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Effect of Urban Land Use on Travel Behaviour: Evidence from Lahore

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In urban areas across Asia and Africa, public investments in road infrastructure subsidise suburban sprawl and privilege car ownership. At the same time, restrictive land use ordinances prevent mixed-use land development, so distances between home and work increase; an outcome particularly burdensome in time and money for marginal groups. To analyse the effects of public investments in road infrastructure on commute times for different modes, the study uses a rare household travel survey from Lahore. A novel multilevel methodology nests individual-level commute times for different modes within a zone level of analysis which controls for differences in urban land use and road infrastructure. Results suggest that individuals who drive to work enjoy significant time benefits over those who walk to work. The policy implications focus attention on the need for infrastructure investments to mitigate the time costs for commuters who walk and who ride the bus.

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1. INTRODUCTION

The worldwide increase in urban population creates challenges for sustainability. In developing countries, urban areas tend to be centers of economic growth where productivity is high. Chief amongst the factors of production necessary to sustain such growth is infrastructure, particularly transportation. Urban transportation systems facilitate human interaction and form the backbone of a regional economy (Duranton and Turner, 2012). However, a negative externality of new infrastructure, particularly roads, is congestion. Naturally, therefore, public investments in infrastructure for different modes of travel besides private vehicles like cars are necessary to simultaneously maximise the benefits of agglomeration and minimise congestion costs (World Bank, 2009).

Unfortunately, the sustainable transportation literature is devoid of empirical evidence on how road infrastructure investments affect travel behaviour in the context of rapid urbanisation in developing countries to help inform future infrastructure decisions. Given the void in the literature, the study uses a household travel survey as a primary data source on travel behaviour to analyse how road infrastructure and urban land use affect commute times in a developing country. Specifically, the study attempts to answer

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the following questions. What key individual-level factors and/or zone-level factors affect commute times the most? What are the commute time benefits of investments in road infrastructure for individuals who have a car available for the work trip versus individuals who walk to work? The multilevel methodology in the study is ideal for analyzing how investment in road infrastructure and development of urban land use at the zone level affect commuting outcomes at the individual-level; the appropriate level of analysis to analyse travel behaviour.

The outline for the study is as follows. Section 2 reviews the literature to provide context for urban land use, and road infrastructure growth in developing countries. Section 3 describes the study area. Section 4 describes the multilevel methodology and the household travel survey data as well as specification of the multilevel model and hypotheses on the effects of the independent variables. Section 5 presents the key results from the multilevel model. Section 6 highlights the contribution of the multilevel model results to the sustainable transportation literature. Section 7 offers specific policy recommendations as well as future research topics to promote sustainable transportation in developing countries.

2. REVIEW OF THE LITERATURE

The urban economic theory emphasises the linkages between land values and transportation costs in labour markets (Alonso, 1964; Mills, 1964; Muth, 1969). The bid-rent framework, specifically, shows that households balance location rents, transport costs, and commute times in their residential location decision. At the same time, most urban areas around the world are not monocentric in form and function, as urban economic theory suggests, but rather polycentric (Clark, 2000). And, much of the growth in urban areas is not planned, particularly in developing countries. It is the unplanned nature of such growth which makes accessibility between home and work locations problematic (Diaz Olvera, et al. 2008). The relative inaccessibility between home and work locations affects not only the economic outcomes of households but also the regional economy, given that empirical and theoretical research suggests that accessible and affordable transportation services can significantly augment productivity (Baldwin et al., 2010; Lucas and Rossi-Hansberg, 2002). Accessible and affordable transportation services enhance productivity because workers can travel greater distances for higher wages which culminate in greater worker-firm matching and thicker labour markets (Moretti, 2012; Storper, 2013). Likewise, the absence of infrastructure severely undermines the productive spatial sorting of firms and of workers to relocate so as to mitigate the negative externality of congestion costs which culminate from rapid growth (Gwilliam, 2002; Imran, 2010).

Across Asia and Africa, changes in the form and the function of urban areas pose new governance challenges for the delivery of public services such as transportation. In many developing countries, local governments lack the fiscal capacity to deliver, monitor, and regulate the most basic of public services (Bahl, 1999). Further, urbanisation is not uniform in the developing world. In Eastern Asia, urbanisation was primarily driven by a concentration of low-skilled manufacturing work not evident elsewhere (Crescenzi, et al. 2012). In sub-Saharan Africa, greater worker productivity and higher governance standards did not accompany large-scale urbanisation as was common elsewhere (Henderson, et al. 2013). Regardless of the nonuniformity in urbanisation, transportation services are the backbone of a regional economy to drive human interaction as well as foster economic productivity (Jacobs, 1961).

