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Exploring the Factors that Provoke and Affecting Commuters of Sustainable Transit (Bus Rapid Transit)

* Zulfiqar Ali Lashari
** Muhammad Yousif Mangi
*** Shahbaz Khan Samoo

Abstract
The sustainable development goals Agenda 2030 encouraged cities to promote public transportation usage, especially bus rapid transit systems (BRT). This study aims to identify the factors affecting the ridership of bus rapid transit (BRT) systems to provide managerial implications for the transportation authorities to enhance the ridership. The factors including population, number of stations, the modal split of public transport, fleet size, frequency, pre-board fare collection, and overtaking lanes are considered in this paper. The data from 146 BRT systems are collected. A two-stage least square (2SLS) model is developed to conduct the analysis. Results revealed that the BRT systems parameters have significant impacts on the number of daily passengers. An increase in the fleet size, frequency of buses, and affordability and provided overtaking lanes significantly attract more ridership per station. This study supports the maximization of ridership in BRT systems by targeting the significant factors affecting the ridership and recommends further research. Resultantly, this will promote sustainable development.

Keywords: Bus Rapid Transit, Two-stage Regression, Daily Ridership, Sustainability

Introduction

Bus Rapid Transit (BRT) is a modern mode of transportation that has greater operational flexibility and comparatively lesser investment and operating costs than light rail transit (LRT) and metro [1]. BRT is a new type of mass transportation system that combines the speed and consistency of railway system with the operational flexibility and lower cost of conventional bus system [2-4]. BRT is a rubber-tired rapid transit system with high service standards, isolated rights-of-way, terminal platforms, intelligent transportation systems, and pre-board ticketing systems [5,6].

In 1974, the first time in history BRT transportation was introduced in Curitiba, Brazil. The Curitiba system has since been followed by several cities around the golbe [7]. Chicago developed the first proposal of the BRT concept in 1937, Washington D.C among the year 1956 and 1959, and St. Louis in 1959 respectively [8]. Around the globe, more than 200 cities have BRT transportation and provide service around 33 million riders twenty-four-seven (Global BRT Data, 2018).

Advantages of BRT over the other form of transit systems are the potential for more considerable patronage, higher capacities, and the opportunity for incremental implementation [6,9]. According to [Hensher [10],11] BRT is a transportation means, which is quickly expanding throughout the world for the reason that of lower cost, operating flexibility, speedy execution, and high performance, i.e., reliability/speed. BRT operates on separate right-of-way contained numerous stops along the busways, and the distance between stops is much larger than the local buses [7]. BRT is like other high-frequency transportation modes like LRT and metro. The data shows that BRT has attracted more riders from private transportation to have social, financial, and environmental benefits [7]. BRT system gained popularity worldwide [12], and the researchers are interested in the evaluation and enhancements of BRT system efficiency. Numerous studies have been conducted to estimate the performance and effects of BRT systems, and their affordability [4,7,13,14]. It is

* Department of City and Regional Planning, Mehran University of Engineering and Technology, Jamshoro 76020, Pakistan Email: zulfiqar.lashari@admin.muet.edu.pk
** Department of City and Regional Planning, Mehran University of Engineering and Technology, Jamshoro 76020, Pakistan Email: yousif.mangi@faculty.muet.edu.pk
*** Department of City and Regional Planning, Mehran University of Engineering and Technology, Jamshoro 76020, Pakistan Email: Shahbaz.khan@faculty.muet.edu.pk

important to recognize factors affecting BRT ridership on the system level as the identification of significant factors can provide intuitions for developing an improved system, which attracts more commuters [6,15].

