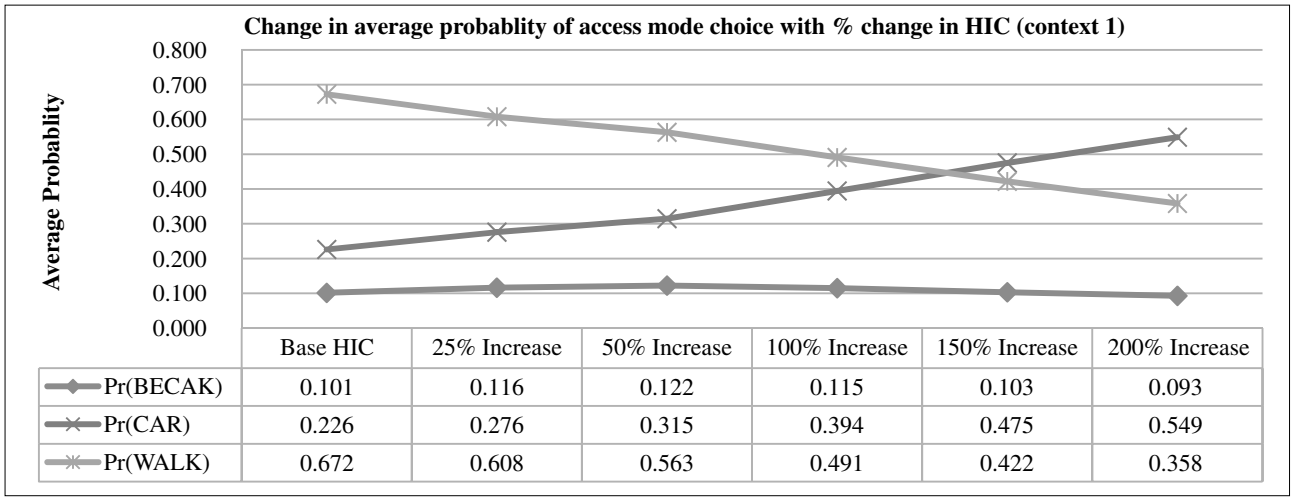
	Base HIC	25% Increase	50% Increase	100% Increase	150% Increase	200% Increase
Pr(BUS)	0.106	0.099	0.093	0.083	0.075	0.068
Pr(BRT)	0.559	0.555	0.548	0.527	0.501	0.471
Pr(CAR)	0.246	0.270	0.294	0.341	0.387	0.431
Pr(ANG)	0.088	0.075	0.065	0.049	0.038	0.030

Fig-14. Sensitivity to change in HIC to main mode choice probability under context 1



	Base HIC	25% Increase	50% Increase	100% Increase	150% Increase	200% Increase
Pr(BECAK)	0.144	0.137	0.137	0.131	0.115	0.099
Pr(MC)	0.217	0.210	0.195	0.165	0.136	0.119
Pr(CAR)	0.255	0.283	0.328	0.420	0.506	0.570
Pr(WALK)	0.383	0.370	0.341	0.284	0.243	0.211

Fig-15. Sensitivity to change in HIC on access mode choice probability under context 6



	Base HIC	25% Increase	50% Increase	100% Increase	150% Increase	200% Increase
Pr(BECAK)	0.101	0.116	0.122	0.115	0.103	0.093
Pr(CAR)	0.226	0.276	0.315	0.394	0.475	0.549
Pr(WALK)	0.672	0.608	0.563	0.491	0.422	0.358

Fig- 16. Sensitivity to change in HIC on access mode choice probability under context 1