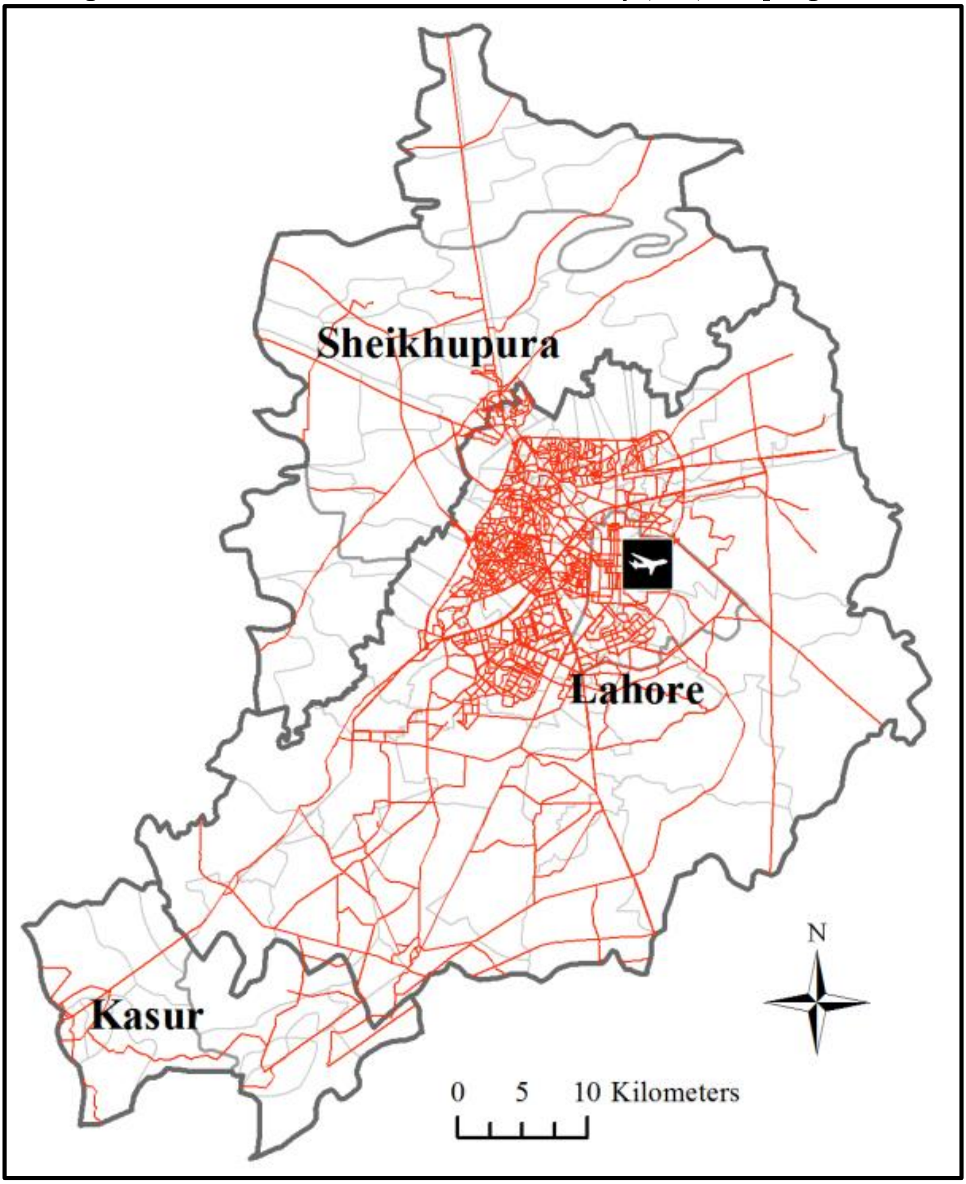
Most conceptual contributions to the urban economics literature rely on empirical research (often panel analyses) in developed countries with standards for economic data collection. Unfortunately, most economic outcomes are context-sensitive, particularly given the nonuniformity in urbanisation in the developing world (Angel, 2012). In addition, the lack of disaggregated data from developing countries hinders intellectual progress in the literature (Glaeser, 2013). The inability to empirically validate economic theory on urbanisation in the developing world means that scholars must often compromise to research the urban contexts of developing countries. Progress in crowdsourced (Crooks, 2012) and remote sensing (night lights) (Henderson, et al. 2013) data collection are innovative, but such sources are not substitutes for primary data sources such as surveys and censuses. The study is, therefore, unique to the transportation sustainability literature in the use of a household travel survey from a rapid-growth city (Lahore) in a developing country (Pakistan). Notwithstanding the intellectual context of the study, the next section introduces the multilevel methodology and the household travel survey data.

3. STUDY AREA

Lahore is the second-most populous city in Pakistan (Pakistan Bureau of Statistics, 2018) as well as the capital of the Punjab (Fig. 1). Population growth in Lahore was the highest in Pakistan between 1998 and 2017 (+116.32 percent) to the extent that it is now a megacity with a population of more than ten million (United Nations, 2015). Amongst the three distinct land use zones in Lahore with regard to population density and to built environment (Lahore Development Authority, 2004), most of the growth has a peripheral orientation. Activity still has a core orientation, but the dispersion of population creates a deficit in the supply of transportation infrastructure to satisfy present and future demand (Malik, 2013).

