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Who benefits from bus rapid transit? Evidence from the Metro Bus System (MBS) in Lahore

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ABSTRACT

Bus rapid transit (BRT) is a popular mode for government investment in public infrastructure, particularly in developing countries where capital resources are scarce. Enthusiastic evaluations of BRT systems worldwide are perhaps premature given that most such systems have been operational for only a short time. Further, little research on BRT systems from the user perspective is evident in the literature. The latter is problematic because one justification for government investment in BRT is the social benefit such systems bestow on groups who are traditionally without access to private modes of transportation. In order to explore the purported social benefits of a BRT system two series of multiple logistic regression models are fit. The first uses disaggregate data from inside a BRT service area and the second uses disaggregate data from inside and from outside a BRT service area. The rider and the commuter data sources, respectively, help to understand who benefits from the new Metro Bus System (MBS) in Lahore and how. To that end, descriptive results show that women are less representative of riders and of commuters, but inferential results show that females are more likely to commute via the MBS. In addition, usage patterns show that females are more habitual users and that they benefit greatly from the fare subsidy. Finally, efforts to further integrate the MBS with the greater public transportation network in Lahore will help to mitigate the monetary and the temporal costs of MBS usage which more so affect females.

1. Introduction

Bus systems operate either in traffic without priority, in traffic with priority or with no traffic interaction (IEA, 2002). The latter systems prioritize the rapidity of buses and therefore are known as bus rapid transit (BRT) systems. Presently, BRT is in operation in 165 cities, in expansion in 55 cities and planned/in construction in 121 cities worldwide (BRT Centre of Excellence, 2018a). Most of the cities where BRT is in operation are in Latin America (33%), in Europe (27%) and in Asia (26%). Further, of the worldwide total passengers per day (32,063,374) and the worldwide total length in kilometers (4888), Latin America ranks first (61% and 36%, respectively). The predominance of Latin America in the worldwide supply of BRT reflects the fact that the first BRT system in the world was in Curitiba in Brazil.

The literature is replete with analyzes of the effectiveness of BRT systems a few years out from the commencement of operations. Gilbert (2008) and Hidalgo et al. (2013) evaluate the effect of the partial system and the impacts of Phase I and of Phase II, respectively, of *Transmilenio* in Bogotá, Delmelle and Casas (2012) evaluate accessibility to and accessibility from the Masivo Integrado de Occidente (MIO) in Cali, Deng and Nelson (2013) evaluate the performance and the impacts of the first line of the Beijing BRT and Yazıcı et al. (2013) evaluate the effect of the Metrobüs in Istanbul. The *Transmilenio*, the Beijing BRT and the Metrobüs are the first BRT systems in their respective countries. Overall, such research suggests that the advantages of the BRT concept will not necessarily accrue to every system (Filipe and Macário, 2013). One area of research which requires more attention is on the benefits of BRT systems from the perspective of the individual. For example, little research on individual usage by income is evident in the literature (Venter et al., 2018). Such research is vital because user satisfaction with BRT is not universally positive (Nikitas and Karlsson, 2015). And, Vermeiren et al. (2015) argue that individuals who are extremely poor rather than poor, middle class or rich are the most vulnerable to exclusion from new BRT systems because of affordability constraints.

In order to address the void in the international literature on the BRT concept, the study attempts to answer the following questions on the first BRT system in Pakistan known as the Lahore Metro Bus System (MBS) from a user perspective. First, who uses the MBS and why? For example, mass rapid transit in the form of BRT purportedly benefits the

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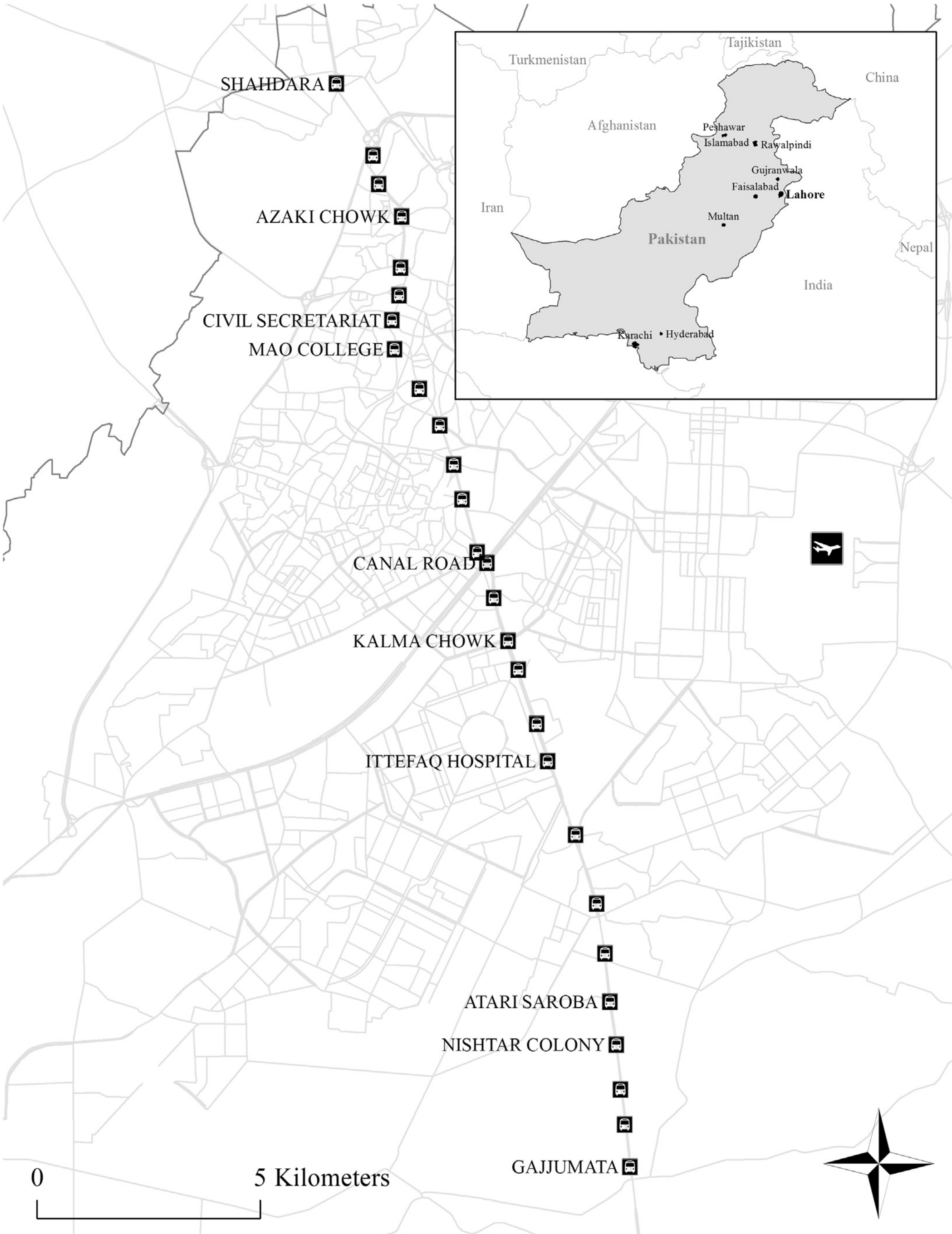