However, the researchers have conducted less studies on the impact of BRT ridership, resultantly less literature and data are available [16]. The Ko, *et al.* [17] gathered data from 111 cities to analyze the factors impacting BRT ridership, in this study, he only focuses on four factors "population, fleet size, number of corridors, and the fare divided by GDP per capita". [13] researched 119 BRT transportation to explore factors impacting ridership. In his research, he only focuses on two factors. Moreover, [16] conduct study to evaluate estimated the ridership model and a service frequency model. Indeed, the results of the studies suggested that BRT may perform well to attract more ridership. While there is abundant literature on BRT planning, implementation, and evaluation of its efficiency, but less research has been on system-level analysis for explaining the relationship between ridership and hypothetically influential factors. To overcome this gap our study has gathered data from 12 countries including 121 BRT transportation in various cities around the world to analyses factors that impacting of BRT ridership. Our study has considered six factors "standard fare, frequency, mode share by car, number of stations, pre-board fare collection, and location of the door and bus lanes" to analyze the impact on BRT ridership.

This study explores the relative passenger attractiveness and identifies potential factors including population, the modal split of public transport, GDP per capita, and system characteristics affecting BRT ridership to promote ridership growth. Findings are helpful for the transport planners, engineers, and policymakers when designing and planning the BRT systems to attract more passengers from the private mode of transportation (car and taxi users). Thorough literature review, research methodology, findings, outcomes and discussions, and conclusion in the next phases briefly elaborated.

Literature Review

Previously, some studies have been conducted on BRT systems [4,9,18]. Taylor, *et al.* [19] elucidated that the studies of transit ridership have been influenced by a variety of factors such as descriptive analysis and causal analysis. The descriptive analysis uses surveys and interviews, emphasizing on behaviors and opinions of operators and users. Whereas casual studies analyze the interior environment, system, and behavioral characteristics, related to commuters.

Furthermore, these elements are generally split into two categories: internal or policy factors and external or control factors [20]. It is often used multivariate regression models that contain a combination of internal and external items related to the transit system [19,21]. The agencies used a wide range of internal factors (i.e., actions solution will be implemented by the agencies) to help ridership growth, including design phase, advertising, cost structure, as well as other types of efforts. Nevertheless, external factors outside of the agency's direct control (i.e., economic conditions/GDP per capita, cost, alternative mode choice, development pattern, and policies) have also exerted substantial impacts on demand levels [22,23]. Ridership and external factors can be easily linked; for example, population and employment growth in a territory can increase public transport demand by simply increasing the total ridership base. Those factors which are impacting commuters of public transportation (BRT) have given more weightage in transportation research [19,24].

The causal analysis allows the researcher to attain better quality and a broader range of data than descriptive studies[25,26]. The causal analysis describes the three separate elements such as station, route, and system levels [20,27]. For station-level analyses, one station of connectivity to other stations was also measured as an essential element for describing commuters. While the route level analyses, measured in terms of frequency, vehicle capacity, station spacing, and speed of the vehicle [13]. Hensher, Li and Mulley [16]; System-level studies focused on the factors including price level and system size (the system's length and the number of stations) [19]. The study focused on the traveler's mode choice preferences in Yichang city of China with a BRT system. The study revealed that saving travel time and the lowest cost results in the greatest use of public transportation. While the share of private vehicles (cars & taxis) would decrease (Mei-Ping Yun and Liu 2013). Numerous studies have conducted reviews on BRT systems and factors affecting ridership, considered station/stop level analysis and route level analyses, but only a limited number of studies have attempted to explanation for the system-level analyses (see, e.g., [4,16,17]. These studies focus on the factors affecting ridership. Some prior studies attempted to account for the simultaneous supply and demand for transit [28]. The studies differ extensively in the modes investigated; few studies focused on the specifics of reviews of rail or subway and bus [14,17,20].

Hence, most earlier aggregate analyses of the aspects influencing transit ridership incestigated only one or some of variables and systems, and/or did not include various of the external, control variables assumed to affect transit utilisation, and did not address the concurrent association between public transit demand and availability and consumption. The models developed in the previous studies were often not fully quantified, and variables included in the models are inconsistent. This research attempts to address the 146 systems in 41 countries around the globe. This study conducted an OLS method analysis of variables influencing the ridership. Meanwhile, the 2SLS model was also used to account for the simultaneity amongst transit service supply and consumption.

