Urban travel characteristics in relation with jobs-housing balance and accessibility: results of a survey in Lahore, Pakistan

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Abstract

The circumstances of the relations of jobs-housing balance and urban travel behavior are not clear in emerging and developing countries. There are limited reliable data suitable for testing the hypotheses regarding the associations of the neighborhood-level number of employment opportunities in these countries. This manuscript summarizes the results of an explorative survey undertaken in Lahore, Pakistan to support empirical analyses testing these hypotheses. The survey was undertaken in spring 2018 in six neighborhoods of Lahore and collected the data of 417 respondents. The short questionnaire applied in the survey facilitated generation of 15 individual and household, socio-economic, and mobility-related variables of different types. Moreover, 9 land use variables as well as jobs-housing ratios were estimated for each respondent within his/her 600-meter street-network pedestrian shed. The produced dataset reveals preliminary descriptive statistics about the relations of employment and travel behavior, particularly commuting, in a less-studied context of Pakistan. It is found that a decent job-housing balance at neighborhood scale alone cannot affect the travel pattern much in the Pakistani context. It needs to be supplemented with other planning interventions, mainly the accessibility to an integrated and efficient mass public transportation system, discouraging private car based policies and promotion of sustainable non-motorized travel modes. In the future, production of disaggregate mobility and land use data will add value to urban transportation research in the Global South.

Keywords

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Highlights for public administration, management and planning:

- A decent job-housing balance alone cannot significantly affect the travel pattern.
- Sufficient number of jobs does not necessarily meet the employment demand.
- Sustainable mobility measures have to be coupled with job-housing balance approach.
- More evidence based inferential studies in the Global South will be the added-value.

1 Introduction

The importance of using the potentials and capabilities of urban land use for encouraging people to have more sustainable transportation modes and reduce their car use has been neglected by academia and researchers in emerging and developing countries. Lack of such studies has mu-

tual relation with weak connections between urban planning and transportation planning. In order to do studies on the interrelations between land use and urban travel behavior, reliable data are needed, which is less available in the Global South. In response to such shortcomings, this study focuses on the associations between availability of employment in the neighborhood scale and characteristics of travels in Lahore, Pakistan. This paper

presents the results of a survey in Lahore, undertaken in spring 2018.

The topic of this manuscript is related to a part of the wider subject of interactions between land use and transport choices. Numerous international studies have addressed the general relations between transportation behaviors and choices and the built environment in industrial countries, the classical works of which have been produced in 1990s (Boarnet & Sarmiento 1998; Cervero 1996; Cervero & Kockelman 1997; Cervero & Radisch 1996; Crane & Crepeau 1998; Handy 1992, 1996; Kockelman 1997; Kitamura et al. 1997), although there are related studies dating back to 1960s and 1970s. However, this study focuses on a narrow part of this wide topic, namely the relations between the number of jobs and houses in a residential area and travel patterns, especially commuting behavior.

Due to lack of the abovementioned data in Pakistani census and secondary data, there is no or very weak empirical basis for testing the repeatedly addressed hypothesis of existence of relationship between jobs-housing balance and travel behavior raised by international literature. Though census data in Pakistan provide housing related basic information at the block level in urban areas, it does not shed any light on the available job opportunities within the same neighborhoods. The absence of such secondary data makes the task of estimating job-housing balance at neighborhood level very difficult. It also poses a serious challenge for the urban transportation researchers to find out any relation between the job-housing balance and the urban mobility behavior of the neighborhood residents. In the absence of such basic data regarding land uses and the travel behavior in the context of Pakistan, there is hard to find literary discussions on the topics of sustainable and energy efficient travel patterns on the neighborhood level.

The Job-housing balance has reported advantages for the promotion of sustainable development through the promotion of walkability and other environment-friendly travelling modes, particularly bikes and public transport. The main aim of this land use planning approach is to cut short the job-related commuting vehicle kilometers by offering a suitable balance between the housing stock and employment opportunities. Wu (2013), while addressing the variations and complexities in defining a decent job-housing balance, quoted a simplistic ratio of 1.0 for decent job-housing balance. Wu (2013) while referring to the work of Margolis (1957), also presented another defining parameter of employment to the resident labour force ratio for a decent job-housing balance if it ranges be-

tween 0.75 to 1.25. There were 550 million vehicles in OECD countries in 2002, out of which 75 % were personal cars. It is estimated that by 2020, there will be an increase of 32 % in the vehicle ownership and 40 % increase in the vehicle kilometers during the same period in OECD countries¹. As Pakistani cities do not have efficient and integrated public transport system (Aziz, Nawaz, Nadeem, & Afzal, 2018), the situation could even be more alarming. To better analyse the travel pattern of the urban residents, grass root level basic data is much needed. Sustainable Development Goal 11 talks about sustainable cities and communities and specifically aims to promote bike, walk or use public transportation to keep our cities' air clean.

The problems that motivate this study are of two types: research-based and practical. This study is an answer to the research gap in the existing international travel behavior studies, which is a strong dependence of the findings on the outcomes of studies in industrial or Western countries, while developing countries have a very small share. This gap results in lack of inclusiveness in conclusions. The international studies have been addressed in the literature section of this paper. To fill this gap, this study focuses on Pakistan as a representative of South Asia and in general developing countries. The connection between the methodological and theoretical part of this study has been established by the similarity between the methods of quantification of qualities as well as data collection and analysis, but the difference in geographical specifications. As a result, conclusions can be derived from statistical analysis of a dataset provided for a less-studied context. Studying basic parameters underlying the topic of job-housing balance in Pakistani cities will not only contribute in filling the research gap, it will also provide important insights for the policy formulation in consideration to achieving the sustainable development goals. Currently, even if policy makers in Pakistan and generally South Asia need to use research-based findings to manage commute travels by land use planning and policy, they must refer to international studies, which root from a different context. When this study and similar ones are present, they can use knowledge produced based on the behaviors of people in their own context. The importance of the above two problems that necessitate this study will felt more when we consider the high population of urban dwellers in South Asia.

The present manuscript presents the results of a data collection in Lahore, Pakistan, carried out in spring 2018. The overall aim of this survey was to provide reliable data concerning the re-

ciprocal relations between jobs-housing balance and travel behavior and decisions with an emphasis on transport mode choice and travel purpose in a less-studied context of developing countries.

The first part of the paper introduces the topic, the problem statement and the rationale of the study. The next part provides a literature review of the similar previous studies to learn their methodological considerations and findings. The third part describes the methodology of the undertaken research work. It presents the research objectives, introduces the case study neighborhoods and informs on the study variables. Fourth part presents the study findings in descriptive, tabular and graphic forms while the last parts generate a discussion on the findings, based on which conclusions of the study are drawn.

2 Similar previous studies

Land use includes not only the physical environment, but also human activities, thus it makes a large portion of human intentions and behaviours. The objective of sustainable urban transportation is to bring people and places together, by focusing on accessibility to destinations, services, activities and goods (UN-Habitat 2013). The relation of the built environment with the travel behaviour has been examined in many studies in the past by considering the various neighborhood attributes. Some studies found the accessibility as the main determinant in deciding the travel behavior of the people (Cao et al. 2006; Handy et al. 2005), some discussed the chief role of population density (Holtzclaw 1994; Niemeier et al. 2011), employment density (Cervero & Menotti 1994) and mixed use development (Kitamura et al., 1997; Frank & Pivo 1994; Cervero & Radisch 1996; Cervero 2002). Likewise, the idea of existence of association between the jobs-housing ratios and urban travel behavior, particularly the characteristics of the commute trips has been discussed in a number of studies since more than three decades ago. Proving this hypothesis is usually difficult because collecting the needed data about the number and locations of employment opportunities is difficult and the needed data are often not collected by census data in many countries. The result is that most of the studies with this topic have been carried out in Western countries. What we know about the correlations of jobs-housing balance is that it might reduce the length of commute trips (Frank & Pivo 1994b; Horner & Mefford 2007; Niedzielski et al. 2015), reduce the number of motorized vehicle travels (Cervero & Duncan, 2006),

and in general reduce trip generation and trip attraction (Cervero 1996b). Though such hypotheses have been criticized by some studies mainly because people and enterprises can freely choose their residential locations (Gordon et al. 1989; Gordon et al. 1991), or some findings oppose such impacts (Levine 1998).