Developing countries, like Pakistan, invest in transportation infrastructure in order to balance the costs and the benefits of rapid growth (Azulai, et al. 2014). To that end, Punjab invests in bus rapid transit (BRT) infrastructure, also known as the surface subway (Worcman, 1995). In Lahore, a 27-kilometer BRT line now serves 27 stations (Punjab Metrobus Authority, 2018). The Lahore Urban Transport Master Plan (LUTMP) recommends a total of seven BRT corridors. Such investments represent a new approach to infrastructure where most of the money in the old approach was for roads, expressways, and flyovers which change the form and the function of the land market and the labour market (Haque, 2014). In addition, the old approach favours private modes of travel like cars over public modes of travel like buses which ultimately leads to more, not less, congestion. Indeed, the number of motor vehicles per 1,000 population rose from 95 to 238 from 2001 to 2008 in Lahore (Punjab Metrobus Authority, 2018), while pedestrian infrastructure like sidewalks is not available to the majority of commuters who walk.

Fig. 1. Districts in the Household Interview Survey (HIS) Sampling Frame



The following section introduces the multivariate methodology and the travel behaviour data.

4. METHODOLOGY AND DATA

4.1. Random-Coefficient Model

The commute time multilevel model is a two-level model of individuals (i) nested within zones (z) (Raudenbush and Bryk, 2002). Within each zone, commute time is modeled as a function of individual-level independent variables plus an individual-level error term as in Equation 1:

$$Y_{iz} = \beta_{0z} + \beta_{1z}X_{1iz} + \beta_{2z}X_{2iz} + \cdots + \beta_{Pz}\beta X_{Piz} + r_{iz} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where

Y_{iz} is the commute time for individual i in zone z;
β_{0z} is the y-intercept term for zone z;
β_{pz} are individual-level coefficients (p = 1, 2, … P);
X_{piz} is the individual-level independent variable p for individual i in zone z; and
r_{iz} is the individual-level random effect term.

The y-intercept and some of the regression coefficients at the individual-level are random. A multilevel model in which the y-intercept and at least one of the regression coefficients are random is known as a random-coefficients model. The model of variation between zones is as follows. For the zone effect β_{0z} in Equation 2:

$$\beta_{0z} = \gamma_{00} + \gamma_{01}W_{1z} + \gamma_{02}W_{2z} + \cdots + \gamma_{0Q}W_{Qz} + u_{0z} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where

γ_{00} is the constant portion of the random y-intercept term for zone z;
γ_{0q} are zone-level coefficients (q = 1, 2, … Q);
W_{qz} are zone-level independent variables; and
u_{0z} is a zone-level random effect term.

The following subsection discusses the multilevel model's data sources and the hypothesised effects of the individual-level and the zone-level independent variables.

4.2. Data

Data are from a Household Interview Survey (HIS) under the auspices of the Transport Department at the Government of the Punjab in Pakistan. The purpose of the HIS is to collect data on travel behaviour for the LUTMP (Japan International Cooperation Agency, 2012). The time frame for the survey is from October to December 2010. The sampling frame for the survey is the istrict of Lahore, the District of Sheikupura and the District of Kasur (Fig. 1). The sample is a geographically-stratified random sample of zones (n = 228) in Lahore. The total number of households in the sample is 18,054: 15,734 from Lahore; 1,639 from Sheikupura; and 681 from Kasur. The selection criterion for the HIS subsample is as follows: working-age individuals who commute to work. Application of the selection criterion and the exclusion of individuals and zones with missing data left a subsample of 11,649 individuals nested within 205 zones from the HIS.

Data at the individual-level (n = 11,649) include information on the characteristics of individuals and the individual's household (Table 1). The dependent variable is the commute time in minutes for a one-way work-trip. The independent variables at the individual-level control for demographic and economic characteristics that are known to affect commute times. Information on the characteristics of individuals includes age in years; sex; car availability; one-way, work-trip cost in PKR (1 PKR = 0.0082 USD); and commute mode. Information on the characteristics of the individual's household includes:

household size; total monthly household income in PKR; and average monthly household transportation expenditures in PKR.

Data at the zone level (n = 205) include information on the characteristics of zones (Table 1). The independent variables at the zone level control for demographic, economic, infrastructure, land use, and locational characteristics that are known to affect commute times. Information on the demographic characteristics of zones includes population density per square kilometer in 2011. Information on the economic characteristics of zones includes the car ownership rate per 1,000 total population. The car ownership rate is a proxy for the aggregate supply of private vehicles. Information on the land use characteristics of zones includes the percent urban in 2009 (Riaz, et al. 2014). Information on the infrastructure and the locational characteristics of zones includes: the percent kilometers of roads versus total kilometers of roads; and linear distance in kilometers from each zone centroid to the mean center of all zone centroids. Road infrastructure is a proxy for the supply of transportation infrastructure, and distance to the mean center is a proxy for proximity to the geographic center of Lahore.