Fig. 1. Metro Bus System (MBS) in Lahore.

poor the most. Given the fare subsidy on the MBS, are the poor actually users? Second, "[g]ender confers some particular disadvantages in terms of diffused trip patterns and timings, as well as particular vulnerability to safety and security problems" (World Bank, 2002, p. xvi). The latter is of particular concern in a developing country like Pakistan (ADB, 2014) where the social benefits of mass rapid transit like BRT affects not only disaggregate vocational and educational outcomes (for women), but aggregate economic growth (for men and for women). To that end, are women who work and who go to school actually users of the MBS?

The organization of the study is as follows. The background section reviews the worldwide literature on BRT systems and BRT cases. The next section on the MBS describes the history of the system as well as the research on the system. The data section presents the sources of information on users of the MBS. The methodology section presents the statistical approach to specify inferential models of MBS users. The results section presents the results from the rider and the commuter models, respectively. The discussion section discusses the results as well as their implications. Finally, the conclusions section highlights the contributions of the results to the international literature on the BRT concept, the limitations of the study as well as the most fruitful direction for future research.

2. Background

The worldwide diffusion of BRT from Latin America reflects the popularity of BRT systems to satisfy present and future trip demand. The popularity of BRT is due to the following (Levinson et al., 2002). First, the construction of bus infrastructure is less costly than rail infrastructure both in terms of time and of money. Second, BRT systems require rights-of-way in order to operate in exclusive corridors and so offer the flexibility for future rail upgrades.

The majority of BRT systems worldwide are relatively new, so empirical evidence to support assertions on their benefits is scant. BRT seems to lower travel times (Ernst, 2005; Alpkokin and Ergun, 2012). Other purported benefits of BRT are economic and environmental. The empirical evidence is not incontrovertible (Munoz-Raskin, 2010; Zhang and Wang, 2013), nor plentiful (Deng and Nelson, 2011), but BRT also seems to increase proximate property values (Rodríguez and Targa, 2004; Rodríguez and Mojica, 2009; Deng and Nelson, 2010; Cervero and Kang, 2011). Further, research on the environmental benefits of BRT systems is not plentiful (Vincent and Jerram, 2006), but what little empirical evidence exists suggests potentially dramatic reductions in emissions from BRT (Wöhrnschimmel et al., 2008; Nugroho et al., 2011; Vincent et al., 2012).

Besides the paucity of empirical evidence on purported benefits, other concerns serve to qualify support for BRT systems (Nikitas and Karlsson, 2015). For one, the public image of bus service is negative in comparison to rail service (Hecker, 2003) even though the empirical evidence suggests that property value effects for BRT systems are larger than for (light or heavy) rail systems (Ingvardson and Nielsen, 2018). The public perception is that buses are slow, noisy and noxious. Further, BRT stations and routes are temporary, while rail stations and lines are permanent. Such permanence enhances the image of places and ultimately engenders greater development potential. Mass rapid transit like BRT purportedly benefits the poor (World Bank, 2002), but BRT may not serve places where the poor reside as in case of the *Transmilenio* in Bogotá (Gilbert, 2008). Indeed, in the case of the MIO in Cali, accessibility to the BRT system is lower from poor neighborhoods than from middle class neighborhoods and from upper-middle class neighborhoods (Delmelle and Casas, 2012). And, even if BRT serves poor neighborhoods, the capitalization of infrastructure investments into proximate property may ultimately price out the very cohorts who benefit the most from such systems (Gwilliam, 2003) as shown by Duarte and Ultramari (2012) in Curitiba. Such an outcome is problematic because the poor as well as the young, the old and women are often without access to private modes of transportation. In the latter case, public modes of transportation provide mobility not available otherwise in order to access work or school locations (Fouracre et al., 2003). Given the dramatic difference in labor participation rates between men (82.2%) and women (24.3%) in Pakistan (UNDP, 2016), public modes of transportation are necessary for present and for future economic prosperity.

3. Study area

Lahore is home to the MBS as well as the capital of the Punjab (Fig. 1). Lahore (11,126,285) ranks second in population in Pakistan (PBS, 2018), but Lahore ranks first in population growth in Pakistan. Indeed, the percentage change in population was +116.32% from 1998 to 2017. Lahore grew to the size of a megacity (population of more than 10 million) well before the 2030 projection by the UN (United Nations) (2015). Rapid growth has wrought rapid urbanization (Riaz et al., 2014) from an inner core to a progressively less dense outer periphery (LDA, 2004) (Fig. 2). The balance of the population resides, shops and works in the inner core of Lahore, but, unfortunately, the supply of public services, particularly for transportation, are not sufficient for present and for future demand (Malik, 2013). The absence of transportation infrastructure is problematic because while the number of motor vehicles per 1000 population in Lahore rose from 95 to 238 from 2001 to 2008, a subsample of commuters, most of whom reside in the District of Lahore, from a survey of travel behavior (JICA, 2012) shows that most walk to work even though pedestrian infrastructure in the form of sidewalks are not often available.

The study area is the service area for the MBS in the inner core of Lahore (Fig. 1). The MBS is the first BRT system in Lahore where the Lahore Urban Transport Master Plan (LUTMP) calls for the construction of seven such systems to satisfy future trip demand (JICA, 2012). The service area is in the District of Lahore, home to the two corridors—Ferozepur Road and Multan Road—to the south and to the southwest of the historic Walled City where growth was greatest in the second half of the last century. Investment in bus infrastructure by the Government of the Punjab is consistent with the LUTMP to focus on the bus as the most important public transportation mode to satisfy present and future trip demand in Lahore.