Because of the mentioned difficulties of collecting the data related to employment, the share of studies on job-housing balance from emerging countries has been weak. Except Chinese scholars who published a considerable number of publications about this topic during the past years (Jiangping et al. 2014; Peng 1997; Sun et al. 2010; Sun et al. 2008; Wang & Chai 2009; Zhao et al. 2009; Zhao et al. 2011; Zhou & Long 2014), researchers in other emerging and developing countries have had fewer opportunities to successfully deal with the subject. The main finding of the sizable publications of the Chinese scholars is that the Chinese cities are heading towards a situation of spatial mismatch and job-housing imbalance in the recent transformation era of Chinese society and economy. By studying the past and present trends of commuting patterns in Chinese cities, Ta et al. (2017) suggest that government intervention for the promotion of mixed land use and job-housing balance could reduce the commuting length in China. A strong evidence of spatial mismatch in Bieijing has been reported (Wang et al. 2011; Zhao et al. 2011) while Zhang et al. (2017) found out a decent balance between job and housing in Shanghai. Zhao et al. (2011) also found a significant association between the job-housing balance and worker's commuting time in Beijing. They found that high job-housing balance reduces the worker's commuting time.

In another study, Alpkokin et al. (2005) investigated the relation between the location of polycentric employment growth centers and the urban commuting patterns in Istanbul. Alpkokin et al. (2005) concluded that the development of polycentric centres of employment opportunities in the central parts of the city assist in the reduction of commuting travel times. Other notable work on the topic conducted in the context of developing countries is by Masoumi (2015) where he examined the relation between the urban travel behavior and urban form transformations in Iran. After investigating different typologies of neighborhoods, he suggested that neighborhood-level design concepts based on centralized Iranian neighborhood patterns can enhance non-motorized travels. In another study conducted by Masoumi et al. (2018), the authors included the large cities of Middle East and North Africa (MENA) region into

their comparative study and investigated the urban travel behaviour of the residents of Cairo, Istanbul and Tehran. In a rare study found in the context of South Asia, [Astrop et al. \(1996\)](#) investigated the urban travel behavior of low income households and females in Pune, India. The main focus of their study was to explore the effects of different land use based trips and other socio-economic characteristics on the urban travel pattern. A recent study by [Kamran et al. \(2016\)](#) compared the urban form features including the employment density and land use mix of Lahore with some of its surrounding cities. Besides, it is hard to find the studies on the topic of job-housing balance from other developing countries. Importantly, some scholars covered similar type of studies under the topics of land use mix and spatial mismatch. However, the share of such studies enriching our understanding on the dynamics of urban mobility pattern in relation to land use changes in developing countries is very less.

Reviewing many of the past similar type of studies reveals that there have been two main approaches for data collection. Many of the studies rely on the already available databases generated through extensive field surveys. The local governments in China are conducting the city-wide travel behaviour surveys of large sample sizes since a few decades. The availability of such city scale dataset could be a motivation behind the emergence of a significant number of scholarly works by Chinese authors on the topic of job-housing balance. Being aggregate data in character, Traffic Analysis Zones (TAZs) were taken as the main unit of analysis for conducting many of such studies. The other approach is the disaggregate data collection where the authors tried to explore the travel behaviour patterns of the residents on neighborhood scale. The main method for data collection during all such approaches was face-to-face interviews. The overall valid response rate was significantly higher in all such studies due to the preferred data collection method. Some studies employed some novel ideas of data collection such as [Zhang et al. \(2017\)](#) used big cellular network data ($n=6.3$ million) to analyse the travel behavior of Shanghai residents. Based on the adopted approach, the main unit of analysis for such studies was either city for aggregate studies or the neighborhoods for disaggregate studies. The sample size ranged from a few hundred respondents to thousands of them depending on the data collection scale. When it comes to the response ratio (the percentage of sampled population to the overall population of the unit of analysis), generally studies con-

stitute a ratio of less than 5%. Specifically, for disaggregate studies, the ratio declines to less than 1% in many cases. [Supplement 1](#) shows main methodological considerations of many of the similar past studies conducted in different contexts.

3 Methodology

3.1 Research objectives and general approach

The objective of this survey was to collect reliable and trustable primary disaggregate data about the relations between jobs-housing balance on the one side and the individual, demographic, socio-economic, other spatial factors on the other side, and finally travel behaviors including travel mode choice and purpose. The survey was done on the basis of the previous international studies that claimed existence of correlations between presence of enough employment in the neighborhood scale and attraction of commute travels. These studies have been addressed in the literature review part of this manuscript. Since the aim of this study was to collect reliable and useful disaggregate data for future mathematical modelling, no correlation analyses have been done at this stage. The following methods, including selection of case-study areas, interviews, and quantification of methods, were applied with the aim of providing a dataset. The general approach of the study, including this paper, is to publish the detailed survey methodology and findings first, and then addressing the details in analytical studies and publications. This approach has its limitations, i.e. this paper has no analytical parts such as correlation studies or factor analyses. This limitation can have positive and negative effects, i.e. other researchers, particularly those working on developing countries can reproduce and repeat the detailed methodology of this study, but the readers cannot gain robust correlation studies including statistical significance examinations. The former objective is very important for scholars in developing countries, because there is usually very weak data about the location of employment opportunities in those areas, so it is needed to initiate methods for quantifying the jobs-housing ratios. Regarding this importance, this paper presents detailed and repeatable methodological approach to data collection as well as detailed findings and keeps statistical analyses for future works. The methodological approach of this study has been taken due to its similarity to several mobility studies in different countries, it can facili-

tate comparative contextual studies within the target topic.

3.2 Introduction to the survey and case-study areas

Lahore, the provincial capital and the second most populous city of Pakistan was selected as the study area. Having a population size of more than 10 million, Lahore is a mega city with its current population standing at 11.13 million (Government of Pakistan 2018). The undergoing urbanization process in Lahore is rapid and the rate of urban expansion in last two decades is much higher as compared to earlier times. The area confined within Lahore urban boundary raised to 665 sq. km in 2015 from a figure of 220 sq. km in 1995 (Ibrahim & Riaz 2018), almost three times of its size in a time span of two decades. Fig. 1 shows the urban expansion of city Lahore over the past two decades which reflects that Lahore mainly experienced its expansion along the southern corridor which is primarily in accordance with its master plan. Such fast sprawling conditions hint the increased commuting distances and travel time of the urban residents which needs to be investigated through evidence based studies. Many of the past studies reflected that residents of central urban neighborhoods having mixed land use development experience lesser travel distances as compared to those living in sprawling neighborhoods. This literature finding shows that the location of neighborhood significantly affects the urban travel behavior of the residents. This further suggests that having a study that aims to examine the relationship between the job-housing balance and the travel behavior needs to nullify the effect of the neighborhood location (and other socio-economic variations also) in order to have the reliable findings. This resulted in the selection of 6 neighborhoods as the case study areas; all located in the central transition part of the city having similar type of socio-economic conditions whereas having the significant variations in the land use features (Fig. 1).

As the main criteria for the selection of case-study neighborhoods was based on the land use variations, the selected neighborhoods dominantly comprised of commercial, partly commercial and residential land uses (two each) and located in the Allama Iqbal Town with close proximity to each other. The development work of Allama Iqbal Town was started in 1970s and it spanned over an area of 647.5 hectares. In 1970s, it was a peripheral development situated in the southwestern part of the old central part of City Lahore. However, as of

today its location can well be specified as in the central transition part of the city. The population, dominant land use character, number of housing units and area of each neighborhood are given in Table 1 whereas the detailed land use survey results showing the availability of different facilities within each neighborhood has been shown in Fig. 1.