Table 1

Data Dictionary for Individuals and Zones

Level (n)			Variable	
Individual (n = 11,649)				
	Dependent			
			Commute time	Commute time in minutes.
	Independent			
		Demographic		
			Age	Age of commuter in years.
			Household size	Size of household.
			Sex	Gender of commuter.
		Economic		
			Car	If car is available for use then 1, otherwise 0.
			Income	Total, monthly household income in PKR.
			Transportation expenditures	Average, monthly household expenditures on transportation in PKR (10,000).
		Trip		
			Cost	Work trip cost in PKR.
			Mode	Work trip mode.
Zone (n = 205)				
	Independent			
		Demographic		
			Population density	Total population (1,000) per square kilometer in 2011.
		Economic		
			Car ownership rate	Car ownership per total population (1,000).
		Infrastructure		
			Roads	Zonal kilometers of roads versus total kilometers of roads in 2011.
		Land use		
			Urban	Percent urban in 2009.
		Location		
			Distance to mean center	Linear distance in kilometers from centroid to mean center.

Note: PKR = Pakistani rupees. 1 PKR = 0.0082 USD.

The following subsection discusses the multilevel model's data sources and the hypothesised effects of the individual-level and the zone-level independent variables. Descriptive statistics for the individual and zone-level independent variables are in Table 2.

Table 2

Descriptive Statistics for Individuals and Zones

Level (n)		Variable		Mean	SD
Individual (n = 11,649)					
	Dependent				
		Commute time (min)		45.75	41.41
	Independent				
	Demographic				
		Age (%)			
			15 and younger	1.35	
			16 to 24	12.16	
			25 to 34	25.48	
			35 to 44	25.86	
			45 to 54	22.97	
			55 to 64	9.68	
			65 and older	2.50	
		Household size		5.15	1.98
		Sex (%)			
			Male	95.52	
			Female	4.48	
	Economic				
		Car (%)			
			No	84.38	
			Yes	15.62	
		Income (%)			
			10,000 PKR or less	19.94	
			10,001 PKR to 20,000 PKR	35.02	
			20,001 PKR to 30,000 PKR	20.98	
			30,001 PKR to 40,000 PKR	9.27	
			40,001 PKR to 50,000 PKR	5.73	
			More than 50,000 PKR	9.07	
		Transportation expenditures (10,000 PKR)		0.28	0.34
	Trip				
		Cost (PKR)		26.88	43.77
		Mode (%)			
			Walk	36.62	
			Bicycle	8.65	
			Motorcycle	33.85	
			Car	10.58	
			Van	1.87	
			Public bus	1.98	
			Rickshaw	4.46	
			Taxi	0.05	
			Private bus	1.09	
			Truck	0.08	
			Train	0.01	
			Other	0.76	
Zone (n = 205)					
	Independent				
	Demographic				
		Population density (1,000/km^2)		30.01	38.67
	Economic				
		Car ownership rate (/1,000)		46.29	77.11
	Infrastructure				
		Roads (%)		0.43	0.40
	Land use				
		Urban (%)		47.91	28.61
	Location				
		Distance to mean center (km)		13.74	11.04

Note: PKR = Pakistani rupees. 1 PKR = 0.0082 USD.

4.3. Hypothesised Effects of Individual-Level Independent Variables

At the individual-level, commute times will increase from younger-age cohorts to middle-age cohorts and will decrease from middle-age cohorts to older-age cohorts, consistent with the life-cycle effect on car ownership: "car ownership increases with the age of the household head up to about the age of 50, and thereafter decreases" (Dargay and Vythoulkas, 1999, p. 290). Household size is a proxy for the number of workers per household, which will be synonymous with longer commute times (Cervero and Kockelman, 1997). The empirical evidence (Peck, 1996; Wyly, 1998) suggests that commute times are longer for men than for women even though women are more reliant on slower modes (walk, bicycle or public bus) than men (Stead, 2001). If a car is available, commute times will be shorter since motorised modes are faster than non-motorised modes. The empirical evidence from developed countries suggests that commute times increase with household income (Izraeli and McCarthy, 1985; Schwanen, et al. 2004; Shen, 2000). However, the income effect and, by default, the transportation expenditures effect will differ for the subsample for two reasons. First, most individuals walk to work. Second, the HIS question on monthly transportation expenditures asks for variable costs (gasoline, parking, and public transportation use), not for fixed costs (purchase, registration, and insurance) which do exist for private modes but do not exist for public modes (Litman, 2009). Commute times will increase with higher work-trip costs. Commute times for different modes will depend on whether or not the mode is motorised and whether the mode is private (Dieleman, et al. 2002; Schwanen, 2002). For example, commute times for non-motorised modes such as bicycles will be longer than commute times for motorised modes such as motorcycles, and commute times for private vehicles like cars will be the shortest.

