World Academy of Science, Engineering and Technology
International Journal of Humanities and Social Sciences
Vol:9, No:8, 2015

Regression Analysis of Travel Indicators and Public Transport Usage in Urban Areas

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***Abstract*—**Currently, planners try to have more green travel options to decrease economic, social and environmental problems. Therefore, this study tries to find significant urban travel factors to be used to increase the usage of alternative urban travel modes. This paper attempts to identify the relationship between prominent urban mobility indicators and daily trips by public transport in 30 cities from various parts of the world. Different travel modes, infrastructures and cost indicators were evaluated in this research as mobility indicators. The results of multi-linear regression analysis indicate that there is a significant relationship between mobility indicators and the daily usage of public transport.

***Keywords*—**Green travel modes, urban travel indicators, daily trips by public transport, multi-linear regression analysis.

I. Introduction

RECENTLY, it is encouraged to set up more transit projects and some researchers such as [1] believes that recent attempts regarding public transport improvements are not enough to solve all transportation problems and. Nonetheless, more transit promotes cities with sustainable areas; it is also the most cost-effective solution for urban transportation [2]. Green and clean travel modes such as public transport are encouraged by many experts to enhance health since most public transport trips are linked with walking and cycling [3].

Considering suitable facilities for walking and public transport encourage people to choose green travel options such as walking and public transport. Therefore, it is important to consider these facilities during planning processes [4] and [5]. Transit Performance Monitoring System (FTA) [6] indicates that in the absence of transit service, almost half of the transit users tend to travel by taxi or automobile. From this statement it can be inferred that reliable public transport facilities and infrastructure may encourage more green urban travels. Gaining such reliability needs technical improvements and of course financial support.

Transport expenses may make transit a prominent travel option for middle and low income people in many cities. As a result, affordable costs may make this form of transport economical for higher proportion of transit users [2]. Shifting from private car to public transport can also reduce consumers' expenses for operating cost, vehicle ownership, parking cost and insurance [2].

Nelson and his colleagues [7] found that rail transit system in Washington DC has congestion reduction benefits to motorists. Preferring public transport to private car to develop sustainability and reducing the frequency of car usage is contemplated in ample studies [2], [5], [8] and [9]. However, in order to gain accurate and reliable results designers need to consider urban travel behavior, urban transport costs and public transport infrastructure in different contexts. Therefore, this research intends to assess the impacts of some important travel modes indicators on public transport trips in various cities around the world using one relationship model that was rarely addressed in previous literature. Although there are considerable studies on the different types of urban mobility indicators and public transport, there are only a few researches that examined the relationships between urban mobility indicators in different cities around the world [10]-[20]. Therefore, this research tries to find the relationship between urban mobility indicators and public transport usage by evaluating walking, cycling, private motorized trips, and public transport indicators in different cities. The results can be used to propose sustainable strategies during urban planning process.

II. Material and Methods

This study tries to find the relationship between urban travel behavior, infrastructure and cost indicators, and the percentage of daily mechanized trips by public transport. 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 relationships in this study was found by estimating a multiple-linear regression model.

Indicators that presented the travel behavior in this study are the percentage of daily trips on foot and by bicycle, the percentage of daily mechanized trips by private motorized modes, and the average duration of a private motorized trip. This research also considered the average operating cost of one public transport passenger journey and the cost of one private motorized passenger kilometer for the traveler for cost indicators. The length of reserved public transport routes per urban hectare was also one of the urban public transport infrastructures factors.

The data needed for this research were selected from International Association of Public Transport (UITP) data

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collection [21] for 30 different cities. Choosing these 30 cities from different parts of the world is significant in examining the relationship between mobility indicators in different contexts (refer Table I).