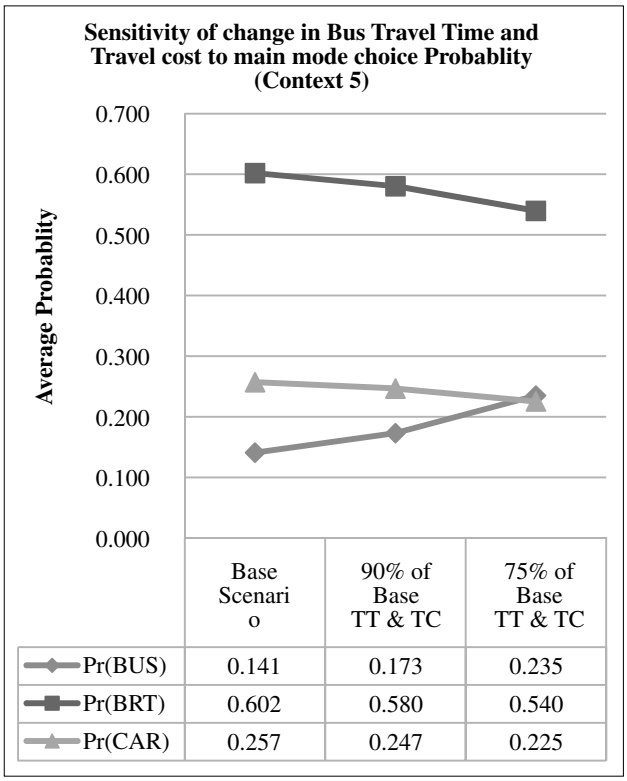
car and also it gives more average utility out of all the public transports. At any level of income and under any availability scenario of the modes BRT have more average choice probability than all the other modes. But, at a certain attainment of HIC, car choice probability exceeds all the others.

From fig-15, it is also worth mentioning that in subset 6 where angkot is not available as main mode average choice probability of car will be equal to that of BRT at an income level which is 1.5 times the present income level. This however found different for different scenario. For example, in the scenario where all main modes are available as in Fig-14, average choice probability of car exceeds that of BRT at a household income level which is more than 3 times higher than the present.

Increase in household income or increase in car choice probability also affects the access mode choice probability as shown in fig-16. The fig shows that increase in car choice probability made reduction of walking as an access mode. Fig-11 and Fig- 12explains scenario where only bus and BRT is available as main mode and increase in income increase BRT choice probability making reduction of bus choice probability which also results in reduction of angkot and walking mode choice probability as an access mode. Probability of BRT is more than bus choice probability and angkot gives the least average choice probability out of this four main modes. With increase of household income walking as well as angkot loses choice probability where as becak has the potential to to be used as access mode under increase in household income

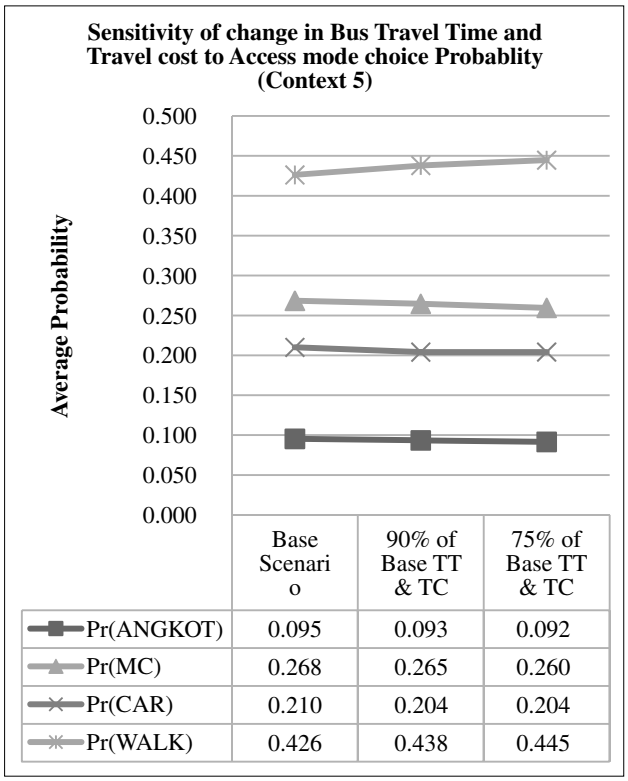
(2) Sensitivity to change in angkot / bus travel time and travel cost on mode choice probability of angkot/bus

In the base scenario angkot has the lowest choice probability among all the four modes followed by bus. So, simulation has been done in quest for policy issues to increase angkot's usage. Simulation has been done assuming that all other variables for all the modes and all the socio economic variables remain unchanged. It was found that (Fig- 19) with 25 % reduction of angkot total travel time and travel cost the choice probability of angkot will be double the base scenario. Increase in angkot's choice probability also influenced to increase the choice probability of MC as an access mode as shown in Fig- 20. Similar simulation was also carried out for bus. Fig-17 shows that 25 percent reduction of bus travel time results in drastic increase in choice probability of bus and which equals the choice probability of car in base scenario under subset 5 where there is no angkot available as main mode. On the other hand increase in bus choice probability brings corresponding changes in access mode preference. Fig-18 shows that bus main mode is synchronized with walking as access mode. That's why increase of choice probability of bus also increases use of walk as access mode and decrease the choice probability of motorized access mode like MC and angkot.



