The Relationship Between Public Transport Facilities And Private Motorized Trips In Urban Areas

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***Abstract*— Decrease in private motorized trips is an essential effort to reduce negative externalities that are related to the urban mobility. Increase public transport usage is one of the important strategies to reduce private motorized trips. There are considerable amount of studies that try to find the relationship between public transport and private motorized trips. However, most of these studies are at the neighborhood level in a single city and there are very limited studies that cover different cities around the world. Therefore, this paper tries to evaluate the mentioned relationship among 34 cities in different parts of the world to find effective public transport facilities that decrease private motorized trips at the city level. In order to fulfill this objective, this research utilized multi-linear regression analysis to estimate the significance of the relationship between public transport facilities and private motorized trips. The results show that the rail mode public transport vehicle kilometers density has negative relationship with the percentage of daily private motorized trips while, cost of public transport for the traveler have positive relationship. This model may help to propose sustainable strategies that decrease private motorized trips in various socio-economic backgrounds.**

***Keywords*— multi-linear regression; public transport; sustainable transport; urban areas; private motorized trips**

I. Introduction

The cities should minimize mobility needs and maximize accessibly in a sustainable way (Asadi-Shekari et. al, 2013a and b; Moeinaddini et. al, 2014a and b). This new paradigm forces the authorities to consider public transport and other alternative travel options instead of private motorized trips in the cities (Asadi-Shekari et. al, 2015a, b, c and d). Therefore, the rapid development of public transport is not surprising. There are lots of studies that find an important role for public transport to reduce private motorized trips (Cervero and Gorham, 1995; Friedman et. al, 1994; Moeinaddini et. al, 2013; Moeinaddini et. al, 2012a and b; Sultan and Rosário, 2008).

Lots of effective factors such as land use, urban design and facilities, reliability and affordability that can influence public transport ridership and private motorized trips are identified by previous studies (Cervero, 1996; Cervero and Gorham, 1995; Friedman et. al, 1994; Estupiñán and Rodríguez, 2008; Moeinaddini et. al, 2015a, b and c; Sultan et. al, 2015). For instance, transit oriented development (TOD) can increase walking and transit trips (Cervero and Gorham, 1995; Sultan et. al, 2016a and b; Gul et. al, 2016). Higher proportion of transit and other non-auto trips are reported in traditional neighborhoods (Friedman et. al, 1994) and people will use transit more than driving if commercials or other residential land use are located nearby (Cervero, 1996; Ryan and Frank, 2009; Sultan and Dave 2009).

Public transport ridership is also related to the distance to the nearest public transport station. People who live closer to the stations drive less and use public transport more (Kitamura et. al, 1997). In addition to the distance, improving walkability near the stations is also important to increase public transport usage (Ryan and Frank, 2009; Asadi-Shekari et. al, 2014). Reliable facilities also can motivate people to change their travel mode from private motorized to public transport (Moeinaddini et. al, 2015c; Sultan et. al, 2010a&b). Affordability is another effective factor to increase public transport ridership. The low cost of public transport for travelers can make public transport an economical option for a higher proportion of travellers (Moeinaddini et. al, 2015c; Sultan et. al, 2016c).

The scope of previous studies for urban public transport is various from sites to the cities but they just covered some cities of a selected country or some neighborhoods in a single city (Asadi-Shekari et. al, 2016). However, the effectiveness of public transport factors at the macro-level such as number of buses, rail mode facilities and frequency in addition to the cost at the city level to reduce private motorized trips have not been investigated sufficiently. More research in this area is essential to achieve more sustainable public transport towards fewer motorized trips. Therefore, this paper tries to overcome this shortcoming by evaluating effective public transport macro-level factors among various cities around the world.

II. Meterial and Methods

This study tries to find the relationship between the public transport facilities and the percentage of daily private motorized trips. Based on the scale of measurement, the number of groups, the nature of the relationship between groups, the number of variables, and the assumptions of statistical tests, the strength of the relationships in this study is found by estimating a multiple-linear regression model.