TABLE I
RESEARCH DATA

Indicator(s)	Length of reserved public transport routes per urban hectare	Percentage of daily trips on foot and by bicycle	Percentage of daily mechanized trips by private motorized modes	Average duration of a private motorized trip	Average operating cost of one public transport passenger journey	Cost of one private motorized passenger kilometer for the traveler	Percentage of daily mechanized trips by public transport
Unit(s)	m			min	0,01 EUR	0,01 EUR	
Amsterdam	6.13	51.4	45.8	23	137	41	19.9
Athens	3.53	8.15	69	30	45.3	26.4	30.1
Bern	14.3	38.5	57.4	24	150	54.6	30.3
Bilbao	7.68	48.6	68.1	26.8	100	36.9	30.7
Bologna	1.44	29.1	75.3	25	77.8	47.3	19.2
Budapest	9.13	23.4	42.5	27	17.4	22.7	55.9
Chicago	1.64	6.18	92.7	27.4	275	38.3	6.66
Clermont Ferrand	0.978	33	89	14	105	42.5	9
Copenhagen	6.04	39	60.3	20	143	35.8	15
Geneva	7.34	33.5	72.8	21	110	58.8	21.7
Glasgow	7.73	23.5	85.1	17	186	33.5	13.7
Graz	1.04	35.2	58.2	18	73.6	40.4	23.1
Hamburg	4.69	36.9	63.3	25	89.2	39.1	21
Hong Kong	6.4	37.8	26	24	54.8	68.1	73.9
Lille	7	30.7	88.6	16	129	41.3	8.6
Lisbon	2.23	24.5	63.6	25	61.5	47	36.4
London	9.67	31.1	71.6	24	170	47.3	26.8
Lyons	6.25	32.7	79.9	19	103	44.3	19.1
Manchester	4.25	22.6	86.1	15	130	36.3	11.8
Marseilles	1.54	34.5	82.1	20	108	34.5	17.2
Moscow	6.44	24.4	33.9	27	11.9	20.1	63.6
Munich	12	37.5	56.5	30	88.1	36.1	30.4
Nantes	2.41	23.3	80.7	16	85.9	43.5	16.2
Oslo	9.79	25.5	74.9	15	187	51.1	19.5
Seville	2.22	41.6	81.5	23	54.5	48.7	17.6
Singapore	2.99	14	50.4	23	33.4	43.1	45.7
Stockholm	4.19	31.4	63.2	21	103	44.6	28.9
Stuttgart	8.03	30.1	76.2	18	125	37	14.3
Turin	3.41	24.8	70.5	26	111	50.8	27.6
Vienna	12.3	30	49.3	21	92.3	58	46.6

III. RESULT

In this section the results of multiple-linear regression analysis are discussed. In multiple-linear regression models the first assumption is a normal distribution for all variables so all variables were tested by Shapiro-Wilk normality test in SPSS. For percentage of daily mechanized trips by public transport Shapiro-Wilk Sig was less than 0.05, so this variable was not normally distributed. Transforming this variable to natural logarithm solves the non-normality problem [22].

The second assumption is the existence of a linear relationship between independent and dependent variables without outliers. This assumption was tested by scatter plots. These plots also show there were not any heteroscedasticity problems. No or little multicollinearity is the other assumption for multiple-linear regression models. Table II shows collinearity statistics. Tolerances in Table II are greater than 0.1 and VIFs are less than 10. This shows that there was no multicollinearity problem in this model 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 III shows this independency (values less than 1 and greater than 3 may cause concern for the model). R^2 value (refer Table III) shows that more than 90 percentages of variables can be explained by the model. Table IV is the ANOVA results of this model. It is very unlikely that the F-ratio in this table has happened by chance, so this model is significantly good at predicting the outcome variables. The confidence level in this model is 95%.

Table V shows that the constant is significantly different from 0 at the 0.05 alpha level using t-test. Therefore, the model indicates a positive constant for the natural logarithm of percentage of daily mechanized trips by public transport.

Table V also presents that the coefficient for length of reserved public transport routes per urban hectare is significantly different from 0 using alpha of 0.05. Therefore, for every unit increase in the length of reserved public transport routes per urban hectare, 0.034 units increase in the natural logarithm of percentage of daily mechanized trips by public transport is predicted.

The coefficient for the percentage of daily trips on foot and by bicycle is significantly different from 0 using t-test. Therefore, the model indicates a negative coefficient for the relationship between the percentage of daily trips on foot and by bicycle and the natural logarithm of percentage of daily mechanized trips by public transport. Thus, for every unit increase in the percentage of daily trips on foot and by bicycle, 0.010 units decrease in the natural logarithm of percentage of daily mechanized trips by public transport is predicted (refer Table V).