Data and Method

Information on 146 BRT transportation is operating from 41 countries, started from 1974 and 2016 and expanding in many countries [29], Institute for Transportation & Development Policy [30], worldbrt.net, Comparecities.org, [31], [32] and [33]. The study focused on Southern America, Northern America, Asia, Europe, Africa, and Oceania countries that have implemented BRT systems. The study focused on the factors that affected the total number of daily ridership.

In line with previous studies [17,34], two stage-least square analyses were used to explore the relationships between BRT ridership and potentially significant variables. An ordinary least square model was also developed. Our study has built a BRT ridership model with the dependent variable of log-transformed of daily ridership. Additionally, the ridership per station model with the dependent variable is log-transformed of passenger per station — furthermore, the two-stage least square (2SLS) model with log-transformed of total daily ridership. The 2SLS model is comprised of the following two linear regression models (Maurice J. G. Bun & Teresa D. Harrison 2018).

$$Y = \beta 1 + \beta 2X2 + \cdots + \beta kXk + e \quad (1)$$

$$\mathrm{X} = \mathrm{a1} + \mathrm{a2z1} + \mathrm{a3z2} + \mathrm{e} \quad (2)$$

where,

Y = Dependent Variable

Table 1. Descriptive Statistics of Considered Factors (n=146)

Category	Variables	Mean	Standard deviation	Minimum	Maximum
City level	Population (million)	2.8	4.2	0.031	24.0
	Population density (1000 people per km^2)	6.3	11.7	0.029	72.3
	GDP per capita (USD)	21.9	19.2	0.865	80.2
	Number of passengers per day (1000)	227863	48134	2000	3354836
	Modal split of public transport (%)	31.5	19.4	2.0	83.0
BRT basic components	The total length of the BRT system (kilometer)	31.4	2.8	3.0	207.0
	Number of corridors	2.3	2.7	1	17
	Total number of stations	44.5	51.8	3	329
	Standard fare (US$)	1.4	1.2	0.13	6
	Distance between station (meters)	869	1068	70	9675
	Fleet size	164	244.7	4	1666
	Number of trunk lines	9.4	17.2	1	122
	Pre-board fare collection (yes=1/no=0)	0.60	0.49	0.00	1
	Platform-level boarding(yes=1/no=0)	0.74	0.43	0.00	1
	Fare integration with the system (yes=1/no=0)	0.36	0.48	0.00	1
	Overtaking lanes (yes=1/no=0)	0.43	0.49	0.00	1
	Number of transfer stations	2.04	4.7	0.00	40.0
	Speed (kilometer per hour)	35.4	17.7	15	90.0
	Real-time information (yes=1/no=0)	0.63	0.48	0.00	1.0
	Peak frequency (buses per hour)	57.88	91.7	3.00	600

Table 1 demonstrates the descriptive statistical analysis of the considered explanatory variables. In the cities, the selection of factors presents a wide dispersal. For example, the residents of Shanghai City, China is around 24 million, larger than 31000 people living in Maubeuge, France.

Likewise, the length of the BRT system varies from city to city. The length of the BRT system, Juiz-de—Fora, Brazil is only 3 kilometers, however the total area of the BRT in Jakarta, Indonesia is 207 km with twelve corridors. Fares also vary significantly across the BRT systems. The minimum fare charge in Guatemala, Guatemala (Latin America) is USD 0.13, while Las Vegas, United States delivers services at a standardized fare of almost six USD. In Chiayi, Taiwan has only 2000 passengers per day, while Sao Paulo, Brazil has more than 3 million passengers per day.