4. Lahore Metro Bus System (MBS)

The first BRT system in Pakistan is the Lahore MBS. The model for the MBS was the Metrobüs in Istanbul. Indeed, the Government of Turkey, in partnership with the Government of the Punjab, built the MBS on a Build-Operate-Transfer (BOT) basis which is an innovative Public-Private Partnership (P3) to finance public transportation infrastructure where resources are scarce (Malik, 2013). The total cost for the 27-kilometer MBS in Lahore was approximately 11 million USD per kilometer in 2013 (BRT Centre of Excellence, 2018b) which is slightly more than the total cost for the 52-kilometer Metrobüs in Istanbul (approximately 9 million USD per kilometer in 2013) (BRT Centre of Excellence, 2018c).

The Punjab MassTransit Authority (PMA) operates the MBS with 64 articulated buses at 27 stations seven days a week from 06:15 to 22:00 (PMA, 2018). The fare, irrespective of destination, is 20 PKR (slightly less than 0.20 USD). For comparison purposes, the range of fares on buses that the Lahore Transport Company operates is from approximately 20 PKR to approximately 40 PKR.[1] A rough estimate of the subsidy per fare from the Government of the Punjab is 40 PKR (slightly less than 0.40 USD) which is approximately 2 billion PKR annually since annual demand in 2015 was 54 million passengers per year (BRT Centre of Excellence, 2018b).

The MBS is a popular topic for BRT research (Ahmed and Azeem, 2014; Ali and Rathore, 2015; Aziz et al., 2015; Naseem, 2015). Ahmed and Azeem (2014) analyze surveys of MBS riders as well as primary and secondary sources of data from the PMA to study system performance. Maximal speed is approximately 45 kilometers per hour (approximately 30 miles per hour) and operational speed is approximately 25 kilometers per hour (approximately 15 miles per hour). Headways are approximately three minutes. Peak hour (07:00 to 10:00 and 16:00 to 20:00) frequency is 27 buses per hour and off-peak hour frequency is 20 buses per hour. Dwell times are approximately 20 seconds, 30 seconds maximum. Maximum travel time (from terminal station to terminal station, that is, from SHAHDARA to GAJJUMATA) is 63 minutes. MBS is reliable. Eighty-seven percent of riders agree with the statement the "[b]us is on time" (p. 9). Regardless of mode, most riders get to their departure station in five to fifteen minutes reflective of the relative accessibility of MBS stations.

Ali and Rathore (2015) evaluate the MBS against international best practices set forth in *The BRT Standard* by the ITDP (2016). *The BRT Standard* is an evaluation tool to establish a universal definition for BRT as well as to ensure a level of service for BRT worldwide. *The BRT Standard* ranks BRT corridors from gold to silver to bronze to basic on design and operations. The maximum score on *The BRT Standard* is 100

[1] In the United States, on the one hand, the price of a liter of gasoline is 0.75 USD which represents 0.46% of average daily income (163.00 USD) (Bloomberg, 2018a). In Pakistan, on the other hand, the price of a liter of gasoline is 0.68 PKR which represents 16.16% of average daily income (4.20 USD) (Bloomberg, 2018b).

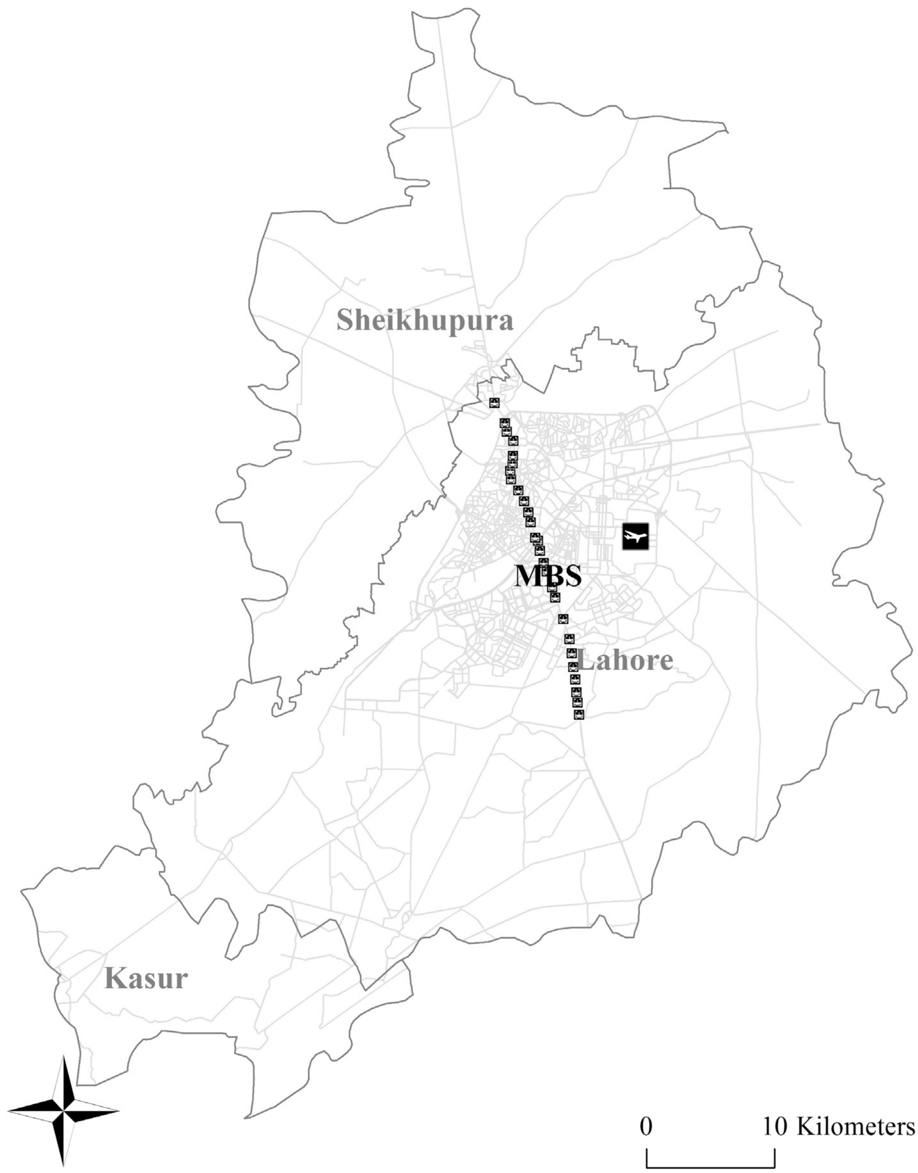

Fig. 2. Service area for the Metro Bus System (MBS) in Lahore.