	Base Scenario	90% of Base TT & TC	75% of Base TT & TC
Pr(BUS)	0.141	0.173	0.235
Pr(BRT)	0.602	0.580	0.540
Pr(CAR)	0.257	0.247	0.225

Fig-17. Sensitivity to bus travel time and travel cost reduction on main mode choice probability in context 5



	Base Scenario	90% of Base TT & TC	75% of Base TT & TC
Pr(ANGKOT)	0.095	0.093	0.092
Pr(MC)	0.268	0.265	0.260
Pr(CAR)	0.210	0.204	0.204
Pr(WALK)	0.426	0.438	0.445

Fig-18. Sensitivity to bus travel time and travel cost reduction on access mode choice probability in context 5

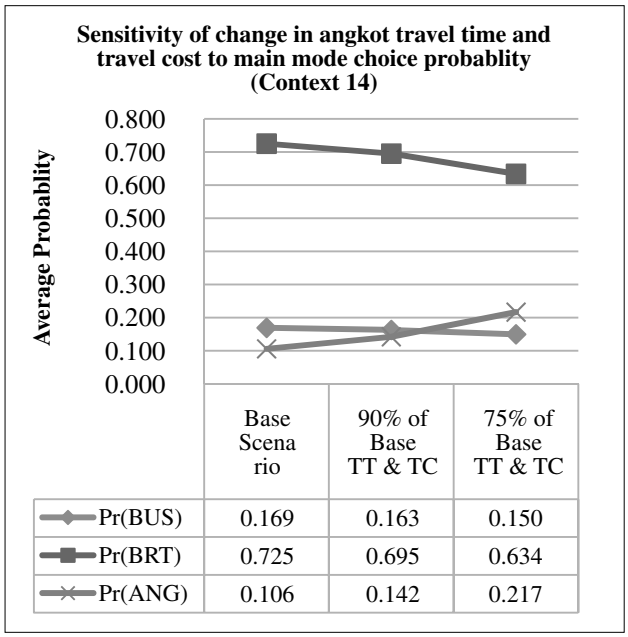


Fig-19. Sensitivity to angkot travel time and cost reduction on main mode choice probability in context 14

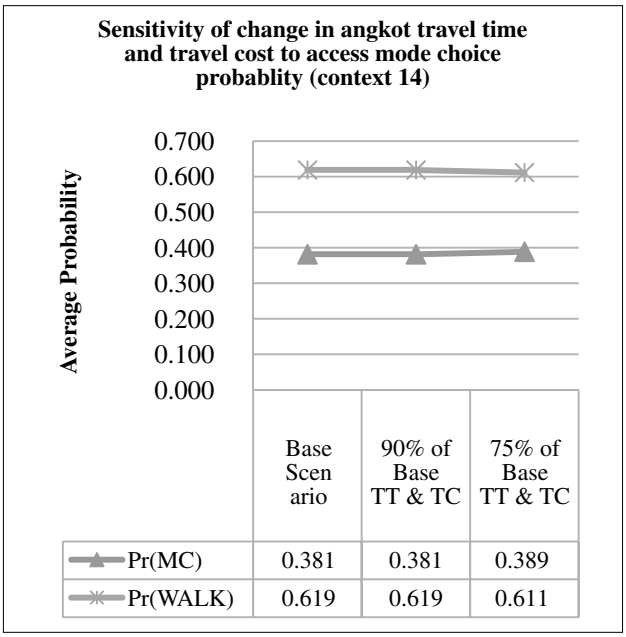


Fig-20. Sensitivity to angkot travel time and cost reduction on access mode choice probability in context 14

Although, bus has more average choice probability than angkot, in all the subset it has lower average choice probability than BRT.In all the contexts, bus was assumed to exist with the BRT and it was assumed to have cheaper and slower attributes than BRT. It will be highly infeasible for buses to operate on the routes where BRT exists unless there are reduction of Travel time and cost. On the other hand, bus has higher average choice probability than angkot at any level of household income and it can compete with angkot to get the more modal share. So, unavailability of BRT on any particular route can draw major trips in to bus over angkot. So, operating bus and BRT in the same route will not be feasible and bus can be an immediate alternative to BRT on routes where BRT is not implemented. Generally, a decrease in the service quality of public transit leads to an increase in demand of private vehicles. To illustrate the effect of change in the public transport service quality on the choice probability, we simulate the case where 25 percent decrease in travel time for bus and angkot was considered separately.