4.4. Hypothesized Effects of Zone-Level Independent Variables

The empirical evidence suggests that commute times shorten as population density increases because commute distances shorten as population density increases (Dieleman, et al. 2002; Schwanen, 2002; Van Acker, et al. 2007). However, given that most individuals in the subsample walk to work (36.62 percent), commute times will lengthen as population density increases at the zone-level. Commute times will be shorter in zones where car ownership rates are higher since motorised modes are faster, even with congestion than non-motorised modes. More road infrastructure and urban land use will be synonymous with shorter commute times because more route choices will decrease commute times for individuals. Again, given that most individuals in the subsample walk to work, the relationship between commute times and distance to the mean center will be negative; the shorter the distance, the longer the commute times.

5. RESULTS

5.1. Individuals

Table 3 lists the coefficient estimates for individuals from the random-coefficients model of individuals nested within zones. Most of the results at the individual-level are consistent with expectations.

Table 3

Coefficient Estimates for Individuals (n = 11,649) from Random-Coefficients Model of Individuals Nested within Zones

	Variable			Coefficient	SE
Demographic					
	Age (%)				
		15 and younger		−6.03***	3.13
		16 to 24		−1.73	1.23
		25 to 34		+0.18	0.99
		35 to 44		Referent	Referent
		45 to 54		−0.37	1.01
		55 to 64		+0.37	1.33
		65 and older		−1.22	2.34
	Household size			+0.44**	0.19
	Sex (%)				
		Male		Referent	Referent
		Female		−0.32	1.72
Economic					
	Car (%)				
		No		Referent	Referent
		Yes			
			Intercept	−5.97*	1.61
			Population density (1,000/km^2)	−0.14**	0.06
			Car ownership rate (/1,000)	+0.09*	0.03
			Roads (%)	+5.70	4.42
			Urban (%)	+0.36*	0.10
			Distance to mean center (km)	+0.03	0.15
	Income (%)				
		10,000 PKR or less		+1.56	1.02
		10,001 PKR to 20,000 PKR		Referent	Referent
		20,001 PKR to 30,000 PKR		−1.86**	1.00
		30,001 PKR to 40,000 PKR		−1.70	1.37
		40,001 PKR to 50,000 PKR		−3.90**	1.71
		More than 50,000 PKR		−6.57*	1.69
	Transportation expenditures (10,000 PKR)				
			Intercept	+8.58*	1.33
			Population density (1,000/km^2)	+0.03	0.04
			Car ownership rate (/1,000)	−0.03*	0.01
			Roads (%)	−0.96	3.82
			Urban (%)	+0.005	0.08
			Distance to mean center (km)	−0.20***	0.11
Trip					
	Cost (10,000 PKR)				
			Intercept	+0.37*	0.01
			Population density (1,000/km^2)	+0.004*	0.001
			Car ownership rate (/1,000)	−0.0005*	0.0001
			Roads (%)	−0.08*	0.03
			Urban (%)	−0.01*	0.001
			Distance to mean center (km)	+0.01*	1.23
	Mode (%)				
		Walk		Referent	Referent
		Bicycle		+9.00*	1.34
		Motorcycle		−9.25*	0.93
		Car			
			Intercept	−16.47*	2.11
			Population density (1,000/km^2)	−0.19**	0.08
			Car ownership rate (/1,000)	+0.01	0.02
			Roads (%)	+5.80	4.79
			Urban (%)	+0.36*	0.13
			Distance to mean center (km)	−0.09	0.20
		Van		+12.22*	2.67
		Public bus		+20.82*	2.58
		Rickshaw		−3.42***	1.79
		Taxi		−6.96	15.60
		Private bus		+21.17*	3.43
		Truck		−56.24*	12.76
		Train		−11.34	37.84
		Other		+0.76	4.09

Note: * = *p*-value < 0.01, ** = *p*-value < 0.05, and *** = *p*-value < 0.10. PKR = Pakistani rupees. 1 PKR = 0.0082 USD.