points, the gold standard is 85 points or above, the silver standard is 70 to 84 points and the bronze standard is 55 to 69 points. If a corridor achieves the minimum criteria for a BRT[2] but scores less than 55 points, then *The BRT Standard* ranks the BRT corridor as basic. The latter is the designation of the MBS (Ali and Rathore, 2015). The design elements of the MBS corridor inconsistent with operational performance and service quality include access and integration, infrastructure and service planning. On the design element of access and integration, MBS stations are indeed pedestrian accessible via bridges or underpasses. However, MBS stations are not universally accessible and integration between the MBS corridor and the greater public transportation network in Lahore is ongoing. In the former case, MBS stations are not universally accessible to wheelchairs. In the latter case, the first phase of MBS feeder routes was operational in March of 2017 (PMA, 2018). Overcrowding[3] (at peak hours on 25% of buses and at stations) and poor busway maintenance (potholes) are also inconsistent with operational performance and service quality.

Aziz et al. (2015) use archival data[4] to analyze operations of the MBS against key performance indicators from the FTA (2004), the ITDP (2007), the APTA (2010), the ADB (2011) and the World Bank (2011). The key performance indicators include travel time savings, service reliability, safety as well as capacity and comfort. On the key performance indicator of travel time savings, the travel time savings (45%) is well above the international benchmark (15% to 25%) from the FTA (2004). And, on the key performance indicator of safety, the number of

[2] The minimum criteria for a BRT in *The BRT Standard* (ITDP, 2016, p. 26) are as follows: at least three kilometers in length with dedicated lanes; score four or more points on the dedicated right-of-way element; score four or more points on the busway alignment element; and score 20 or more total points across all five of the BRT basic elements.

[3] *The BRT Standard* (ITDP, 2016) defines overcrowding by passenger standing density (p. 68). On buses, the passenger standing density threshold is five passengers per square kilometer on more than 25% of buses on critical links in the peak direction at peak times. At stations, the passenger standing density threshold is three passengers per square kilometer at one or more stations at peak times. If the above criteria are not calculable, then observable signs of overcrowding on buses and at stations are acceptable criteria.

(footnote continued)

[4] Data consist of PMA reports on automatic bus schedule and vehicle location systems from April of 2013 to December of 2013.

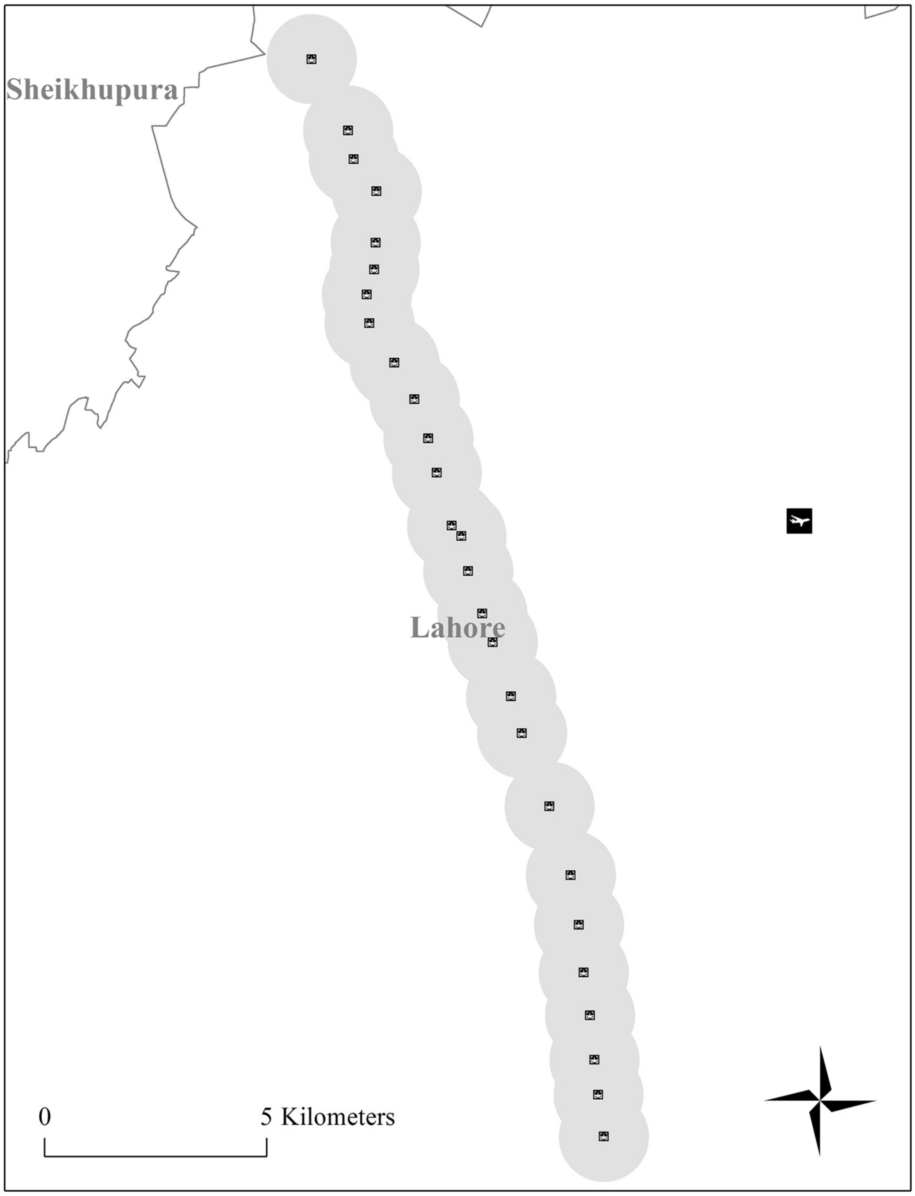

Fig. 3. One-kilometer buffer from the Metro Bus System (MBS) stations.

kilometers per accident (390,000) is well below the international benchmark (10,000 to 60,000) from the World Bank (2011). However, on the key performance indicator of service reliability, schedule adherence (39%) is well below the international benchmark (85%) from the APTA (2010) and headway regularity (57%) is well below the international benchmark (85%) from the APTA (2010). Interestingly, the latter problem is due to early departures, not late arrivals, 50% of total trips are ahead of schedule and 12% of total trips are behind schedule.