3.3 Survey and data

In general, 417 interviews were conducted in the six selected case-study neighborhoods. The systematic sampling technique was used in order to distribute the sample among the case study neighborhoods in proportion to their population sizes. The frequency and percentage of respondents in each neighborhood is shown in Table 2. The data collection was an explanatory effort to provide a preliminary understanding about people's behaviors in the large city of Lahore, so it is not representative of all of residents and socio-economic statuses. The survey was undertaken using a short survey instrument including 12 questions. The questions were meant to generate four continuous variables (age, car ownership, bike ownership, and the number of shopping activities), seven binary/categorical variables (education, occupation, work/study location, commute mode choice, place of shopping, and shopping mode choice), and two open-ended questions (occupation type and house location). For cultural observations, there were male and female options for gender in the questionnaire. The highest level of education, the respondents were asked to choose from four options of no degree, high school/diploma, university degree (bachelor), and higher education degree (masters or doctoral). The current occupation was chosen from employed or student, unemployed, and work at home. The interviewers asked respondents to tell them their work types such as government employee, construction worker, and accountant in a bank. Work/study place included two options: inside the neighborhood and outside it. Here the interviewer told the respondent what was meant by neighborhood referring to the administrative neighborhoods of Lahore. In the same question, the respondents were asked to sign the nearest intersection or landmark to their work/study place on the neighborhood map given to them in case they work or study inside their neighborhood, or mention the name of the district or intersection so that the interviewer sign on the city map. This concluded in having the work/study place (if applicable) without violating privacy issues. The same was true about living places; respondents were asked to sign the nearest place, in-

Fig. 1 Urban extent of Lahore (1995 to 2015) and location of case-study neighborhoods. Source: Adapted from Ibrahim and Riaz (2018)

Table 1 General characteristics of the case-study neighborhoods

Sr. No.	Neighborhood	Population (2017)	Dominant Land use Character	Number of Housing units	Area (km ²)
1	Khyber Block	4805	Residential	759	0.108
2	Raza Block	4085		645	0.199
3	Kashmir Block	3658	Partly	578	0.120
4	Karim Block 1	3156	commercial	499	0.097
5	Karim Block 2	3651	Commercial	577	0.170
6	Satluj Block	2427		383	0.099

tersection, or landmark on the neighborhood map to show approximately where they live. The respondents were asked to choose one dominant mode for their commuting (if any) from six options: private car, motorbike, public transport, walking or cycling, app. based (uber/careem), and paratransit (taxi/shared taxi/rickshaw/quiringchi). The number of cars and motorbikes of the household was asked in another question. The scholars of this study took shopping as one of the main purposes of non-commute travels and focused on it. To quantify the number of shopping activities, the respondents were asked to estimate and tell the interviewers about the number of the shopping activities in the last seven days before the interview in a retrospective way. The respondents were also asked about the dominant place of their shopping including destinations inside their neighborhoods or outside it. Finally, the respondents were asked about the dominant mode of their shopping trips provided the same modes as commute travels in a previous question. Ten land use variables were developed, including intersection density, link-node ratio, street-length density, job commuting distance, population density, no. of bus stops, average distance to bus stops, no. of facilities, and average distance to facilities. All of the above variables were calculated on a disaggregate basis for each respondent within the 600-meter street network-based catchment area from his/her living location using Geographic Information Systems (GIS) by ArcGIS software. The diameter of the catchment areas was selected to be 600 meters using the previous studies that took between 600 and 800 as the diameter of the pedestrian buffer zones centered by homes or public transportation stations (Gouda & Masoumi 2018; Farber & Marino 2017; Masoumi 2019; Ransom 2018). This area is a normal and frequently used walking distance in mobility behavior studies. For calculation of intersections density, the number of intersections within the catchment areas were counted and divided by the area of the catchment area (ha). Link-node ratio was another street connectivity measure, which was calculated by dividing

the number of streets by the number of intersections within each area. The street length density was the result of dividing the total length of the streets within the catchment area of each house by the area of that pedestrian shed. The commuting lengths were calculated by connecting the nearest intersections to houses to the nearest points to work/study places by the best street network-based Google route. The population density within each person's catchment area was estimated using the 2017 census data of Lahore. Availability and accessibility to public transportation was limited to urban buses. The number of the bus stops and the average number of kilometers to them were from each house were calculated for each catchment area. The same procedure was taken for other types of public facilities such as bakeries, retail, schools, urban open or green spaces, as well as medical and religious buildings. Thus, two sets of accessibility to local public facilities variables were generated (the number of facilities and the average distance to them) for buses and other facilities.

Table 2 Number of respondents in case-study neighborhoods

Location of residence	No. of respondents	Percent
Karim Block 1	63	15.1
Karim Block 2	70	16.8
Kashmir Block	70	16.8
Khyber Block	90	21.6
Raza Block	74	17.7
Satluj block	50	12.0
Total	417	100.0

3.4 Quantification of Land Use Variables

The land use survey was conducted to measure the land use variables based on street pattern buffer of 600-meter originated from the nearest intersections to the respondents' houses in case study neighbourhoods. The number of facilities and accessibility was measured using five types

of facilities including commercial (that are intended for profits businesses such as restaurants, shopping malls, retail shops, service areas, etc.), education (such as school and colleges), health (including dispensaries, clinics, and hospitals, etc.), religious (which includes mosques and graveyards), and open spaces (as the dominant urban parks and green spaces). Amenities outside the street pattern buffer of 600-meter were also marked for estimating their accessibility distances from the houses located at the periphery of neighborhoods. The methodology for calculating land use variables is shown by Fig. 2 while the definitions of selected variables and explanations to their calculations have been presented in Supplement 2.

3.5 Estimation of Employment Opportunities

Employment Density Guide (EDG), 3rd edition (Homes and Communities Agency, 2015) was followed for estimating the employment opportunities at neighborhood level. The count of all the employment generating land use classes and sub-classes along with the number of floors was made during the land use survey. All the collected field data was then transferred to GIS environment which facilitated the calculation of Gross Internal Areas (GIA) of the building parcels and later Net Internal Areas (NIA) by applying a 15% reduction factors suggested by EDG. Multiplying them with number of floors of each building parcel gave Floor Space Area (FSA) which then distributed to the count of different land use sub-classes. Applying the EDG suggested employment density rates on FSAs of different land use sub-classes gave the estimation of employment opportunities which at the end, were added up to estimate the job opportunities available in every neighborhood.

4 Results

4.1 Findings regarding categorical measures

Gender, education, occupation, work location, shopping location, shopping mode choice, and commute mode choice were the categorical variables, the data of which were collected from the respondents by the survey instrument. The frequencies of the responses related to different categories related to the overall sample can be seen in Supplement 3 and Fig. 3. As seen in the table, more than 67% of the respondents were male and most of the respondents had high school diploma or a bachelor's degree. Slightly less than

two-thirds of the respondents worked or studied at the time of the survey. More than half of them worked, studied, or did their daily shopping in far-away places outside of their neighborhoods. Private car and motorbike were the main shopping and commuting modes (44% and 30% for shopping and 50% and 33% for commuting). Supplement 4 shows the breakdown of these categorical data based on neighborhoods. The least and most respondents with respect to private car based commuting trips lived in Kashmir block (31%) and Karim Block 2 (70%) respectively, while for the shopping trips, it is the same Kashmir Block which have the least percentage of car-based trips (27%) while the highest percentage is of Raza Block (64%). However, it is important to note that the highest share of commuting and shopping trips on motorbike (46% and 41%) also belong to Kashmir Block. The highest percentage of workers or students was found in Raza (81%) and Kashmir Blocks (83%), while 52% of the respondents of Karim Block 1 were unemployed. Raza and Kashmir Blocks also had the highest percentage of Bachelor's degree holders (42% and 40%). The highest share of walking and cycling for commuting is of Karim Block 1 (6.3 %) and for shopping, it is of Karim Block 2 (30.0%). The highest public transit ridership for commuting purpose is seen in Satluj Block (12%). The same Satluj Block has the highest share of commuting and shopping trips made through app based para transit modes (16% and 14%). Fig. 4 depicts the frequency of responses for categories of each neighborhood.

4.2 Findings regarding continuous measures

4.2.1 Data derived from the questionnaire

As mentioned in the methodology section, age, car ownership, bike ownership, and the number of shopping activities were generated as continuous variables as direct results of the interviews. The descriptive statistics of these four variables are summarized in Table 3. As seen in the table, the respondents of the survey were almost 39 years old on average and their family had an average of slightly more than one car and one bike. Household car ownership ranges from zero to 8, while bike has a smaller range. The frequency of shopping activities in the past seven days before the interview ranged from zero to seven times leading in a mean of 1.3 times in seven days. In order to check the distribution of these variables, Kolmogorov-Smirnova and Shapiro-Wilk tests were applied, the results of which indicates non-normal distributions ($P < 0.001$). The normal lines are de-

Fig. 2 Calculating the land use variables

Fig. 3 Findings regarding categorical questions of the overall sample

picted on frequency graphs to provide a visual understanding about non-normality of the distributions (Fig. 5). For the future empirical studies on these variables, the outliers were not eliminated from the dataset.