Indicators that represent the public transport facilities at macro-level in this study are the bus per inhabitant, the rail mode public transport vehicle kilometres per inhabitant, the total public transport place kilometres per urban hectare in addition to the average cost of one public transport passenger kilometre for the traveller. The data needed for this research were selected from International Association of Public Transport (UITP) data collection (MCD, 2006). This database includes 52 cities around the world. However, the data for the indicators that are needed in this study are available for just 34 cities (see Table 1).

III. Analysis Results

The normality assumption for multiple-linear regression analysis is tested by Shapiro-Wilk normality. This is the most reliable normality test for small to medium sized samples (Shapiro and Wilk, 1965). Table 2 shows that the bus kilometres per inhabitant (B), rail mode public transport vehicle kilometres per inhabitant (RP) and total public transport place kilometres per urban hectare (TP) are not normally distributed. Transforming these variables to natural logarithm helps to solve the non-normality problem (Cuesta et. al 2008). Because rail mode public transport vehicle kilometres per inhabitant (RP) have some zero values, a constant is added before transforming this variable. This constant is considered to be 30 to have better normality result. LN (30) is deducted from all RP values after transforming to save zero values. Table 3 presents the second normality test after transforming.

The second assumption is the existence of a linear relationship between independent and dependent variables without outliers. This assumption was tested by scatter plots. The scatter plots also show there is not heteroscedasticity problem. No or little multicollinearity is the other assumption for multiple-linear regression models. Table 4 shows the matrix of Pearson's Bivariate correlation coefficients, in which all coefficients are smaller than 1. Table 5 shows collinearity statistics. Tolerances in Table 5 are greater than 0.1 and VIFs are less than 10. Therefore, there is no multicollinearity problem for this model (see Tables 4 and 5) and thus independent variables are independent from each other.

Little or no autocorrelation in data also should be considered in multi-linear regression models. Autocorrelation occurs when residuals are not independent. Durbin-Watson value which is presented in Table 6 shows this independency (values less than 1 and greater than 3 may cause concern for the model). R2 value (see Table 6) shows that the model can explain more than 60 percentages of variables. The value of standard error of the estimate (see Table 6) indicates that this model is good for prediction. Table 7 is the ANOVA results of this model. It is very unlikely that the F-ratio in this table has happened by chance. Therefore, this model is significantly good at predicting the outcome variable. The confidence level in this model is 95%.

Table 8 also presents that the coefficient for the natural logarithm of bus kilometres per inhabitant is not significantly different from 0 (see Table 8). Therefore, there is no significant relationship between bus kilometres density and private motorized daily trips (see Table 8). The coefficient for the natural logarithm of total public transport place kilometres per urban hectare is not also significantly different from 0. Thus, there is no also significant relationship between public transport place kilometres density and private motorized daily trips (see Table 8).

Table 9 shows R2 value after removing insignificant variables that is 0.567and Table 10 that is the ANOVA results of this model after removing insignificant variables shows that this model is significantly good at predicting the outcome variables. The new model shows the constant is significantly different from 0 (see Table 11). Therefore, the model indicates a positive constant for private motorized daily trips. Table 11 indicates a negative coefficient for the relationship between the natural logarithm of rail mode public transport vehicle kilometres per inhabitant and private motorized daily trips and this coefficient is significant (see Table 11). Therefore, for every unit increase in the natural logarithm of rail mode public transport vehicle kilometres per inhabitant, 14.828 units decrease in the private motorized daily trips is predicted (see Table 8).

Table 11 also shows a positive coefficient for the relationship between the average cost of one public transport passenger kilometre for the traveller and private motorized daily trips and this coefficient is significant (alpha is 0.05 and p value is 0.004). Therefore, for every unit increase in the average cost of one public transport passenger kilometre for the traveller, 0.909 units increase in the private motorized daily trips is predicted (see Table 8). Therefore, the final relationship model can be defined as follows (see Eq. (1) and Table 11).

$$DPMT = 53.562 – 14.828LNRP + 0.909CP \quad (1)$$

Where

DPMT = percentage of daily trips by private motorized modes

LNRP = natural logarithm of rail mode public transport vehicle kilometres per inhabitant

CP = average cost of one public transport passenger kilometre for the traveler

The model shows that cities with more rail mode public transport facilities have fewer daily private motorized trips. More rail mode public transport leads to more direct routes for public transport users without conflicts with other modes. The model also shows that more cost of public transport for the traveler increase the percentage of daily private motorized trips. More cost can discourage the public transport users and increases the percentage of daily trips by private motorized vehicles.