A survey of 3900 MBS commuters in 2015 by Naseem (2015) shows that demographically, most commuters: are male (68%), use MBS on a daily basis (61%), walk one kilometer or less than one kilometer to the departure station (53%) and trip purpose is work (48%). Socially, most commuters think MBS improves accessibility to hospitals, home and food (89%). Economically, most commuters: are in the low monthly income bracket—10,000 PKR to 20,000 PKR (approximately 90 USD to approximately 180 USD) (47%), work more hours or work a second job because MBS makes work more accessible (84%), earn more because MBS makes work more efficient or because MBS makes better-paying jobs more convenient (74%), pay less for transportation by using MBS (74%) and own a vehicle—bicycle, motorcycle or car (54%). For the latter group (commuters who own a vehicle), MBS is a partial replacement for private vehicle use (45%) and MBS use lowers fuel costs (79%). The following section presents the sources of information on MBS users.

5. Data and methodology

5.1. Data

Two surveys provide information on users of the MBS in order to examine "micro-level details" on BRT system usage in a developing country (Delmelle and Casas, 2012, p. 45). The first is a rider survey and the second is a household survey. The rider survey was undertaken by the Lahore University of Management Sciences (LUMS). The purpose was to obtain information on the socioeconomic characteristics of MBS riders as well as the travel behavior of MBS riders. The sampling frame was chosen with permission from the PMA. It covers the 27-station MBS from the terminal stations to approximately every third station between the terminal stations (Fig. 1). The ten stations (from north to south) are the two terminal stations (SHAHDARA and GAJJUMATA) and eight intermediate stations (AZADI CHOWK, CIVIL SECRETARIAT, MAO COLLEGE, CANAL ROAD, KALMA CHOWK, ITTEFAQ HOSPITAL, ATARI SAROBA and NISHTAR COLONY). Three of the stations serve public institutions such as a hospital (ITTEFAQ HOSPITAL), a school (MAO COLLEGE) and a government (CIVIL SECRETARIAT). The CANAL ROAD station is a flyover. Riders were surveyed on random weeks from February 16th of 2016 to March 15th of 2016. Surveys were administered on all days of the week and at random morning, afternoon or evening hours. Teams with equal numbers of male enumerators and female enumerators were instructed to survey every fifth rider as they departed from an MBS station. The intent was to select a random sample of MBS riders, not a representative sample of MBS riders. Exclusion of riders with missing data left a subsample of 2295 riders.

The household survey was undertaken by Gallup Pakistan for the LUMS. The purpose was to obtain information on the economic impact of the MBS. The sampling frame covers 228 zones. Zones were selected via a quasi-experimental, difference-in-difference design that matched treatment zones with control zones based on the commonality of their demographic characteristics and their economic characteristics. Treatment zones had MBS and control zones were going to get MBS. Random samples of households from each zone are population stratified and so are representative of zones, not districts. The total number of households is 16,856—16,828 from the District of Lahore, 22 from the District of Sheikhupura and 6 from the District of Kasur. The majority of households are therefore from the service area of the MBS (Fig. 2) given that the majority of MBS commuters in the Naseem (2015) survey walk, at the extreme, one kilometer to the departure station (Fig. 3). The time frame for the survey is from September 21st of 2015 to May 31st of 2016. The selection criterion for the subsample of individuals is working-age individuals who commute to work. Application of the selection criterion as well as the exclusion of individuals with missing data left a subsample of 8671 individuals from 6137 households. The next section presents the methodology for the rider and the commuter models.

5.2. Methodology

The dependent variables in the rider and in the commuter models are binary (0 or 1). Therefore, the appropriate statistical methodology for the respective models is multiple logistic regression. To that end, the models in the study are generalized linear models of the log odds the dependent variable is 1. Generalized linear models transform the dependent variable and then equate the transformation, known as the link function, to a linear function of the regression coefficients, known as the structural model (Hosmer et al., 2013). In the rider model and in the commuter model, the dependent variables are binary and the link functions are logit, so the structural models are Bernoulli.

Data on riders includes demographic and economic information as well as information on their trips (Table 1). The dependent variable is sex—1 if the rider is female or 0 if the rider is male. The independent variables control for the differences between riders as well as the differences between their trips. Demographic information on riders includes their age in years. Economic information on riders includes their work status. Information on their trips includes:

- accompaniment (alone, with children, with women or with men);
- destination (work, shopping, recreation, social, school, medical, religious, home or legal);
- fare change (change in fare for one-way trip from before MBS to after MBS in PKR);
- origin (work, shopping, recreation, social, school, medical, religious, home or legal);
- past mode (mode to destination before commencement of MBS operations in February of 2013);
- regularity (daily, weekly, monthly or first);
- stops (number of stops from origin station to destination station);

Table 1
Data dictionary for riders (n = 2295) from rider survey.

Variable	Description
Demographic	
Age	Age of rider in years.
Sex	Gender of rider.
Economic	
Work	Work status of rider.
Trip	
Accompaniment	Riding alone, with children, with women or with men.
Destination	Destination of trip.
Fare	Fare for one-way trip in PKR.
Fare change	Change in fare for one-way trip from before MBS to after MBS in PKR.
Regularity	Regularity of ridership.
Origin	Origin of trip.
Past mode	Mode before MBS.
Stops	Number of stops from origin station to destination station.
Time	Time for one-way trip in minutes.
Time change	Change in time for one-way trip from before MBS to after MBS in minutes.

MBS = Metro Bus System.

and

- time change (change in time for one-way trip from before MBS to after MBS in minutes).

Descriptive statistics for the demographic, economic and trip variables for total riders appear in Table 2. Table 2 also shows the mean values for the same variables for male riders and for female riders.