TABLE II
COLLINEARITY STATISTICS

	Model	Collinearity Statistics	
		Tolerance	VIF
1	Length of reserved public transport routes per urban hectare	.688	1.453
	Percentage of daily trips on foot and by bicycle	.825	1.212
	Percentage of daily mechanized trips by private motorized modes	.424	2.357
	Average duration of a private motorized trip	.721	1.387
	Average operating cost of one public transport passenger journey	.542	1.844
	Cost of one private motorized passenger kilometer for the traveler	.852	1.174

Dependent Variable: Natural logarithm of percentage of daily mechanized trips by public transport

TABLE III
MODEL SUMMARY

Model	*R*	*R Square*	*Adjusted R Square*	*Std. Error of the Estimate*	*Durbin-Watson*
1	.949[a]	.901	.875	.20465	1.993

Predictors: (Constant), Cost of one private motorized passenger kilometer for the traveler, Percentage of daily mechanized trips by private motorized modes, Percentage of daily trips on foot and by bicycle, Length of reserved public transport routes per urban hectare, Average duration of a private motorized trip, Average operating cost of one public transport passenger journey

Dependent Variable: Natural logarithm of percentage of daily mechanized trips by public transport

The model indicates a negative coefficient for the relationship between the percentage of daily mechanized trips by private motorized modes and the natural logarithm of percentage of daily mechanized trips by public transport and this coefficient is significant using t-test (refer Table V). Therefore, for every unit increase in the percentage of daily mechanized trips by private motorized modes, 0.018 units decrease in the natural logarithm of percentage of daily mechanized trips by public transport is predicted.

Table V shows a positive coefficient for the relationship between the average duration of a private motorized trip and the natural logarithm of percentage of daily mechanized trips by public transport and this coefficient is significant. Therefore, for every unit increase in the average duration of a private motorized trip, 0.021 units increase in the natural logarithm of percentage of daily mechanized trips by public transport is predicted (refer Table V).

TABLE IV
ANOVA RESULTS

Model		*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
1	Regression	8.729	6	1.455	34.738	.000[a]
	Residual	.963	23	.042		
	Total	9.692	29			

Predictors: (Constant), Cost of one private motorized passenger kilometer for the traveler, Percentage of daily mechanized trips by private motorized modes, Percentage of daily trips on foot and by bicycle, Length of reserved public transport routes per urban hectare, Average duration of a private motorized trip, Average operating cost of one public transport passenger journey

Dependent Variable: Natural logarithm of percentage of daily mechanized trips by public transport

TABLE V
COEFFICIENTS

Model		*Unstandardized Coefficients*		*Standardized Coefficients*	*t*	*Sig.*
		B	*Std. Error*	*Beta*		
1	(Constant)	3.984	.458		8.700	.000
	V_1	.034	.013	.213	2.692	.013
	V_2	-.010	.004	-.167	-2.309	.030
	V_3	-.018	.003	-.524	-5.194	.000
	V_4	.021	.010	.165	2.138	.043
	V_5	-.004	.001	-.412	-4.612	.000
	V_6	.010	.004	.184	2.582	.017

Dependent Variable: Natural logarithm of percentage of daily mechanized trips by public transport

- v1: length of reserved public transport routes per urban hectare
- v2: percentage of daily trips on foot and by bicycle
- v3: percentage of daily mechanized trips by private motorized modes
- v4: average duration of a private motorized trip
- v5: average operating cost of one public transport passenger journey
- v6: cost of one private motorized passenger kilometer for the traveler

The model indicates a negative coefficient for the relationship between the average operating cost of one public transport passenger journey and the natural logarithm of percentage of daily mechanized trips by public transport. This coefficient is significant using t-test (refer Table V). However this relationship is positive for the cost of one private motorized passenger kilometer for the traveler. Therefore, by each unit increase in the average operating cost of one public transport passenger journey, the predicted natural logarithm of percentage of daily mechanized trips by public transport have 0.004 units decrease, while each unit increase in the cost of one private motorized passenger kilometer for the traveler have 0.010 units increase in the predicted natural logarithm of percentage of daily mechanized trips by public transport (refer Table V). Therefore, the final relationship model can be defined as follows (see (1)).

$$LNPT = 3.984 + 0.034PR - 0.010FB - 0.018P + 0.021D - 0.004PTC + 0.010PC \quad (1)$$

where: LNPT = natural logarithm of percentage of daily mechanized trips by public transport; PR = length of reserved public transport routes per urban hectare; FB = percentage of daily trips on foot and by bicycle; P = percentage of daily mechanized trips by private motorized modes; D = average duration of a private motorized trip; PTC = average operating cost of one public transport passenger journey; PC = cost of one private motorized passenger kilometer for the traveler.

The model shows that cities with higher reserved public transport routes have higher daily mechanized trips by public transport. Higher reserved public transport routes cause more direct routes for public transport users without conflicts with other modes. In addition, public transport can give better services with higher reserved routes in case of reliability. The model also shows that more trips on foot and by bicycle decrease the percentage of daily trips by public transport. The distribution of destinations in walkable distances in areas with mixed land use may increase non-motorized travel modes. The possibility to walk or cycle easily may also decrease the other travel modes and even transit.