Table 3 Descriptive statistics of continuous variables derived from the questionnaire

Category	Age of respondent	Ownership of Car	Ownership of Bike	Shopping freq.
Valid (n)	417	393	384	383
Missing (n)	0	24	33	34
Mean	39.25	1.18	1.2	1.309
Std. Deviation	14.794	0.85	0.707	1.3
Variance	218.864	0.723	0.5	1.689
Range	70	8	5	7
Minimum	13	0	0	0
Maximum	83	8	5	7

4.2.2 Land use and accessibility variables

The main factor that is the target of this survey was jobs-housing ratio, the estimation method of which was introduced in previous sections. The descriptive statistics of the number of housing units, the number of employment facilities, employment density, the number of employment opportunities, and the jobs-housing ratios for 600-meter catchment areas around the nearest point to the house of each respondent are shown in Table 4. As explained above, the catchment areas of more than one nearby house were clustered for simplification of GIS work. As seen there, the standard deviation of 0.792 is a large value for the mean of 0.711 jobs for each house. The ratio varies from 0.025 to 2.968 in each catchment area. In fact, the highest accessibility to jobs is related to a pedestrian shed that reaches 2.968 employment opportunities. For better possibility of comparing different types of neighborhoods in case of availability

Fig. 4 Findings regarding categorical questions of the overall sample

of employment opportunities, the descriptive statistics were categorized for the three types of residential, partly commercial, and commercial neighborhoods. Table 5 shows the descriptive statistics of jobs-housing ratios for the three neighborhood types that include six neighborhoods. This table shows how different the ratios of the three employment availability categories are. The mean of ratios related to two residential neighborhoods are 0.033 and 0.112, meaning that people in Khyber Block have on average access to 0.033 job opportunities within the walking distance of their home and the average available jobs around each home in Raza Block is 0.112. This can be compared to the means of neighborhoods in partly commercial areas that average 0.568 and 0.581 jobs within pedestrian sheds. As neighborhoods located in com-

mercial areas, Karim Block 2 and Satluj Block have the highest job opportunity availability. In addition to the main land use variable of this study, jobs-housing ratio, nine other land use variables were developed (Table 6). These nine variables were calculated by GIS as explained in the methodology section for each cluster of pedestrian sheds around several houses. Four of these variables represent accessibility measures: number of bus stops, average distance to bus stops, number of facilities, and average distance to facilities. Again, in order to provide comparable measures for the three types of neighborhoods with different levels of accessibility to job opportunities, the breakdown of the urban form variables was estimated for the neighborhoods separately. These values can be observed in Supplement 5.

Table 4 The steps of estimation of jobs-housing ratios for the overall sample (N=417)

Variable	Mean	Minimum	Maximum	Range	Standard Deviation	Variance
No. of Housing Units	5013.17	2831	6171	3340	957.34	916505.92
No. of Employment Facilities	68.2	14	128	114	26.75	715.51
Employment Density	44.27	2.86	125.41	122.55	40.02	1601.5
Employment Opportunities	3032.10	152	8402	8250	2789.41	7780780.11
Jobs-Housing Ratio	0.711	0.025	2.968	2.943	0.792	0.628

Table 5 Descriptive statistics of jobs-housing ratios for six neighborhoods categorized in three types of employment opportunities (N=417)

Neighborhood Type	Neighborhood	Mean	Minimum	Maximum	Range	Standard Deviation	Variance
Residential	Khyber Block	0.033	0.025	0.042	0.017	0.006	0
	Raza Block	0.112	0.044	0.152	0.108	0.042	0.002
Partly Commercial	Kashmir Block	0.568	0.457	0.679	0.222	0.081	0.006
	Karim Block 1	0.581	0.503	0.644	0.141	0.058	0.003
Commercial	Karim Block 2	1.145	1.051	1.263	0.212	0.058	0.003
	Satluj Block	2.571	2.218	2.968	0.750	0.270	0.073

Table 6 Land use variables for the overall sample of Lahore (N=417)

	Mean	Minimum	Maximum	Std. Deviation	Variance
Intersection Density (Nodes/ha)	1.63	0.932	2.876	0.62	0.379
Link-Node Ratio	1.35	1.015	1.789	0.27	0.07
Street-Length Density (m/ha)	0.15	0.091	0.259	0.51	0.003
Job Commuting Distance (meter)	6.77	0.128	18.470	4.29	18.39
Population Density (Persons/acre)	298.11	205.097	444.789	88.46	7825.14
No. of Bus Stops	2.91	0	5	1.47	2.16
Average Distance to Bus Stops (meter)	0.57	0	0.854	0.26	0.07
No. of facilities	80.77	18	151	30.74	944.80
Average Distance to Facilities (meter)	0.38	0.039	1.116	0.30	0.09

5 Discussion

The results show that around half of the respondents commute outside of their neighborhoods for making work and education based trips. It generally shows that the studied neighborhoods as a whole are not self-sufficient in terms of jobs and educational facilities. The use of private vehicles, mainly the car and motorbike is more for commuting as compared to shopping activity. Importantly, the private car is the most preferred traveling mode for both commuting and shopping. This finding describes the state of available public transport infrastructure in Lahore which is currently neither efficient nor integrated (Aziz et al. 2018). The average commuting distance is 6.77 kilometers, although the selected neighborhoods are located in the transitional central part of Lahore. This reflects on even higher commuting distances

for the neighborhoods located at the sprawling peripheries of the Lahore, for which research findings are not available yet.

While looking closely the commuting pattern across different case-study neighborhoods, it is depicted that the use of private car is highest for the Karim Block 2 while the least usage has been found in Kashmir Block which is partly commercial. The former neighborhood was selected apparently due to its dominantly commercial character while the latter was chosen due to seemingly its partly commercial character. Interestingly, Karim Block 2 is the same neighborhood where residents have the longest commuting distance on average, i.e. 9.39 kilometer. A simple analogy can be drawn from here that the longer the commuting distance, higher will be the private car based commuting trips in the absence of an efficient and integrated public transport system. Digging down deep in the land use character of the selected neighborhoods

Fig. 5 Continuous data resulted by the questionnaire, related to the overall sample

and analysing them with respect to job-housing balance, which is the prime focus of this study, Karim Block 2 is the only neighborhood which observes close to decent job-housing balance (1.15). Our current finding suggests that the only neighborhood with the decent job-housing balance has the highest private car based commuting trips and the longest commuting distances which is, apparently, in contradiction with many of the literature findings such as concluded by [Frank & Pivo \(1994\)](#), [Horner & Meford \(2007\)](#), [Niedzielski et al. \(2015\)](#) and [Cervero & Duncan \(2006\)](#).

However, it is significant to note that, Karim Block 2 has the lowest share of motor bike use for both commuting (20%) and shopping trips (19%), and second highest car ownership ratio (1.43) among all other neighborhoods. At the same time, it has the highest share of walking or cycling based shopping trips (30%). Analysing the land use characteristics of Karim Block 2 reveals that it has the highest average distance to bus stops (0.77 kilometers) which could be a discouraging factor for the residents to opt public transport bus as a preferred travel mode choice. These statistics support the viewpoint that a better accessibility to an efficient and integrated public transport system can reduce the use of private cars. As the residents of Karim Block 2 have the highest share of shopping based trips on sustainable, non-motorized modes of walking and cycling, improved public transport service might reduce their dependence on private cars for commuting trips as well. Another important consideration is that Karim Block 2 is a specialized commercial market for sale and purchase of garments products. This means that though the residents can find sufficient number of desired shopping outlets within their pedestrian sheds, but

they remain unable to find a variety of employment opportunities that would match with their varying qualifications and skills, although they are sufficient in number. To sum up the presented discussion so far, job-housing balance alone cannot reduce the vehicle travel miles; it needs to be supplemented with many other factors as discussed above. This outcome is generally in line with the literature findings that opposes a simple and straightforward relation of job-housing balance and travelled miles such as [Gordon et al. \(1989 and 1991\)](#) and [Levine \(1998\)](#).