Data on commuters includes information on their commutes as well as demographic and economic information (Table 3). The dependent variables are sex—1 if the commuter is female or 0 if the commuter is male—or present mode—1 if MBS/bus/van or 0 if rickshaw/chingchi, car, motorcycle, bicycle, walk or other. The independent variables are known to affect the mode choices of commuters. Information on the commute includes the number of days the commuter works per week, the fare of the one-way commute in PKR, the number of hours the commuter works per day, if the commuter's household owns a motorcycle, the mode for the one-way commute (MBS/bus/van, rickshaw/chingchi, car, motorcycle, bicycle, walk or other)[5] and the one-way commute time in minutes. Demographic information on commuters includes age in years. Economic information on commuters includes monthly, personal income in PKR. Descriptive statistics for the commute, demographic and economic variables for total commuters appear in Table 4. Table 4 also shows the mean values for the same variables for male commuters and for female commuters. Interestingly, the percentage of households who own a motorcycle in Lahore (70.97%) is much higher than the percentage of households that have a motorcycle/scooter in Pakistan (43%) (Poushter, 2015). The explanation for the difference is twofold. First, the sampling frame for the commuter survey is exclusively urban while the sampling frame for the national survey is not exclusively urban (Simmons et al., 2014). The sampling frame difference is relevant because average, monthly household incomes are approximately 15,000 PKR higher in urban Pakistan than in rural Pakistan (Government of Pakistan, 2017). Second, generally, vehicle ownership increases with income worldwide (Dargay and Gately, 1999), and, specifically, motorcycle ownership is high in South Asia (Poushter, 2015). Indeed, Pakistan ranks 7th out of 44 countries on the percentage of households that have a motorcycle/scooter. In support of

[5] Present mode includes MBS, bus and van because MBS use alone will not capture demand for bus service in the District of Lahore where Naseem (2015) found that most MBS users walk one kilometer or less than one kilometer to the departure station.

Table 2
Descriptive statistics for total riders (n = 2295), male riders (n = 1598) and female riders (n = 697) from rider survey.

Variable	Total	Male	Female
	Mean (SD)	Mean (SD)	Mean (SD)
Demographic			
Age	30.46 (12.64)	31.03 (13.32)	29.14 (10.82)
Sex (%)			
Male	69.63	100	0
Female	30.37	0	100
Economic			
Work (%)			
Work outside home	55.08	66.15	29.7
Agriculture	0.92	1.31	0
Work inside home	0.09	0.06	0.14
Not in labor force	0.61	0.38	1.15
Housewife	9.28	0.88	28.55
Student	30.85	27.35	38.88
Unemployed	1.57	1.88	0.86
Retired/disabled/other	1.61	2	0.72
Trip			
Accompaniment (%)			
Alone	79	84.23	67
With children	7.32	3.63	15.78
With women	6.49	2.82	14.92
With men	7.19	9.32	2.3
Destination (%)			
Work	26.8	32.23	14.35
Shopping	1.26	1.19	1.43
Recreational	3.79	4.57	2.01
Social	8.19	7.51	9.76
School	10.37	8.82	13.92
Medical	5.1	3.94	7.75
Religious	0.92	1	0.72
Home	42.57	39.49	49.64
Legal	1	1.25	0.43
Fare change (PKR)	−7.26 (104.51)[a]	5.72 (99.96)[b]	−31.33 (108.94)[c]
Regularity (%)			
Daily	47.8	47.8	49.93
Weekly	22.1	24.85	15.78
Monthly	23.87	22.4	27.26
First	6.23	5.88	7.03
Origin (%)			
Work	20.13	22.97	13.63
Shopping	1.05	1.25	0.57
Recreational	1.53	1.81	0.86
Social	7.15	7.51	6.31
School	14.25	11.45	20.66
Medical	2.57	1.63	4.73
Religious	1.96	2.38	1
Home	50.02	49.19	51.94
Legal	1.35	1.81	0.29
Past mode (%)			
Bus/van	37.6	38.92	34.58
Rickshaw/chingchi	15.73	14.01	19.65
Car	4.44	4.94	3.3
Motorcycle	9.72	11.39	5.88
Bicycle	0.31	0.38	0.14
Walk	0.7	0.81	0.43
None	31.5	29.54	36.01
Stops	12.30 (5.94)	12.25 (5.97)	12.44 (5.88)
Time change (min)	−22.75 (50.03)[d]	−20.67 (52.15)[e]	−27.92 (43.96)[f]

[a] n = 274.
[b] n = 178.
[c] n = 96.
[d] n = 1227.
[e] n = 875.
[f] n = 352.

Table 3
Data dictionary for commuters (n = 8729) from household survey.

Variable	Description
Commute	
Days	Number of days per week commuter works.
Fare	Fare for one-way commute in PKR.
Hours	Number of hours per day commuter works (excludes commute time).
Motorcycle	If household owns motorcycle then 1, otherwise 0.
Present mode	Mode for one-way commute.
Time	One-way commute time in minutes.
Demographic	
Age	Age of commuter in years.
Sex	Gender of commuter.
Economic	
Wage	Monthly, personal income of commuter in PKR.

the second explanation, a statistically significant difference in wages ($t = -13.92$, p-value < 0.0001) is evident between households who do not own a motorcycle ($\overline{X} = 13.06$, s = 14.92, n = 2534) versus households who own a motorcycle ($\overline{X} = 20.43$, s = 34.56, n = 6195) in the commuter survey (n = 8729).

The survey of MBS commuters by Naseem (2015) provides some context on the representativeness of the rider survey by LUM and the commuter survey by Gallup Pakistan. Most users are indeed male (68% in the Naseem survey versus 69.63% in the rider survey by LUMS and 92.52% in the commuter survey by Gallup Pakistan). And, most use the MBS on a daily basis (61% in the Naseem survey versus 47.80% in the rider survey by LUMS). The incomes of users coincide—47% of MBS commuters in the Naseem survey are low income (10,000 PKR to 20,000 PKR) and the mean monthly wage of commuters in the survey by Gallup Pakistan is 18,290 PKR. Finally, most commuters in Naseem pay less for transportation by using MBS (74%) and the mean fare change in the rider survey by LUMS is negative (−7.26 PKR).