IV. Discussions And Conclusions

The relationships between the macro-level public transport indicators as the independent variables and private motorized daily trips as the dependent variable are evaluated in this research using multi-linear regression analysis. From this study it is concluded that the rail mode public transport vehicle kilometres per inhabitant and the average cost of one public transport passenger kilometre for the traveller are the macro-level public transport factors that influence the percentage of daily trips by private motorized.

It was indicated that the natural logarithm of rail mode public transport vehicle kilometres density have negative relationship with the percentage of daily private motorized trips while, the cost of public transport for the traveller have positive relationship. Therefore, among the public transport indicators providing more rail mode facilities is more effective to have fewer predicted daily private motorized trips and this facility is more efficient than bus (that is not significant in this model). The cost of public transport for the traveller has the positive coefficient and it increases daily private motorized trips. Finally, urban structure strategies and planning that increase rail mode public transport and decrease cost of public transport for the traveller may produce less car dependent urban structure.

Overall, more green urban areas and sustainable developments are needed currently. In order to gain these kinds of areas, having fewer private motorized trips in the cities is a prominent goal. Therefore, this research made an attempt to evaluate the relationship between public transport indicators and private motorized usage at macro-level to show how this relationship can be useful to decrease automobile usage in urban areas around the world.

In addition to the more green urban areas and sustainable developments, public transport facilities can affect other urban management approaches. For instance, public transport facilities can be very useful during disasters such as earthquake or flood. Although there are lots of studies that try to introduce innovative ways to reduce the disaster effects (Chau-Khun Ma et al. 2016b; I. Faridmehr et al. 2016; M. Azimi et al. 2014a and b; M. Azimi et al. 2016b; T. M. Alhajri et al. 2016), the role of transport accessibility during disaster is highlighted by considering time factor (Adnan A. et al. 2015; CK. Ma, et al. 2016a; I. Faridmehr et al. 2014; I. Faridmehr et al. 2015; M. Azimi et al. 2015a and b; M. Azimi et al. 2016a). Therefore, further studies can use the same relationship methods to show how public transport facilities can affect other urban management approaches such as disaster management.

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TABLE 1. RESEARCH DATA

Indicator(s)	Bus kilometers per inhabitant	Rail mode public transport vehicle kilometers per inhabitant	Total public transport place kilometers per urban hectare	Average cost of one public transport passenger kilometer for the traveler	Percentage of daily trips by private motorized modes
Unit(s)	**VKm**	**VKm**	**PlaceKm/1000**	**0,01 EUR**	
Athens	28.7	8.21	236	5.99	63.9
Barcelona	21	33.1	426	6.24	46.9
Bologna	41.1	0	182	10.6	56.6
Brussels	38.9	52.1	652	10	58.9
Budapest	50.8	57.8	514	1.94	33.1
Clermont Ferrand	28.8	0	94.8	9.4	60.7
Copenhagen	47.6	61.2	233	11.6	48.9
Dubai	25.7	0	53.3	4.09	77.3
Glasgow	79	20.65	207	14.9	65.9
Graz	36.3	13.8	146	13.7	46.4
Helsinki	88.4	30.1	455	7.88	44
Lille	13.7	19.97	183	10.8	63.2
Lisbon	44.9	19.242	196	5.4	48
London	53	104.05	832	20	50.2
Lyons	28.7	17.09	143	12	54.3
Madrid	44.3	40.8	622	5.99	51.4
Manchester	52.9	5.63	174	17.8	68.1
Marseilles	26.8	11.129	232	12.1	54.1
Moscow	45.1	110.21	2800	0.591	26.3
Munich	29.7	91.72	808	9.91	40.6
Nantes	31.1	6.1	140	7.1	63.9
Newcastle	73.7	10.29	308	14.9	57.1
Oslo	40.8	48.57	252	14.8	59.1
Paris	26	58.126	519	7.4	46.4
Prague	54.3	81.16	707	1.65	35.6
Rome	44	26.869	495	2.67	56.2
Rotterdam	26.8	21.93	190	10.1	48.3
Seville	22.7	2.29	112	7.75	48
Singapore	87.4	25.03	1460	4.98	45.1
Stockholm	65.3	80.31	314	7.94	47.1
Stuttgart	20.7	48.85	256	10.8	58.9
Turin	33.4	5.449	162	4.86	54
Vienna	19	87.616	797	9.03	36
Warsaw	64.3	47.675	460	2.13	28.6