(3) Direct/Cross elasticity with respect to BRT travel fare

Travel fare sensitivity of BRT is measured using elasticities in this study, defined as the percentage change in probablities of modes resulting from a one-percent change in travel fare, all else held constant. Cross-elasticity refers to the percentage change in probablities of choosing other modes resulting from change in fare of one mode. Table-6 shows direct and cross elasticities of BRT travel fare on other main modes and also access mode under different choice contexts. It has been found that BRT fare have profound effect on choosing bus and car as main mode and which in turns affects access mode choice. The degree of changes in utility for other modes resulting from percentage change in BRT also varies from one context to another.

8. POLICY RECOMMENDATIONS AND CONCLUSION

Bus rapid transit system got the highest utility and average choice probability among the public transport modes, since it embodies the characteristics of a mode that urban travelers consider fast, comfortable, convenient and accessible, not withstanding its highly subsidized fare system. Hence, it is therefore important for the government to focus its attention to the provision of BRT system in Surabaya. And also for successful implementation of BRT it is necessary to predict the actual demand which might generate due to introduction of BRT under predefined attributes. Utility of bus is found less than BRT in every choice context. With almost same level of fare, operating bus on the route of BRT would be infeasible as BRT got much higher utility than bus.

It has been found that, access mode choice is strongly dependent on main mode choice in Surabaya. In this sense, successful implementation of BRT requires attention to accessibility policies. Under BRT system access mode choice will be dependent on main mode choice and unless good walking facilities are provided there can be major shift in motorized access mode in future.Walking Facilities should be improved in the Surabaya City which can reduce the use of private motorized

Table-6. Direct/cross elasticity with respect to BRT travel fare

	Main Mode				Access mode				
Context	Bus	BRT	Car	Angkot	Becak	Angkot	MC	Car	Walk
1	0.868	–0.541	0.546	0.864	0.356	–	–	0.427	–0.197
2	0.891	–0.454	0.700	–	–	–0.177	–0.228	1.328	–0.299
3	0.807	–0.592	0.535	0.839	–	–0.019	–	0.174	–0.054
4	0.767	–0.715	0.570	0.766	–	–0.376	–	0.906	–0.450
5	0.971	–0.379	0.706	–	–	–0.074	–0.187	0.759	–0.096
6	0.842	–0.583	0.586	–	0.940	–	–0.468	0.908	–0.558
7	1.065	–0.217	–	–	0.000	0.000	–	–	0.000
8	0.821	–0.620	0.411	0.802	0.107	–	–	0.145	–0.067
9	1.073	–0.215	–	–	0.000	0.000	–	–	0.000
10	0.908	–0.432	–	0.935	0.000	0.000	0.000	–	0.000
11	0.920	–0.435	–	0.937	0.000	0.000	0.000	–	0.000
12	0.820	–0.635	0.571	–	0.591	–	–0.438	0.613	–0.447
13	1.003	–0.282	–	–	–	–	–	–	0.000
14	0.955	–0.365	–	0.976	–	–	0.000	–	0.000
15	0.964	–0.373	–	0.967	–	–	0.000	–	0.000
16	0.995	–0.304	–	–	–	–	–	–	0.000

vehicles in Surabaya city as an access mode and can also stimulate public transit use. Becak can still be very effective for elderly people for access mode choice and sufficient road safety and security measure should be provided for its effective use. Under BRT system there should be park and ride system for motorcycle so that commuters can use this as a faster access mode.With a high motorcycle ownership in Surabaya, it can be used as an access mode under BRT system; especially, it has high preference among younger people. Travel time and travel cost reduction of both angkot and bus can be a solution for its existence in Surabaya City. Security, safety, drivers' manner and punctuality are the key issues for angkot and becak to improve passengers' satisfaction levels on these modes. In future, angkot owners should have to make it faster and safer from the criminal activities and it should be more customers oriented.

This paper explores the factors which can affect the utility of BRT in future. Various mode availability contexts can be properly tested through this model and outcomeof the study can be used in demand predictions as for changes in the variables both for access mode and main mode; for instance travel timeand various scenarios of mode availability. The proposed model can be used in Surabaya metropolitan region to design and implement more effective and appropriatetransportation solutions for relieving congestion under a sustainable transportation horizon.

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