On the other side, it is noted that Kashmir block which has a poor job-housing balance (0.57) has the lowest share of private car based commuting and shopping trips. This finding does not tell the whole story alone as the residents of same neighborhood experience the highest share of commuting and shopping trips on motor bike (46% and 41% respectively), yet another motorized travel mode. It means while studying the relation of job-housing balance and vehicle travelled miles, results for private cars only can be misleading in the context of developing world. Kashmir Block also has the highest share of public transport usage for shopping trips (7%), second lowest car ownership ratio (1.20) and the second lowest value of average distance to bus stop and third lowest value of average commuting distance. These are generally the contributing reasons for having the least value of private car based trips in Kashmir Block. Karim Block 1 is another neighborhood, which has a similar job-housing balance (0.58) as that of Kashmir Block. It observes the maximum commuting trips through walking and cycling (6%). This finding also grasps the attention at the first sight, but around half of the respondents (52%) were unemployed, means

a reliable conclusion on the basis of this finding cannot be drawn. With respect to the public transport usage, including application based services for commuting purposes, the Satluj Block, the neighborhood with an overly supplied number of jobs (job-housing balance of 2.57), enjoys the maximum ridership (30%). Besides being a general purpose commercial market and the land form features influence, the other main reason could be the easy accessibility of the neighborhood through public transport.

Land use characteristics also play a vital role in shaping up the travel behavior of neighborhood residents. Karim Block 1 has the second highest intersection density, which could have a role in having the highest share of the commuting trips and second highest share of shopping trips through walking or cycling. Education is also an important factor that can affect the travel pattern of the neighborhood residents. The highest share of the respondents holding a masters or doctoral degree (34%) resides in Karim Block 2, yet it has the highest share of commuting trips made by private car and the longest commuting distance. Location of work is another important variable to consider while investigating the urban travel pattern. Highest share of the respondents having the job location outside the neighborhood reside in Kashmir Block (74%) which could be a reason for having the highest share of commuting trips by motor bikes. Another interesting finding is that Khyber Block has the highest share of the residents who work at home (34%) which could be a reason for having the lowest car ownership rate (0.83) and the least job commuting distance (3.6 km).

The major urban centres in Pakistan have recently experienced a shift in transportation planning towards having integrated mass public transportation system. Metro Bus System (Bus rapid transits) along with its feeder routes in Lahore, Islamabad/Rawalpindi, Multan, and Peshawar (under construction) and Orange Line Metro Train System (light rail transit) in Lahore (under construction) are a few examples of this paradigm shift in urban transportation planning. The main aim of introducing integrated mass public transportation system is to promote the sustainable mode of urban travelling and easing out the traffic congestion on urban roads. However, provision of integrated mass public transport system cannot deliver alone, unless it would be coupled with other urban planning related interventions which are responsible in shaping up the built up areas. The provision of urban highways in the shape of (traffic) signal free corridors, road widening projects, exclusive

zoning paradigm, low density sprawled urban development, mandatory minimum parking requirements, are some of the many measures that are being currently practiced in urban centres of Pakistan and are responsible for encouraging the use of private cars. With such measures in place at the same time, the mass public transport system cannot serve the purpose of reducing the motorized vehicle use. Many studies conducted in the developed world have reported the advantages of decent job-housing balance in terms of reduced vehicular travelled miles. However, the results of this study do not coincide with such literature findings; instead it resonates with those literature findings which point out on the role of other factors while analysing any such relationship between job-housing balance and travel patterns. Current practices of urban planning in Pakistan follow the principles of exclusive zoning that does not support the mixed use development. The findings of this study do not provide distinctive contextualized evidence which encourages the paradigm shift in urban planning practices towards more flexible and mixed use type zoning, however, it provides sufficient evidence that certain prerequisites have to be adopted in order to get the benefits of mixed use development, primarily for reducing the travelled vehicle miles. On top of them, it is the accessibility to an integrated and efficient mass public transport system, discouraging the use of private car, promotion of sustainable travelling modes through the development of affiliated required infrastructure and having a variety of sufficient job opportunities at a neighborhood scale. Making a planning intervention to reduce the vehicles travelled miles is very much important and significant as in recent times, large urban centres of Pakistan; particularly Lahore is experiencing hazardous levels of smog and air pollution, and the transportation sector energy consumption is regarded as one of the main contributors to such adverse air pollution. Mixed use development with a decent job-housing balance, discouraging the use of private vehicles in favor of environment friendly travelling modes are a few strategies which have been successfully implemented in many advanced countries to promote sustainable development. Pakistan has to follow the same trajectory of promoting mixed use development with affiliated required measures as mentioned above to achieve the targets set under sustainable development goals.

The audience of this multi-disciplinary paper is a wide array of professionals including urban and transport planners, geographers, environmentalists, behavioral and social scientists, urban development professionals, housing experts, policy mak-

ers and sustainability proponents. These professionals will have important insights from the presented research findings, which can effectively be utilized in their respective domains of research and practical oriented work. Bringing all the relevant professionals to a same page, for a better understanding of urban travel pattern in developing countries will contribute positively in resolving the affiliated issues in an integrated and efficient manner.

Census data in Pakistan do not provide the details of employment opportunities available at neighborhood scale, due to which an estimation of job opportunities was done by using the Employment Density Guide, 3rd edition (Homes and Communities Agency, 2015) which is not locally contextualized. In Pakistan, the job market is more labor intensive and the actual job opportunities might be higher as those are estimated for different neighborhoods. Also, a significant amount of informal sector business activity is also a trademark of local shopping areas, particularly in Moon Market of Satluj Block and Karim Block garments market. The most preferred location of such business activity is along the main roads in front of shopping plazas and the walking corridors within these markets. Mainly this sector offers a number of unregulated self-employment opportunities to low income vendors/entrepreneurs. There is no documentation or data available for the number of such job opportunities. Such opportunities have also not been accounted for while estimating the job opportunities available in different neighborhoods. However, such unregulated informal sector job opportunities are generally occupied by low income people. While the case study neighborhoods belong to middle or higher income groups, it could be inferred that such unregulated jobs are not meant for the residents of the same neighborhood to be taken. It means that not counting them in the estimation of job opportunities is insignificant. Moreover, descriptive analysis has been used in this paper to summarize the research findings and to highlight the travel pattern of the residents for a clear understanding, however there are limitations too. Firstly, the research findings cannot be generalized for a larger set of population and secondly, clear relationship among the study variables cannot be established, for which inferential statistical methods are needed to be used.

6 Conclusion

The study concludes that a decent job-housing balance and accessibility at neighborhood scale cannot reduce the commuting distances alone; rather this much favored land use approach has to be coupled with certain other measures and interventions. On top of them, these are the development of an integrated and efficient mass public transport system, discouraging the use of private car through policy interventions and encouraging the use of sustainable modes of travelling through the provision of required infrastructure. The study also concludes that having sufficient number of job opportunities within the pedestrian sheds of the residents does not necessarily meet the employment demands of the residents. The thing which matters is the variety of available jobs that could match with the varying levels of academic qualifications and skills of the residents. Also, the neighborhoods with improper job-housing balance may have the lowest share of private car use, which could be a result of low car ownership rates, higher usage of motor bikes and app based taxi services (Uber and Careem), and close proximity to the available public transport service. The conclusion of this study is an important theoretical contribution as it challenges those research findings, which present a significant association between the job-housing balance and vehicle miles travelled. However, it is important to note that many of such studies have been conducted in the developed world, thus it also points out at the differences in the travel pattern and built up environment of the developed and developing world.

However, there is a need for more evidence based studies on the topic in the context of developing countries, particularly for statistically testing the relation between the job-housing balance and travel patterns. Further, there is a need for studying the employment opportunities at neighborhood scale and establishing guidelines for the estimation of job opportunities in the developing countries. Such studies need also to take into consideration the unregulated informal sector job opportunities as well for facilitating the estimation close to reality. Also, it is strongly suggested to have the same kind of studies conducted in the smaller cities of the developing countries as they may bear the different results as compared to the large urban centres.