Table 2. Bus Rapid Transit Length and Ridership by Continent

Region	Africa	Asia	Europe	Latin America	Northern America	Oceania
Number of countries	3	12	10	12	2	2
Number of cities	4	37	33	51	17	4
Length (km)	118 (29.5)	1,461 (39.5)	703 (21.9)	1,747 (34.9)	467 (29.2)	96 (24)
Number of passengers per day	468,178 (117,044)	9,726,582 (262,880)	1,541,988 (46,726)	20,204,026 (396,157)	891,116 (52,418)	436,200 (109,050)

Source: Global BRT (brtdata.org)

Note: Average values for the city are length and number of passengers shown in brackets.

The development of BRT systems over the entire world has unveiled enormous growth in the past decade. Recently, there are 169 cities in 43 countries with BRT systems, serving more than 33 million passengers every single day [29]. We have considered 146 cities (BRT systems) in 41 countries in the final dataset (Table 2). BRT systems of Latin America have been implemented in their 51 cities of 12 states and serving 20 million passengers per day. Europe has implemented BRT systems in 32 different locations. Currently, Asia has adopted BRT operations in 37 cities. China's BRT system has dominated other Asian cities. Recently, 20 Chinese cities have BRT systems and host almost 0.1 million average passengers each day.

Five cities have BRT systems in Africa, three cities in South Africa are Johannesburg, Cape Town, and Pretoria, Lagos in Nigeria, and recently implemented BRT system in Dar-es-Salaam, Tanzania, which selected four cities in this study. Started the BRT system in the four cities of Oceania, Adelaide, Brisbane, and Sydney-metropolitan area in Australia and only one city of New Zeeland is Auckland has a BRT system.

Results

Daily Ridership Model

The ridership model is described in Table 3. The explanatory variables included population, population density, the modal split of public transport, fleet size, the number of stations, stations spacing, fare integration within the system, frequency, fare divided by GDP per capita, pre-board fare collection, real-time information, speed, over-taking lanes, station boarding level, number of transfer stations, and the location of the system.

Considering all factors mentioned in table 3 an OLS model was created. The model explains that overtaking lanes has a major effect on the total number of everyday travelers, and the total number of stations has the strongest effect on everyday travelers as explained by the beta coefficient. Also, the size of the population, fleet size, pre-board fare collection, frequency, and Asia have been significantly associated with the total number of passengers per day. The model identified that fleet size and service frequency have a positive effect on ridership and demand level, indicating that BRT should be operational for at least 16 hours per day, with peak headways of no more than 10 minutes (Levinson et al. 2003). Furthermore, fare divided by log-GDP, population density, real-time information, speed, number of transfer stations, and station boarding level appears to have a significant effect on the daily ridership at the significance level of > 0.10. This model accounts for 67.4% of the variation in frequent ridership across the 146 BRT systems.

Table 3. Daily Ridership Model (n=146)

	Variables	OLS Model			2SLS Model		
		Coefficient coefficient	Beta	P-value	coefficient	Beta coefficient	P-value
	Constant	3.278***		000	3.508***		000
City characteristics	log of population density (1000 person per sq.	0.006	0.014	0.833	1.085	0.038	0.970