Source: International Association of Public Transport (UITP)

TABLE 2. FIRST NORMALITY TEST

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
B	.126	34	.185	.920	34	.016
RP	.149	34	.053	.901	34	.005
TP	.216	34	.000	.629	34	.000
CP	.067	34	.200*	.980	34	.776
DPMT	.099	34	.200*	.983	34	.864

a. Lilliefors Significance Correction
**. This is a lower bound of the true significance.*
DPMT: dependent variables

TABLE 3. SECOND NORMALITY TEST AFTER TRANSFORMING

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
LNB	.090	34	.200*	.982	34	.821
LNRP	.093	34	.200*	.950	34	.119
LNTP	.126	34	.192	.975	34	.618

a. Lilliefors Significance Correction
**. This is a lower bound of the true significance.*
LNB=LN(B)
LNRP=LN(RP+30)-LN(30)
LNTP=LN(TP)

TABLE 4. MATRIX OF PEARSON'S BIVARIATE CORRELATION COEFFICIENTS

Coefficients[a]				
Model		Correlations		
		Zero-order	Partial	Part
1	*LNB*	-.216	-.090	-.057
	LNRP	-.654	-.360	-.244
	LNTP	-.685	-.221	-.143
	CP	.443	.439	.309

a. Dependent Variable: DPMT

TABLE 5. COLLINEARITY STATISTICS

Coefficients[a]			
Model		Collinearity Statistics	
		Tolerance	VIF
1	*LNB*	.843	1.187
	LNRP	.362	2.761
	LNTP	.306	3.266
	CP	.886	1.129

a. Dependent Variable: DPMT

TABLE 6. MODEL SUMMARY

Model Summary[b]					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.775[a]	.601	.546	7.6811	1.965

a. Predictors: (Constant), LNB, LNRP, LNTP, CP
b. Dependent Variable: DPMT

TABLE 7. ANOVA TABLE

ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2575.197	4	643.799	10.912	.000[a]
	Residual	1710.998	29	59.000		
	Total	4286.194	33			

a. Predictors: (Constant), LNB, LNRP, LNTP, CP
b. Dependent Variable: DPMT

TABLE 8. COEFFICIENTS TABLE

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	110.542	15.197		7.274	.000
	LNB	-1.541	3.174	-.062	-.486	.631
	LNRP	-9.805	4.721	-.405	-2.077	.047
	LNTP	-3.569	2.928	-.258	-1.219	.233
	CP	.797	.303	.328	2.632	.013

a. Dependent Variable: DPMT

TABLE 9. MODEL SUMMARY (FINAL PUBLIC TRANSPORT MODEL)

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.753[a]	.567	.539	7.7409

a. Predictors: (Constant), LNRP, CP

TABLE 10. ANOVA TABLE (FINAL PUBLIC TRANSPORT MODEL)

ANOVA[b]						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2428.608	2	1214.304	20.265	.000[a]
	Residual	1857.587	31	59.922		
	Total	4286.194	33			

a. Predictors: (Constant), LNRP, CP
b. Dependent Variable: DPMT

TABLE 11. COEFFICIENTS TABLE (FINAL PUBLIC TRANSPORT MODEL)

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	53.562	3.636		14.731	.000
	LNRP	-14.828	2.882	-.612	-5.146	.000
	CP	.909	.289	.374	3.146	.004

a. Dependent Variable: DPMT