Consistent with expectations, commute times are shortest for the youngest age cohort. Commute times are slightly more than six minutes shorter for individuals in the 15-and-younger age cohort than for individuals in the 35-to-44 age cohort who are more likely to own a car. Larger household sizes are synonymous with longer commute times; a one standard deviation increase in household size (1.98) increases commute times by slightly less than one minute. Consistent with expectations, if a car is available, then commute times are shorter; commute times are slightly less than six minutes shorter for individuals who have a car available for the work trip. After controlling for car availability at the individual-level, commute times are much longer in zones where car ownership rates are higher and where land use is more urban suggestive of a congestion-inducing effect from high car ownership rates and more urban land use. Looking at variation in the car availability effect, a one standard deviation increase in car ownership rate (77.11) at the zone-level increases commute times by slightly less than seven minutes, and a one standard deviation increase in urban land use (28.61) at the zone-level increases commute times by slightly more than ten minutes. Consistent with expectations, the income effect is negative and the transportation expenditures effect is positive. Commute times are more than six minutes shorter for individuals in the more-than-50,000 PKR income cohort than for individuals in the 10,000 PKR-to-20,000 PKR income cohort, and a one standard deviation increase in transportation expenditures (3,400 PKR) increases commute times by slightly less than three minutes. After controlling for transportation expenditures at the individual-level, commute times are shorter in zones where car ownership rates are higher and where the distance to the mean center is greater. Looking at variation in the transportation expenditures effect, a one standard deviation increase in car ownership rate (77.11) at the zone-level decreases commute times by slightly more than two minutes and a one standard deviation increase in distance to the mean center (11.04 kilometers) at the zone-level decreases commute times by slightly more than two minutes. Higher work-trip costs are indeed synonymous with longer commutes; a one standard deviation increase in work-trip costs (43.77 PKR) increases commute times by slightly more than 16 minutes. After controlling for work-trip costs at the individual-level, commute times are slightly shorter in zones where land use is more urban suggestive of the time-saving effect of more mode choices. Looking at variation in the work-trip cost effect, a one standard deviation increase in urban land use (28.61 percent) at the zone-level decreases commute times by less than one-half minute. Commute times are indeed much longer for non-motorised (bicycle) modes versus motorised (motorcycle) modes. Commute times for bicycles are nine minutes longer than commute times for walking, and commute times for motorcycles are slightly more than nine minutes shorter than commute times for walking. Commute times for cars are indeed the shortest; commute times for cars are more than 16 minutes shorter than commute times for walking. After controlling for car mode at the individual-level, commute times are much longer in zones where land use is more urban suggestive, again, of a congestion-inducing effect from more urban land use. Looking at variation in the car mode effect, a one standard deviation increase in urban land use (28.61 percent) at the zone-level increases commute times by more than ten minutes.

5.2. Zones

Table 4 lists the coefficient estimates for zones from the random-coefficients model of individuals nested within zones. Most of the results at the zone-level are consistent with expectations.

Table 4

Coefficient Estimates for Zones (n = 205) from Random-Coefficients Model of Individuals Nested within Zones

	Variable	Coefficient	SE
	Intercept	+51.39*	1.09
Demographic			
	Population density (1,000/km^2)	+0.10*	0.02
Economic			
	Car ownership rate (/1,000)	−0.06*	0.01
Infrastructure			
	Roads (%)	−2.10	1.87
Land use			
	Urban (%)	−0.29*	0.04
Location			
	Distance to mean center (km)	−0.18*	0.05

Note: * = *p*-value < 0.01, ** = *p*-value < 0.05, and *** = *p*-value < 0.10.

Commute times are longer in zones where population density is higher; a one standard deviation increase in population density (38.67) at the zone-level increases commute times by slightly less than four minutes. Consistent with expectations, the car ownership rate effect is negative; a one standard deviation increase in the car ownership rate (77.11) at the zone-level decreases commute times by more than four minutes. More road infrastructure is synonymous with shorter commute times; a one standard deviation increase in road infrastructure (0.40) at the zone-level decreases commute times slightly less than one minute. However, the road infrastructure effect is not statistically significant. Commute times are indeed shorter in zones where land use is more urban; a one standard deviation increase in urban land use (28.61 percent) at the zone-level decreases commute times by more than eight minutes. Finally, the distance effect is negative; a one standard deviation increase in distance to the mean center (11.04 kilometers) decreases commute times by slightly less than two minutes.

6. DISCUSSION

Results from the random-coefficients model highlight how urban land use affects travel behaviour differently in developing countries versus developed countries. One example, results on the positive, not negative, population density effect at the zone-level are inconsistent with the sustainable transportation literature; higher population density is synonymous with lower private vehicle usage (Gordon and Richardson, 1989; Newman and Kenworthy, 1989). Context helps to understand such inconsistent results (Van Acker, et al. 2007). First, most study areas in the sustainable transportation literature are Northern American or Western European, not Southern Asian, where the rate of urbanisation is high (United Nations, 2015) and where urban population density is amongst the highest worldwide (Demographia, 2015). Indeed, eight of the ten highest population density cities are Southern Asian; Lahore ranks 154th in population density worldwide. Second, most commuters in the HIS subsample do not have a car available for the work trip. Indeed, motor vehicles (including cars, buses, and freight vehicles, but excluding two-wheeled vehicles) per 1,000 inhabitants are very low in Pakistan (approximately 18 per 1,000 inhabitants in 2010) in comparison to the United States (797 per 1,000 inhabitants in 2010) and other study areas in the sustainable transportation literature: (Van Acker, et al. 2007) Belgium (559 per 1,000 inhabitants in 2010); (Schwanen, et al. 2004) Netherlands (527 per 1,000 inhabitants in 2010); and (Stead, 2001) United Kingdom (519 per 1,000 inhabitants) (International Road Federation, 2015).