	kilometer)						
	Log of the population of the city (million)	0.151^{*}	0.130	0.083	---	---	---
	Modal split of public transport (%)	0.007^{***}	0.207	0.003	5.938^{**}	2.088	0.036
System characteristics	Fare divide by log-GDP per capita	0.086	0.039	0.504	3.229	0.216	.0829
	Stations spacing (meters)	2.953	0.045	0.387	6.058^{**}	2.229	0.026
	The logarithm of a fleet size	0.170^{***}	0.139	0.032	3.507^{**}	2.119	0.034
	Fare integration within the system	0.019	0.013	0.811	1.660	0.200	.0841
	log of frequency	0.160^{***}	0.267	0.000	---	---	---
	Number of stations	0.004^{***}	0.264	000	1.054^{**}	2.978	0.002
	Pre-board fare collection	0.181^{***}	0.132	0.024	1.827^{*}	1.846	0.064
	Real-time information	-0.022	-0.015	0.793	-4.984	-0.426	0.670
	Speed (kilometer per hour)	0.002	0.024	0.680	9.736^{*}	1.751	0.079
	Station boarding level	0.023	0.038	0.571	6.432	0.149	0.881
	Overtaking lanes	0.213^{**}	0.148	0.013	2.082^{**}	2.186	0.028
	Number of transfer stations	0.006	0.040	0.505	-1.525	-1.041	0.298
	Asia	0.253^{*}	0.157	0.027	1.702	1.172	0.241
	Latin America	0.223	0.152	0.112	2.985^{*}	1.994	0.046
		Adjusted R^2 =0 .674			Adjusted R^2=0.455		
	Dependent Variable = Passenger per day (1000)				Wald-statistics = 259.7		
	F-statistics = 17.93 (p-value: < 2.2e-16)				Hausman p-value = 0.001		
	Endogenous variable = Number of stations				Instrumental variables=Population & frequency		

* Significant at 10 %; ** Significant at 5%; *** Significant at 1%.

The possibility that the number of stations should be affected by demand levels that we investigate the how BRT operators to adjust the number of stations according to changes in demand levels. By using the 2-stage least square (2SLS) method, a model was estimated in which a total number of stations was treated as an endogenous variable with 2 instrumental variables (IVs): the logarithm of people and frequency buses per hour. Entirely explanatory factors elucidate 45.2 percent of the variation. The 2SLS model specified that modal split public transport, fleet size, overtaking lanes, station spacing, pre-board fare collection, and Latin America are a significant influence on the daily ridership. The results reveal that the total number of stations would be strongly affected the daily ridership growth. The study has examined the degree to which the endogenous nature of a total number of stations as suggested by the beta coefficient in the daily ridership model (Table 3). We should explore the (instrumental) variables, which affect the number of stations.

Additionally, the significance of the 1st model is at the level of 0.01 ($p < 0.01$) rejects the null hypothesis that the IVs are weak [35]. The station spacing variable has a positive parameter estimate, implying that decreasing station spacing would increase daily ridership. The fleet size has a positive influence on ridership, indicating that higher ridership supports potentially higher demand for the number of the fleet to attract more passengers.

Ridership per Station Model

The ridership per station model is summarized in Table 4, with a dependent variable of the logarithm of the total number of passengers per station. All explanatory variables explain the 52 percent variation in the total number of passengers per station of the 146 BRT systems. The model identified that factors such as modal split of public transport, frequency, speed, overtaking lanes, and pre-board fare collection are positively associated with the ridership per station. The model identified that the log of frequency has a major effect on everyday travelers as recommended by the beta coefficient. Associated with the current indication, the frequency elasticity assessed in this model has a higher value, indicating higher demand for BRT daily ridership. The model suggests that pre-board fare collection would significantly increase dwelling time. The study revealed that over-taking lanes have a positive impact on the ridership per station. Furthermore, the BRT system equipped with the station boarding level would attract more passengers.

Table 4. Ridership per station (n = 146)

	Variables	Coefficient	Beta Coefficient	P-value
City characters	Constant	1.322***		0.002
	Population (million)	0.133	0.141	0.129
	Population density	0.020	0.053	0.498
	Modal split of public transport	0.09***	0.299	0.000
System characteristics	Fare divided by GDP	0.002	0.001	0.989
	Logarithm of frequency	0.207***	0.424	0.000
	Log of fleet size	0.101	0.101	0.200
	Station spacing	1.205	0.020	0.727
	Fare integration with system	0.005	0.004	0.949
	Pre-board fare collection	0.149**	0.134	0.030
	Log of speed (kilometer/hour)	0.295**	0.137	0.025
	Overtaking lanes	0.197*	0.167	0.010
	Station boarding level	0.019	0.040	0.595
	Number of transfer stations	-1.64	-0.007	0.998
	Real-time information	-0.028	-0.023	0.744
	Asia	0.094	0.071	0.478
	Latin America	-0.021	-0.017	0.879
	Adjusted R^2 = 0.52	Dependent variable: Log of number of passengers (1000) per station		