Notes

¹ <https://www.un.org/sustainabledevelopment/sustainable-consumption-production/>, accessed on 10.01.2018

References

- Alpkokin P, Hayashi Y, Black J, Gercek H (2005) Polycentric employment growth and impacts on urban commuting patterns: Case study of Istanbul. *Journal of the Eastern Asia Society for Transportation Studies* 6: 3835–3850.
- Astrop A, Palmner C, Maunder D, Babu DM (Eds.) (1996) The urban travel behaviour and constraints of low income households and females in Pune. Citeseer, India.
- Aziz A, Nawaz MS, Nadeem M, Afzal L (2018) Examining suitability of the integrated public transport system: A case study of Lahore. *Transportation Research Part a: Policy and Practice* 117: 13–25.
- Boarnet MG, Sarmiento S (1998) Can land-use policy really affect travel behaviour? A study of the link between non-work travel and land-use characteristics. *Urban Studies* 35(7): 1155–1169.
- Cao X, Handy SL, Mokhtarian PL (2006) The influences of the built environment and residential self-selection on pedestrian behavior: evidence from Austin, TX. *Transportation* 33(1): 1–20.
- Cervero R (1996) Mixed land-uses and commuting: Evidence from the American housing survey. *Transportation Research Part A: Policy and Practice* 30(5): 361–377.
- Cervero R (1996b) Jobs-housing balance revisited: Trends and impacts in the San Francisco Bay Area. *Journal of the American Planning Association* 62: 492–511.
- Cervero R (2002) Built environments and mode choice: toward a normative framework. *Transportation Research Part D: Transport and Environment* 7(4): 265–284.
- Cervero R, Duncan M (2006) Which reduces vehicle travel more: Jobs-housing balance or retail-housing mixing? *Journal of the American Planning Association* 72: 475–490.
- Cervero R, Kockelman K (1997) Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment* 2(3): 199–219.
- Cervero R, Menotti V (1994) Market profiles of rail-based housing projects in California. Institute of Urban and Regional Development. Berkeley. Working Paper 622.
- Cervero, R., & Radisch, C. (1996) Travel choices in pedestrian versus automobile oriented neighborhoods. *Transport Policy* 3(3): 127–141.
- Crane R, Crepeau R (1998) Does neighborhood design influence travel?: A behavioral analysis of travel diary and GIS data. *Transportation Research Part D: Transport and Environment* 3(4): 225–238.
- Farber S, Marino MG (2017) Transit accessibility, land development and socioeconomic priority: A typology of planned station catchment areas in the Greater Toronto and Hamilton Area 10(1): 879–902.
- Frank LD, Pivo G (1994) Impacts of mixed use and density on utilization of three modes of travel: single-occupant vehicle, transit, and walking. *Transportation Research Record* 1466: 44–52.
- Frank LD, Pivo G (1994b) Relationship between land use and travel behavior in the Puget Sound Region.
- Gordon P, Kumar A, Richardson HW (1989) The influence of metropolitan spatial structure on commuting time. *Journal of Urban Economics* 26: 138–151.
- Gordon P, Richardson HW, Jun M-J (1991) The commuting paradox evidence from the Top Twenty. *Journal of the American Planning Association* 57: 416–420.
- Gouda AA, Masoumi HE (2018) Compactness, connectivity, and walking accessibility on the neighborhood level according to sustainability certifications: improvement or downgrade? A case study of Cairo, Egypt. *Journal of Geographical Systems* 20(4): 413–449.
- Government of Pakistan (2018) District and Tehsil level population summary with region breakup. Retrieved from http://www.pbscensus.gov.pk/sites/default/files/bwpsr/punjab/LAHORE_SUMMARY.pdf
- Handy SL (1992) Regional versus local accessibility: neo-traditional development and its implications for non-work travel. *Built Environment* 18(4): 253–267
- Handy S (1996) Methodologies for exploring the link between urban form and travel behavior. *Transportation Research Part D: Transport and Environment* 1(2): 151–165.
- Handy S, Cao X, & Mokhtarian P (2005) Correlation or causality between the built environment and travel behavior? Evidence from Northern California. *Transportation Research Part D: Transport and Environment* 10(6): 427–444.
- Holtzclaw J (1994) Using residential patterns and transit to decrease auto dependence and costs (Vol. 11). San Francisco, CA: Natural Resources Defense Council.
- Homes and Communities Agency (2015) Employment density guide. <https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/484133/employment_density_guide_3rd_edition.pdf>
- Horner MW, Mefford JN (2007) Investigating urban spatial mismatch using job-housing indicators to model home-work separation. *Environment and Planning A* 39: 1420–1440.
- Ibrahim M, Riaz S (2018) Lahore growth - Past and future. <<http://urbanunit.gov.pk/Upload/Photos/Urban%20Gazette%20Issue%202018.pdf>>
- Jiangping Z, Chun Z, Xiaojian C, Wei H, Peng Y (2014) Has the legacy of Danwei persisted in transformations?: The jobs-housing balance and commuting efficiency in Xi'an. *Journal of Transport Geography* 40: 64–76.
- Kamran M, Batool Z, Rehman Z (2016) Comparison of Urban Form Parameters of Lahore with its Neighboring Cities. *Pakistan Journal of Science* 68.
- Kitamura R, Mokhtarian PL, Laidet L (1997) A micro-analysis of land use and travel in five neighborhoods in the San Francisco Bay Area. *Transportation* 24(2): 125–158.
- Kockelman MK (1997) Travel behavior as function of accessibility, land use mixing, and land use balance: evidence from San Francisco Bay Area. *Transportation research record* 1607(1): 116–125.
- Levine J (1998) Rethinking Accessibility and jobs-housing balance. *Journal of the American Planning Association* 64: 133–149.
- Long Y, Thill J-C (2015) Combining smart card data and household travel survey to analyze jobs-housing relationships in Beijing. *Computers, Environment and Urban Systems* 53: 19–35.
- Margolis J (1957) Municipal fiscal structure in a metropolitan region. *Journal of Political Economy* 65: 225–236.
- Masoumi HE (2015) Transformation of urban form and the effects on travel behavior in Iran. Discussion paper No. 36/15 published

by Center for Technology and Society of Technische Universität Berlin. <https://www.tu-berlin.de/fileadmin/f27/PDFs/Discussion_Papers_neu/discussion_paper_Nr_36.pdf>

Masoumi HE, Gouda AA, Layritz L, Stendera P, Matta C, Tabakh H, ... Kılınc Ö (2018) Urban travel behavior in large cities of MENA Region: Survey results of Cairo, Istanbul, and Tehran. Discussion paper No. 41/18 published by Center for Technology and Society of Technische Universität Berlin. <https://www.tu-berlin.de/fileadmin/f27/PDFs/Discussion_Papers_neu/discussion_paper_Nr_41_18.pdf>

Masoumi HE (2019) A Discrete Choice Analysis of Transport Mode Choice Causality and Perceived Barriers of Sustainable Mobility in the MENA Region. *Transport Policy*, in press.

Niedzielski MA, O’Kelly ME, Boschmann EE (2015) Synthesizing spatial interaction data for social science research: Validation and an investigation of spatial mismatch in Wichita, Kansas. *Computers, Environment and Urban Systems* 54: 204–218.

Niemeier D, Bai S, Handy S (2011) The impact of residential growth patterns on vehicle travel and pollutant emissions. *Transport and Land Use* 4(3): 65–80.

Peng Z-R (1997) The jobs-housing balance and urban commuting. *Urban Studies* 34: 1215–1235.

Qin P, Wang L (2017) Job opportunities, institutions, and the jobs-housing spatial relationship: Case study of Beijing. *Transport Policy*. Advance online publication.

Ransom MR (2018) The effect of light rail transit service on nearby property values: Quasi-experimental evidence from Seattle. *Journal of Transport and Land Use* 11(1).

Sun B, Li N, Song J, Wu X (Eds.) (2010) A Study on the impact of job-housing balance on commuting travels: An empirical test of a traditional idea in the field of urban planning [J].

Sun B, Pan X, Ning YM (Eds.) (2008) Analysis on influence of job-housing balance on commute travel in Shanghai. *Urban Planning Forum* 01. <<http://en.cnki.com.cn>>

Ta N, Chai Y, Zhang Y, Sun D (2017) Understanding job-housing relationship and commuting pattern in Chinese cities: Past, present and future. *Transportation Research Part D: Transport and Environment* 52: 562–573.