Another example, the road effect at the zone-level is negative; more road infrastructure is synonymous with shorter commute times. However, the road effect is not statistically significant, counter to expectations. The zone-level coefficient for road infrastructure is probably not statistically significant because the variation between zones in road infrastructure is almost equal to the average road infrastructure within zones. Indeed, the coefficient of variation in road infrastructure is approximately 93 percent. Nevertheless, the road effect and the distance effect at the zone-level—greater distance to the mean center is synonymous with shorter commute times—suggests that commuters who drive a car or ride a motorcycle to work enjoy a substantial time advantage over commuters who walk or ride a public bus to work in Lahore. Such results provide empirical justification for the argument to increase the supply of public infrastructures such as the surface subway (Worcman, 1995) or BRT known as Metrobus, which the Punjab Metrobus Authority operates. Metrobus went into operation in February of 2013, after the administration of the HIS from October to December of 2010, but estimates of the potential travel time benefits of BRT from a case study in another developing country are substantial, especially for pedestrians (Vermeiren, et al. 2015).

7. CONCLUSIONS

The implications of the results for sustainable transportation policy in Lahore are to focus on the balance of infrastructure investments for non-motorised modes like walk and bicycles versus motorised modes like motorcycles and cars. In addition, bus is not yet a viable alternative since most commuters walk. In the interest of economic productivity, greater accessibility to more employment centers is necessary, but more dense development is not likely to greatly impact commute times in Lahore.

The small percentage of women in the HIS subsample is justification for future research on the commute challenges unique to women in the Lahore labour market. Indeed, the low representation of women in the HIS subsample means the results from the multilevel model do not reflect the travel behaviour of women in Lahore. One fruitful topic for future research, therefore, is to explore the differences in accessibility to different modes for work trips between men and women in Lahore. Another fruitful topic is to identify and to measure more zone-level characteristics on the supply of public modes such as the new BRT line. The density of BRT stops, for example, is a useful proxy for the supply of such infrastructure. The analysis of the effects of zone-level measures on the supply of infrastructure for public modes is important in order to analyse how BRT benefits commuters in the Lahore labour market and to inform future investments in BRT infrastructure.

REFERENCES

Alonso, W. (1964). *Location and land use: Toward a general theory of land rent*. Harvard University Press.

Angel, S. (2012). *Planet of cities*. Lincoln Institute of Land Policy.

Azulai, M., Bandiera, O., Blum, F., Kleven, H., La Ferrara, E., Padro, G., & Tejada, C. (2014). *State effectiveness, growth, and development*. International Growth Centre.

Bahl, R. (1999). *Fiscal decentralisation as development policy*. *Public Budgeting & Finance*, (*19*)2, 59–75.

Baldwin, J., Brown, W., & Rigby, D. (2010). Agglomeration economies: Microdata panel estimates from Canadian manufacturing. *Journal of Regional Science*, (*50*)5, 915–934.

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3D's: Density, diversity and design. *Transportation Research D: Transport and Environment*, (*2*)3, 199–219.

Clark, W. (2000). Monocentric to policentric: New urban forms and old paradigms. In G. Bridge, & S. Watson (eds.) *A companion to the city* (pp. 141–155). Blackwell.

Crescenzi, R., Rodríguez-Pose, A., & Storper, M. (2012). The territorial dynamics of innovation in China and India. *Journal of Economic Geography*, (*12*)5, 1055–1085.

Crooks, A. (2012). The use of agent-based modelling for studying the social and physical environment of cities. In G. de Roo, J. Hillier, & J. Van Wezemael (eds.) *Complexity and planning systems, assemblages and simulations* (pp. 385–408). Ashgate.

Dargay, J., & Vythoulkas, P. (1999). Estimation of dynamic car ownership model: A pseudo-panel approach. *Journal of Transport Economics and Policy*, (*33*)3, 287–301.

Demographia (2015). *Demographia world urban areas: Built-up urban areas or urban agglomerations*. Demographia.

Dieleman, F., Dijst, M., & Burghouwt, G. (2002). Urban form and travel behaviour: Micro-level household attributes and residential context. *Urban Studies*, (*39*)3, 507–527.

Duranton, G., & Turner, M. (2012). Urban growth and transportation. *Review of Economic Studies*, (*79*)4, 1407–1440.

Glaeser, E. (2013). *A world of cities: The causes and consequences of urbanisation in poorer countries*. National Bureau of Economic Research.