6. Results

6.1. Riders

Odds ratios for the demographic, economic and trip independent variables in the rider model appear in Table 5.[6] To reiterate, the dependent variable is sex and, as noted in the table, the odds ratios are for female riders. The demographic independent variable (age) is not statistically significant.[7] However, the economic independent variable (work) is statistically significant—female riders are 77.8% less likely to work outside the home than male riders—consistent with labor force participation rate gender differences countrywide. In addition, four of the six trip independent variables (accompaniment, destination, origin and regularity) are statistically significant, but two of the six independent variables (past mode and stops) are not statistically significant. Female riders are 61.5% less likely to travel alone than male riders. Surprisingly, female riders are 1.765 times more likely to use the MBS on a daily basis than male riders. Finally, female riders are 2.264 times more likely to be coming from home than male riders and female riders are 2.664 times more likely to be going home than male riders perhaps because female riders make more round trips from and to home by MBS than male riders.

Odds ratios for the change independent variables for fare and for

[6] The R^2 statistic is the coefficient of discrimination. Tjur (2009) argues that the coefficient of discrimination is a more intuitive summary measure of explanatory power than the coefficient of determination (Cox and Snell, 1989; Nagelkarke, 1991) because it measures “the model’s ability to discriminate between successes and failures” (p. 369).

[7] The threshold for statistical significance in the study is the 90% confidence level.

Table 4
Descriptive statistics for total commuters (n = 8729), male commuters (n = 8076) and female commuters (n = 653) from household survey.

Variable	Total	Male	Female
	Mean (SD)	Mean (SD)	Mean (SD)
Commute			
Days	6.12 (0.63)	6.13 (0.64)	5.99 (0.58)
Fare (PKR)	7.26 (22.24)	6.67 (20.71)	14.46 (35.34)
Hours	9.38 (2.38)	9.54 (2.32)	7.39 (2.24)
Motorcycle (%)			
Yes	70.97	71.64	62.63
No	29.03	28.36	37.37
Present mode (%)			
MBS/bus/van	4.83	4.6	7.65
Rickshaw/chingchi	16.56	15.74	26.8
Car	2.69	2.59	3.98
Motorcycle	41.91	44.01	15.93
Bicycle	5.34	5.75	0.31
Walk	27.51	26.15	44.26
Other	1.17	1.18	1.07
Time (min)	24.12 (19.44)	24.3 (19.42)	21.89 (19.61)
Demographic			
Age			
15 to 24	23.64	22.66	35.68
25 to 34	31.2	31.46	28.03
35 to 44	22.1	22.27	19.91
45 to 54	15.58	15.86	12.1
55 to 64	6.15	6.34	3.83
65 to 74	1.34	1.41	0.46
Sex (%)			
Male	92.52	100	0
Female	7.48	0	100
Economic			
Wage (per 1000 PKR)	18.29 (30.39)	18.71 (31.26)	13.07 (15.22)

MBS = Metro Bus System.

Table 5
Odds ratios from rider model (n = 2295).

Variable	Odds ratio	*p*-value
Demographic		
Age	1.007	0.1165
Economic		
Work		
Work outside home	0.222	< 0.0001
Trip		
Accompaniment		
Alone	0.385	< 0.0001
Destination		
Home	2.664	< 0.0001
Regularity		
Daily	1.765	< 0.0001
Origin		
Home	2.264	< 0.0001
Past mode		
Bus/van	0.949	0.6302
Stops	1.009	0.3271

Odds ratios are for female riders.
R^2 = 0.166.

time in the rider model appear in Table 6. To reiterate, the dependent variable is sex and, as noted in the table, the odds ratios are for female riders. The sample size in the rider model with the change independent variables for fare and for time is dramatically lower than the sample size in the rider model without the change independent variables for fare and for time (260 versus 2295) because of missing data. No systematic pattern is evident in the missing data so bias is not an issue.

The demographic independent variable (age) is statistically significant—females are 2.9% more likely than males to ride MBS as age increases by one unit. Consistent with the results from the rider model without the change independent variables for fare and for time, the economic independent variable (work) is statistically significant—female riders are 88.4% less likely to work outside the home than male riders. Four of the eight trip independent variables (accompaniment, destination, fare change and regularity) are statistically significant, but four of the eight independent variables (origin, past mode, stops and time change) are not statistically significant. Female riders are 58.5% less likely to travel alone (without children, without other women or without men), 3.466 times more likely to be going home, 0.4% less likely to ride MBS as change in fare increases by one unit and 1.986 times more likely to use the MBS on a daily basis than male riders.

Table 6
Odds ratios from rider model with change independent variables for fare and for time (n = 260).

Variable	Odds ratio	*p*-value
Demographic		
Age	1.029	0.0288
Economic		
Work		
Work outside home	0.116	< 0.0001
Trip		
Accompaniment		
Alone	0.415	0.0118
Destination		
Home	3.466	0.0043
Fare change (PKR)	0.996	0.0442
Regularity		
Daily	1.986	0.0645
Origin		
Home	1.577	0.3036
Past mode		
Bus/van	0.899	0.7821
Stops	0.98	0.4774
Time change (min)	0.998	0.3983

Odds ratios are for female riders.
R^2 = 0.284.

6.2. Commuters

Odds ratios for the commute, demographic and economic independent variables in the commuter model with sex as the dependent variable appear in Table 7. To reiterate, the dependent variable is sex and, as noted in the table, the odds ratios are for female commuters. Five of the six commute independent variables (fare, hours, motorcycle, present mode and time) are statistically significant, but one of the six commute independent variables (days) is not statistically significant.

Table 7
Odds ratios from commuter model with sex as dependent variable (n = 8729).

Variable	Odds ratio	*p*-value
Commute		
Days	0.961	0.5259
Fare (PKR)	1.012	< 0.0001
Hours	0.62	< 0.0001
Motorcycle		
Yes	0.812	0.0279
Present mode		
MBS/bus/van	1.416	0.0624
Time (min)	0.988	< 0.0001
Demographic		
Age		
15 to 34	1.487	< 0.0001
Economic		
Wage (per 1000 PKR)	0.97	< 0.0001

Odds ratios are for female commuters.
R^2 = 0.125.

Table 8
Odds ratios from commuter model with present mode as dependent variable (n = 8729).

Variable	Odds ratio	*p*-value
Commute		
Days	0.975	0.775
Fare (PKR)	1.04	< 0.0001
Hours	0.963	0.1449
Motorcycle		
Yes	0.645	0.0002
Time (min)	1.026	< 0.0001
Demographic		
Age		
15 to 34	0.875	0.2446
Sex		
Female	1.031	0.8804
Economic		
Wage (per 1000 PKR)	1	0.819

Odds ratios are for MBS/bus/van commuters.
R^2 = 0.198.