UN-Habitat (2013) Planning and design for sustainable urban mobility: Global report on human settlements 2013. Taylor & Francis, New York.

Wang E, Song J, Xu T (2011) From “spatial bond” to “spatial mismatch”: An assessment of changing jobs-housing relationship in Beijing. *Habitat International* 35: 398–409.

Wang L, Waddell P, Outwater ML (2011) Incremental integration of land use and activity-based travel modeling: Workplace choices and travel demand. *Transportation Research Record* 2255: 1–10.

Won S, Kim S (2017) Mobility is in the eye of the beholder: A comparison of travel patterns and urban spatial use between migrants and the original residents of Danang, Vietnam. *Cities* 67: 63–73.

Wu Q (2013) Jobs-housing balance: the right ratio for the right place.

Zhang M, He S, Zhao P (2018) Revisiting inequalities in the commuting burden: Institutional constraints and job-housing relationships in Beijing. *Journal of Transport Geography* 71: 58–71.

Zhang P, Zhou J, Zhang T (2017) Quantifying and visualizing jobs-housing balance with big data: A case study of Shanghai. *Cities* 66: 10–22.

Zhao P, Lu B, Linden GJJ (2009) The effects of transport accessibility and jobs-housing balance on commuting time: Evidence from Beijing. *International Planning Studies* 14: 65–83.

Zhao P, Lü B, Roo GD (2011) Impact of the jobs-housing balance on urban commuting in Beijing in the transformation era. *Journal of Transport Geography* 19: 59–69.

Zhou J, Long Y (2014) Jobs-housing balance of bus commuters in Beijing. *Transportation Research Record* 2418: 1–10.

Supplement 1: Methodological considerations of similar past studies

Study	Sample Size for Travel Behavior Study	Response Rate	Case-study areas	Response Ratio	Data collection method
Frank & Pivo, 1994	30,000 trips taken by 1,500 households	Not available	3 counties of King, Pierce and Snohomish	Not available	Puget Sound Regional Council two-days Survey in 1989
Masoumi, 2015	192 persons	Not available	Two neighborhoods located in Region 5 of Tehran	0.70%	Interview
Masoumi et al., 2018	8284 persons	Not available	18 neighborhoods in Tehran, Istanbul and Cairo	0.86%	Face-to-face interviews
Wang et al., 2011	1090	68.35%	13 residential communities in the suburban part of Beijing	Not available	Distributed and later collected
Zhao et al., 2011	1500 households	92.0% (47.47 % valid only)	60 communities from all urban districts of central and inner-suburban areas of Beijing	Not available	Household Interview Survey (Face-to-face) in 2001
Long & Thill, 2015	81,760 households/ 208,290 persons	Not available	1118 Traffic Analysis Zones (TAZs) in all 18 districts of Beijing Municipal Area	1.36%	2005 Beijing Travel Behaviour Survey
Jiangping et al, 2014	50,000 households	Not available	City-wide survey of all households	3.57%	Xi'an Household Travel Survey, 2008
Qin & Wang, 2017	46,900 households/ 116,142 persons	44.99% (valid only)	City-wide survey of households in Beijing	Not available	2010 Beijing Household Travel Survey (Face-to-face interviews)
Won & Kim, 2017	460 residents (building owners)	Not available	Buildings located near the Nguyen Tat Thanh Road	Not available	Face-to-face interviews
Zhang et al., 2018	750 respondents	Not available	15 neighborhoods selected from five administrative districts in central area and four administrative districts in the inner suburban region	0.004%	Household Travel Survey in Beijing conducted in 2015

Supplement 2: Estimation methods of land use variables

Variable	Unit	Quantification Method
Commuting Distance	meter	It is the measure of distance along the street network from home to workplace of respondents.
Intersection density	Nodes/ha	It is the measure of number of intersections per unit hectares in a 600m catchment area along the street network of respondents' homes. Calculations were done for areas inside the neighborhood boundary or outside. The basic purpose of the analysis was to get an idea about the connectivity, i.e. higher the intersection density, higher will be the connectivity.
Link Node Ratio		It is the measure of number of links (street segments) to the number of intersections within the catchment boundary of respondents' home. Calculations were made for areas inside the neighborhood boundary or outside.
Street Length Density	m/ha	It is the measure of length of street divided by the area of catchment boundary of 600m along the street network. Calculations were made for areas inside the neighborhood boundary or outside. Higher densities indicate better connectivity.
Number of Accessed Facilities		The number of facilities within the catchment boundary of 600m (based on street network) for each respondents' home were used to evaluate the accessibility of facilities. The facilities included parks, mosques, commercial areas, schools, and health facilities.
Number of Accessed Commercial Areas		The number of commercial areas within the catchment boundary of 600m along the street network of each respondents home.
Number of Accessed Parks		The number of parks within the catchment boundary of 600m along the street network of each respondents home.
Number of Accessed Mosques		The number of mosques within the catchment boundary of 600m along the street network of each respondents home.
Number of Accessed Public Buildings		The number of public buildings within the catchment boundary of 600m along the street network of each respondents home.
Number of Accessed Schools		The number of schools within the catchment boundary of 600m along the street network of each respondents home.
Number of Accessed Health Facilities		The number of health facilities within the catchment boundary of 600m along the street network of each respondents home.
Access to Neighborhood Facilities	meter	It is the measure of average distance from respondents' homes to all neighborhood facilities along the street pattern within the catchment boundary of 600m buffer outside the neighborhood boundary of each respondents home.
Accessibility to Commercial Areas	meter	It is the measure of average distance from respondents' homes to commercial areas along the street pattern within the catchment boundary of 600m buffer outside the neighborhood boundary of each respondents home.
Accessibility to Parks	meter	It is the measure of average distance from respondents' homes to parks along the street pattern within the catchment boundary of 600m buffer outside the neighborhood boundary of each

		respondents home.
Accessibility to Mosques	meter	It is the measure of average distance from respondents' homes to mosques along the street pattern within the catchment boundary of 600m buffer outside the neighborhood boundary of each respondents home.
Accessibility to Public Buildings	meter	It is the measure of average distance from respondents' homes to all public buildings along the street pattern within the catchment boundary of 600m buffer outside the neighborhood boundary of each respondents home.
Accessibility to Schools	meter	It is the measure of average distance from respondents' homes to schools along the street pattern within the catchment boundary of 600m buffer outside the neighborhood boundary of each respondents home.
Accessibility to Health facilities	meter	It is the measure of average distance from respondents' homes to health facilities along the street pattern within the catchment boundary of 600m buffer outside the neighborhood boundary of each respondents home.

Supplement 3: Frequencies and percentages of categorical findings of the overall sample.

	Category	Frequency	Percent		Category	Frequency	Percent		Category	Frequency	Percent
Gender	Male	282	67.6%	Location of work	Not Applicable	134	32.1%	Commute Mode Choice	Private car	209	50.1%
	Female	135	32.4%		Inside Neighborhood	67	16.1%		Motorbike	137	32.9%
					Outside Neighborhood	216	51.8%		Public transport	18	4.3%
Education	No degree	51	12.2%	Shopping Mode Choice	Not Applicable	2	0.5%		Walking or Cycling	12	2.9%
	High School/Diploma	136	32.6%		Private car	184	44.1%		App Based	26	6.2%
	University Degree Bachelors	145	34.8%		Motorbike	123	29.5%		Paratransit	15	3.6%
	Higher Education Degree(Master or Doctoral)	85	20.4%		Public transport	14	3.4%				
Occupation	Not Applicable	1	0.2%	Location of shopping	Walking or Cycling	61	14.6%	Location of shopping	Not Applicable	1	0.2%
	Employed or Student	265	63.5%		App Based	18	4.3%		Inside Neighborhood	146	35.0%
	Unemployed	85	20.4%		Paratransit	15	3.6%		Outside Neighborhood	270	64.7%
	Work at home	66	15.8%						Total / each	417	100.0%

Supplement 4: Frequencies and percentages of categorical findings based on case-study neighborhoods.