The model shows that increasing daily mechanized trips by private motorized modes discourages people to use public transport. More private motorized trips mean more car dependent urban areas and less alternative travel modes. In addition, the model indicates that a higher duration of a private motorized trip increases daily mechanized trips by public transport. Therefore, if people have to spend more money and time to use their private cars, they have more motivation to change their travel mode from private motorized to non-motorized and/or public transport.

For an average operating cost of one public transport passenger journey, the model shows that higher operating cost decreases daily trips by public transport modes. More operating cost of one public transport passenger journey makes the passengers of public transport spend more money. Therefore, this issue discourages the users of public transport and declines the percentage of daily mechanized trips by public transport. In addition, the model shows that the higher cost of one private motorized passenger kilometer for the traveler increases daily mechanized trips by public transport. Higher costs of private transport may encourage people to use alternative travel modes like public transport. Therefore, the strategies that increase the costs of private transport for travelers may extend the usage of public transport in urban areas.

IV. Discussion and Conclusions

The relationships between urban mobility indicators as the independent variables and public transport daily trips as the dependent variable are evaluated in this research using multi-linear regression analysis. From this study it is concluded that the length of reserved public transport routes per urban hectare, the percentage of daily trips on foot and by bicycle, the percentage of daily mechanized trips by private motorized modes, the average duration of a private motorized trip, the average operating cost of one public transport passenger journey, and the cost of one private motorized passenger kilometer for the traveler are the urban mobility indicators that influence the percentage of daily mechanized trips by public transport.

It was indicated that the length of reserved public transport routes per urban hectare, the average duration of a private motorized trip, and the cost of one private motorized passenger kilometer for the traveler have positive relationship with the natural logarithm of percentage of daily mechanized trips by public transport; while, the percentage of daily trips on foot and by bicycle, the percentage of daily mechanized trips by private motorized modes, and the average operating cost of one public transport passenger journey have negative relationship. Among these predictors the length of reserved public transport routes per urban hectare has the highest positive coefficient; therefore, among the urban mobility indicators, longer reserved public transport routes per urban hectare is more effective to have more predicted public transport daily trips. The second effective indicator is the average duration of a private motorized trip with positive relationship; thus, its impact on public transport daily trips is more than the percentage of daily mechanized trips by private motorized modes which is the third effective indicator with negative relationship. Increasing the duration of a private motorized trip is more effective than decreasing daily private motorized trips in order to have more public transport daily trips.

The fourth effective indicators are the percentage of daily trips on foot and by bicycle with negative relationship and the cost of one private motorized passenger kilometer for the traveler with positive relationship; therefore, their impacts on public transport daily trips are the same, but in opposite directions. The average operating cost of one public transport passenger journey has the least negative coefficient; so, it has the least negative effect on public transport daily trips.

Finally, urban structure strategies and planning that increase the length of reserved public transport routes per urban hectare, the average duration of a private motorized trip, and the cost of one private motorized passenger kilometer for the traveler, and decrease the percentage of daily mechanized trips by private motorized modes, and the average operating cost of one public transport passenger journey may produce more public transport trips. Fewer daily trips on foot and by bicycle increase daily public transport usage but it should be taken into consideration that walking and cycling are green travel options.

Overall, more green and sustainable urban areas are needed currently. In order to gain these kinds of areas, having more transit trips in cities is a prominent goal. So, this research made an attempt to evaluate the relationship between public transport usage and urban mobility indicators to show how this relationship can be useful to increase public transport usage in urban areas in different cities from various parts of the world.

Just some cities of a selected country or some neighborhoods from a single city were covered by the majority of the previous studies. This study however, evaluates the relationship between various urban mobility indicators in different cities with various backgrounds. This study considered the infrastructure, travel behavior, and travel cost indicators in one urban transport model for different cities.

ACKNOWLEDGMENT

The authors wish to thank all of those who have supported this research for their useful comments during its completion. In particular, we would like to acknowledge the Universiti Teknologi Malaysia Research Management Centre (RMC) and Centre for Innovative Planning and Development (CIPD). The funding for this project is made possible through the research grant obtained from the Ministry of Education, Malaysia under the Fundamental Research Grant Scheme (FRGS) 2014 (FRGS grant no:R.J130000.7821.4F602).

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