Commuters are 1.2% more likely to be female as fare increases by one unit. Commuters are 38% less likely to be female as hours increase by one unit. Females are 41.6% more likely to commute via MBS/bus/van. If their household owns a motorcycle then females are 18.8% less likely to commute via MBS/bus/van. Finally, females are 1.2% less likely to commute via MBS/bus/van as the one-way commute time increases by one unit. The demographic independent variable (age) is statistically significant—commuters are 48.7% more likely to be female as age increases by one unit. The economic independent variable (wage) is also statistically significant—commuters are 3.0% less likely to be female as wage increases by one unit.

Odds ratios for the commute, demographic and economic independent variables in the commuter model with present mode as the dependent variable appear in Table 8. To reiterate, the dependent variable is present mode and, as noted in the table, the odds ratios are for MBS/bus/van commuters. Three of the five commute independent variables (fare, motorcycle and time) are statistically significant, but two of the five commute independent variables (days and hours) are not statistically significant. Commuters are 4.0% more likely to commute via MBS/bus/van as fare increases by one unit. If their household owns a motorcycle then commuters are 35.5% less likely to commute via MBS/bus/van. Finally, commuters are 2.6% more likely to commute via MBS/bus/van as the one-way commute time increases by one unit.

6.3. Discussion

Results from the rider models help to understand who benefits from the MBS. Female riders are less likely to work outside the home, less likely to travel alone and more likely to be daily users. The first result suggests that women who reside in the MBS service area use it for trips other than work. The second and third results suggest that women who reside in the MBS service area travel on a daily basis with children, with men and with other women perhaps to mitigate safety/security problems. To that end, 34% of respondents to a national survey of Pakistani women (n = 857) assert that “someone always accompanies me while traveling” (Gallup Pakistan, 2017, p. 2) on public transportation because of the fear of harassment. And, interviewees in another Pakistani study area “feel insecure while traveling” but “when they travel in groups then the feeling of insecurity disappears” (URC, 2015, p. 33). Higher fares, at least to a slight degree, more adversely affect female ridership in the MBS service area which suggests that female ridership is somewhat conditional on the fare subsidy. Likewise, a decrease in the fare subsidy will more adversely affect female ridership in the MBS service area since female riders are less likely to travel alone.

Results from the commuter models provide context for the results from the rider models to help understand how commuters benefit from the MBS. Consistent with the literature (Naseem, 2015), the majority of MBS users were bus/van riders before the commencement of operations in February of 2013. Interestingly, commuters who are female incur higher fares perhaps because conductors are unable or unwilling to return change for inexact fares (URC, 2015). Further, commuters who work more hours on a daily basis are less likely to be female. However, commuters who travel to work via MBS/bus/van are more likely to be female. Also, private-vehicle (motorcycle) ownership at the household level lowers MBS usage for females. In addition, longer commute times decrease female usage, commuters are more likely to be female as age increases and higher monthly, personal wages slightly lowers usage for females. Fares and times are slightly higher and slightly longer, respectively, for MBS/bus/van commuters suggestive of relatively higher commuter costs in terms of money and of time. Finally, private vehicles are normal goods whose consumption increases with income so motorcycle ownership lowers reliance on public vehicles (MBS/bus/van) for commutes (Poushter, 2015).

The implications of the results are as follows. Overall, usage of the MBS is dependent on access to resources; if users can afford a private vehicle, for example, then usage is less likely. To that end, relaxation of the fare subsidy by the Government of the Punjab as well as the acquisition of private vehicles by households are likely to lower ridership amongst the groups BRT systems purport to benefit, particularly women who are, in general, more likely to commute via bus. Economic benefits in terms of more work hours, that is, MBS commuters work more hours (Naseem, 2015), are not evident, rather females who work longer hours are less likely to commute via the MBS. However, differences in ridership patterns by gender are evident as in another Pakistani study area (Adeel et al., 2016). Such differences probably result from the overcrowding on the MBS found by Ali and Rathore (2015) though more research is necessary. Further, females incur higher fares and so are more vulnerable to fare increases on the MBS because integration between the MBS corridor and the greater public transportation network in Lahore in terms of transfers and fares is not yet seamless. Finally, the hint of differences in the effect of age on usage provides empirical evidence to show other groups benefit from the MBS.

7. Conclusions

The contributions of the results to the international literature on the BRT concept are attributable to the sampling frames of the data in the study. The use of disaggregate data on riders from inside the MBS service area helps to understand who benefits from the MBS. The use of disaggregate data on commuters from inside and from outside the MBS service area helps to understand how commuters benefit from the MBS. The decision to contextualize the results from the rider models with results from the commuter models highlights the major contribution of the study, that is, MBS usage patterns differ dramatically by gender where women are the major beneficiary.

In light of the contributions of the results, the limitations of the study are important to acknowledge. The international literature on the BRT concept equates usage with benefits both economic and social. But usage of the MBS is not necessarily beneficial to the user. And, as the results show, whatever benefits accrue to users, the economic costs of usage are real. For example, women are more likely than men to be users, but, at the same time, women incur higher fares. Further, generalization of the usage patterns from the results to estimate who benefits the most from the MBS is not possible because of the designs and the frames of the samples. Likewise, the data sources provide no information on the absolute locations of origins and destinations necessary to map the activity patterns of MBS users or the times of departure/arrival for different trips. The absence of spatial/temporal information on the trips of riders and/or commuters precludes any assessment of how use of the MBS affects accessibility and/or mobility in the inner core of Lahore.

The most fruitful direction for future research is to study how the MBS affects mode choices by gender. To that end, specification of a statistical model with data from the household survey on individuals and their households with a method such as a nested logit is necessary. A more elaborate method such as a nested logit is necessary because of the nesting, or the nonindependence, of mode choices evident in Lahore, that is, most MBS users are legacy bus users so not all modes are equally likely to be chosen after the introduction of, what is after all, a new bus service. Such an approach will test the robustness of the results from the present study with regard to the benefits of the MBS for women. Finally, such an approach will provide a realistically complex model of mode choices by gender as well as a more accurate estimate of the magnitude of the benefits for women.

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