* Significant at 10%; ** Significant at 5%; *** Significant at 1%

Table 5. Comparison of significant factors

Variables	**The present study (n=146)** Daily ridership model OLS	2SLS	Ridership per station	**[16] (n=54)** Daily ridership model	**[17] (n=111)** Daily ridership model OLS	2SLS	Ridership per kilometer
Number of stations	+	+		+			
Mode share of public transport (%)	+	+	+				
Mode share by car				-			
Population	+				+		
Fare				-	-	-	-
Population density							+
Stations spacing		+					
Fleet size	+	+			+	+	+
Service frequency	+		+	+			
Number of BRT corridors					+		
Pre-board fare collection	+	+	+	+			
Doorways for passengers (Yes)				-			
Longitudinal location of with-flow bus lanes on sides				-			
Real-time information & fare collection						+	
Overtaking lanes	+	+	+				
Speed		+	+				
Asia	+						
Latin America		+					
Adjusted R^2	**0 .67**	**0.45**	**0.52**	**0.85**	**0.81**	**0.78**	**0.70**

Note: +: significantly at the level of 0.1 positive relationship

-: significantly at the level of 0.1 negative relationship

A shown in Table 5, the present study has compared two analytic methods OLS regression and 2SLS methods with previous referred studies. In the present study, we conducted analyses of all variables that have a significant impact on the daily ridership and all variables explain 67.4 percent. While Hensher et al., (2014) was selected seven explanatory variables in 54 BRT systems elucidating 85 percent of the variation in the ridership model and the study by Ko et al. (2019) designed the model selecting four explanatory variables indicates 80 percent difference in the 111 systems. Further, all the parameters of present and previous studies are estimated revealing as statistically significant at the level of 0.1. Moreover, an OLS regression was employed to identify the factors affecting daily ridership. The number of stations, service frequency, pre-board fare collection, and speed has a positive impact on the ridership as shown in the present study and as well as in the study conducted by [16]. Population and fleet size has a positive influence on the travelers in the study conducted by[17] and the present study as well. Also, the fare is negatively associated with ridership.

There is some clear consistency in all three studies. It is useful to summarize and validate the critical factors been revealed from our current studies that affect ridership. The findings from the comparison of studies that what kind of features of BRT systems contribute to growing the number of ridership and how to attract more passengers from the other modes of transport, i.e. car users and taxi users.

Conclusion

BRT systems are now used all over the world and have achieved substantial success as a result of citizen satisfaction. BRT systems have proved a capacity to increase transit ridership within well-defined corridors. This study explored the factors affecting daily ridership by collecting information on BRT systems in 146 cities from 41 countries. This study has provided different indicators to identify more elements of BRT systems that seem to be positive contributors to investment growth. We have developed the statistical models using two dependent variables such as total daily ridership and ridership per station. The 2SLS model was also constructed, considering bidirectional interactions between daily ridership and BRT basic components, particularly the number of stations.

This study shows that all transit service factors have a important effect on ridership and affect transit ridership in the expected ways. The statistical significance of the majority of the explanatory variables has not changed. Pre-board fare collection and overtaking lanes in the daily ridership model and service frequency and BRT speed in the ridership per station model are marginally significant. It the useful to summarize variables that have been revealed from our present study, as shown in Table 5. There are some clear constancies/similarities (in the variables such as) across all three studies, notably the number of stations, population, fleet size, service frequency, and pre-board fare collection. The study also focuses on other factors such as station spacing, over-taking lanes, mode share, and location of the systems. The study findings offer valuable suggestions that which factors of BRT systems are supported to growing ridership.

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