Gordon, P., & Richardson, H. (1989). Gasoline consumption and cities: A reply. *Journal of the American Planning Association*, (*55*)3, 342–346.

Gwilliam, K. (2002). *Cities on the move: A World Bank urban transport strategy review*. World Bank.

Haque, N. (2014). *Pakistan's urbanisation: Achieving progress, growth, and development through urban renewal*. Wilson Center.

Henderson, J., Roberts, M., & Storeygard, A. (2013). *Is urbanisation in sub-Saharan Africa different?* World Bank.

Imran, M. (2010). *Institutional barriers to sustainable urban transport in Pakistan*. Oxford University Press.

International Road Federation. (2015). *Motor vehicles (per 1,000 people)*. Retrieved July 30, 3028, from https://web.archive.org/web/20140209114811/http://data.worldbank.org/indicator/IS.VEH.NVEH.P3

Izraeli, O., & McCarthy, T. (1985). Variations in travel distance, travel time and modal choice among SMSAs. *Journal of Transport Economics and Policy*, (*19*)2, 139–160.

Jacobs, J. (1961). *The death and life of great American cities*. Random House.

Japan International Cooperation Agency (2012). *The project for Lahore urban transport master plan in the Islamic Republic of Pakistan*. ALMEC Corporation.

Lahore Development Authority (2004). *Integrated master plan for Lahore 2021: Volume I–existing scenario*. NESPAK.

Litman, T. (2009). *Transportation cost benefit analysis: Techniques, estimates and implications*. Victoria Transport Policy Institute.

Lucas, R., & Rossi-Hansberg, E. (2002). On the internal structure of cities. *Econometrica*, (*70*)4, 1445–1476.

Malik. A. (2013). Policy options for financing urban transportation in resource constrained environments: The case of Lahore, Pakistan. *The Pakistan Development Review*, (*52*)2, 139–155.

Mills, E. (1967). An aggregative model of resource allocation in a metropolitan area. *American Economic Review*, (*57*)2, 197–210.

Moretti, E. (2012). *The new geography of jobs*. Houghton Mifflin Harcourt.

Muth, R. (1969). *Cities and housing: The spatial pattern of urban residential land use*. University of Chicago Press.

Newman, P., & Kenworthy, J. (1989). Gasoline consumption and cities: A comparison of U.S. cities with a global survey. *Journal of the American Planning Association*, (*55*)1, 24–37.

Pakistan Bureau of Statistics (2018). *Population size and growth of major cities*. Pakistan Bureau of Statistics.

Peck, J. (1996). *Work-place: The social regulation of labour markets*. Guilford.

Punjab Metrobus Authority (2018). *Lahore metrobus system*. Retrieved August 1, 2018, from https://pma.punjab.gov.pk/lmbs.

Raudenbush, S., & Bryk, A. (2002). *Hierarchical linear models: Applications and data analysis methods*. Sage.

Riaz, O., Ghaffar, A., & Butt, I. (2014). Modelling land use patterns of Lahore (Pakistan) using remote sensing and GIS. *Global Journal of Science Frontier Research: Environment & Earth Science*, (*14*)1, 25–30.

Ross-Larson, B. (ed.). (2009). *Reshaping economic geography*. World Bank.

Schwanen, T. (2002). Urban form and commuting behaviour: A cross-European perspective. *Tijdschrift voor Economische en Sociale Geografie*, (*93*)3, 336–343.

Schwanen, T., Dieleman, F., & Dijst, M. (2004). The impact of metropolitan structure on commute behaviour in the Netherlands: A multilevel approach. *Growth and Change*, (*35*)3, 304–333.

Shen, Q. (2000). Spatial and social dimensions of commuting. *Journal of the American Planning Association*, (*66*)1, 68–82.

Stead, D. (2001). Relationships between land use, socioeconomic factors and travel patterns in Britain. *Environment and Planning B*, (*28*)4, 499–528.

Storper, M. (2013). *Keys to the city: How economics, institutions, social interaction, and politics shape development*. Princeton University Press.

United Nations (2015). *World urbanisation prospects: The 2014 revision*. United Nations.

Van Acker, V., Witlox, T., & Van Wee, B. (2007). The effects of land use system on travel behaviour: A structural equation modeling approach. *Transport Planning and Technology*, (*30*)4, 331–353.

Vermeiren, K., Verachtert, E., Kasaija, P., Loopmans, M., Poesen, J., & Van Rompaey, A. (2015). Who could benefit from a bus rapid transit system in cities from developing countries? A case study from Kampala, Uganda. *Journal of Transport Geography*, (*47*), 13–22.

Worcman, N. (1995). Surface subway. *Popular Science*, (*246*)4, 32.

Wyly, E. (1998). Containment and mismatch: Gender differences in commuting in metropolitan labour markets. *Urban Geography*, (*19*)5, 395–430.