Shopping Mode Choice							Commute Mode Choice																																									
Category							Category																																									
Location of residence							Location of residence																																									
Karim Block 1							Karim Block 2																																									
Karim Block 2							kashmir block																																									
Khyber block							Raza Block																																									
Satluj block							Total																																									
Paratransit	%	N	%	N	%	N	Not Applicable	%	N	%	N	App Based	%	N	%	N	Walking or Cycling	%	N	%	N	Public transport	%	N	%	N	Motorbike	%	N	%	N	Private car																
0.0%	0	0.0%	0	15.9%	10	60.3%	38	0.0%	0	1.6%	1	3.2%	2	6.3%	4	4.8%	3	22.2%	14	61.9%	39	22.2%	3	22.2%	14	61.9%	39	22.2%	3	22.2%	14	61.9%	39															
1.4%	1	2.9%	2	30.0%	21	0.0%	0	18.6%	13	44.3%	31	2.9%	2	4.3%	3	1.4%	1	2.9%	2	20.0%	14	70.0%	49	20.0%	14	70.0%	49	20.0%	14	70.0%	49																	
1.4%	1	4.3%	3	18.6%	13	7.1%	5	41.4%	29	27.1%	19	0.0%	0	5.7%	4	11.4%	8	2.9%	2	31.4%	22	45.7%	32	31.4%	22	45.7%	32	31.4%	22	45.7%	32	31.4%	22															
11.1%	10	5.6%	5	0.0%	0	5.6%	5	40.0%	36	37.8%	34	0.0%	0	5.6%	5	5.6%	5	2.2%	2	3.3%	3	41.1%	37	42.2%	38	41.1%	37	42.2%	38	41.1%	37	42.2%	38															
1.4%	1	1.4%	1	2.7%	2	1.4%	1	29.7%	22	63.5%	47	0.0%	0	1.4%	1	2.7%	2	4.1%	3	2.7%	2	29.7%	22	59.5%	44	29.7%	22	59.5%	44	29.7%	22	59.5%	44															
4.0%	2	14.0%	7	22.0%	11	4.0%	2	26.0%	13	30.0%	15	0.0%	0	2.0%	1	16.0%	8	0.0%	0	12.0%	6	36.0%	18	34.0%	17	36.0%	18	34.0%	17	36.0%	18	34.0%	17															
3.6%	15	4.3%	18	14.6%	61	3.4%	14	29.5%	123	44.1%	184	0.5%	2	3.6%	15	6.2%	26	2.9%	12	4.3%	18	32.9%	137	50.1%	209	32.9%	137	50.1%	209	32.9%	137	50.1%	209															
Occupation							Gender							Location of work							Education																											
Category							Category							Category							Category																											
Location of residence							Location of residence							Location of residence							Location of residence																											
Karim Block 1							Karim Block 2							kashmir block							Khyber block							Raza Block							Satluj block							Total						
Work at home	%	N	%	N	%	N	Unemployed	%	N	%	N	Male	%	N	%	N	Outside Neighborhood	%	N	%	N	Inside Neighborhood	%	N	%	N	Not Applicable	%	N	%	N	Higher Education Degree(Master or Doctoral)	%	N	%	N	University Degree Bachelors	%	N	%	N	High School/Diploma	%	N	%	N	No degree	
4.8%	3	52.4%	33	42.9%	27	0.0%	0	27.0%	17	73.0%	46	33.3%	21	11.1%	7	55.6%	35	15.9%	10	27.0%	17	38.1%	24	19.0%	12	19.0%	12	19.0%	12	15.9%	10	27.0%	17	38.1%	24	19.0%	12	19.0%	12	15.9%	10	27.0%	17	38.1%	24	19.0%	12	
18.6%	13	8.6%	6	71.4%	50	1.4%	1	25.7%	18	74.3%	52	57.1%	40	14.3%	10	28.6%	20	34.3%	24	32.9%	23	22.9%	16	10.0%	7	10.0%	7	10.0%	7	34.3%	24	32.9%	23	22.9%	16	10.0%	7	10.0%	7	34.3%	24	32.9%	23	22.9%	16	10.0%	7	
11.4%	8	5.7%	4	82.9%	58	0.0%	0	14.3%	10	85.7%	60	74.3%	52	20.0%	14	5.7%	4	18.6%	13	40.0%	28	38.6%	27	2.9%	2	2.9%	2	2.9%	2	18.6%	13	40.0%	28	38.6%	27	2.9%	2	2.9%	2	18.6%	13	40.0%	28	38.6%	27	2.9%	2	
34.4%	31	16.7%	15	48.9%	44	0.0%	0	46.7%	42	53.3%	48	40.0%	36	8.9%	8	51.1%	46	12.2%	11	32.2%	29	38.9%	35	16.7%	15	16.7%	15	16.7%	15	12.2%	11	32.2%	29	38.9%	35	16.7%	15	16.7%	15	12.2%	11	32.2%	29	38.9%	35	16.7%	15	
5.4%	4	13.5%	10	81.1%	60	0.0%	0	35.1%	26	64.9%	48	58.1%	43	25.7%	19	16.2%	12	17.6%	13	41.9%	31	25.7%	19	14.9%	11	14.9%	11	14.9%	11	17.6%	13	41.9%	31	25.7%	19	14.9%	11	14.9%	11	17.6%	13	41.9%	31	25.7%	19	14.9%	11	
14.0%	7	34.0%	17	52.0%	26	0.0%	0	44.0%	22	56.0%	28	48.0%	24	18.0%	9	34.0%	17	28.0%	14	34.0%	17	30.0%	15	8.0%	4	8.0%	4	8.0%	4	28.0%	14	34.0%	17	30.0%	15	8.0%	4	8.0%	4	28.0%	14	34.0%	17	30.0%	15	8.0%	4	
15.8%	66	20.4%	85	63.5%	265	0.2%	1	32.4%	135	67.6%	282	51.8%	216	16.1%	67	32.1%	134	20.4%	85	34.8%	145	32.6%	136	12.2%	51	12.2%	51	12.2%	51	20.4%	85	34.8%	145	32.6%	136	12.2%	51	12.2%	51	20.4%	85	34.8%	145	32.6%	136	12.2%	51	

Supplement 5: The descriptive statistics of nine land use variables for the six case-study neighborhoods in Lahore (N=417).

		Mean	Minimum	Maximum	Range	Standard Deviation	Variance
Karim Block 1	Intersection Density	1.637	1.384	1.801	0.418	0.177	0.031
	Link-Node Ratio	1.038	1.015	1.075	0.060	0.024	0.001
	Street-Length Density	0.196	0.158	0.232	0.074	0.035	0.001
	Job Commuting Distance	6.351	0.257	15.410	15.153	4.895	23.960
	Population Density	326.179	326.179	326.179	0	0	0
	No. of Bus Stops	3.25	3	4	1	0.439	0.193
	Average Distance to Bus Stop	0.649	0.630	0.706	0.076	0.033	0.001
	No. of facilities	56.68	51	61	10	4.417	19.510
	Average Distance to Facilities	0.574	0.314	1.116	0.802	0.323	0.105
Karim Block 2	Intersection Density	1.223	0.932	1.450	0.519	0.155	0.024
	Link-Node Ratio	1.219	1.028	1.485	0.457	0.135	0.018
	Street-Length Density	0.114	0.106	0.126	0.020	0.006	0.000
	Job Commuting Distance	9.390	2.900	17.360	14.460	3.512	12.335
	Population Density	214.981	214.981	214.981	0	0	0
	No. of Bus Stops	5	5	5	0	0	0
	Average Distance to Bus Stop	0.769	0.754	0.785	0.031	0.010	0.000
	No. of facilities	96.79	91	104	13	3.799	14.432
	Average Distance to Facilities	0.273	0.106	0.491	0.385	0.131	0.017
Kashmir Block	Intersection Density	1.103	1.025	1.223	0.198	0.061	0.004
	Link-Node Ratio	1.430	1.272	1.574	0.302	0.086	0.007
	Street-Length Density	0.216	0.183	0.259	0.077	0.024	0.001
	Job Commuting Distance	6.618	0.128	13.216	13.088	3.811	14.525
	Population Density	303.939	303.939	303.939	0	0	0
	No. of Bus Stops	3.36	3	4	1	0.483	0.233
	Average Distance to Bus Stop	0.552	0.467	0.706	0.239	0.115	0.013
	No. of facilities	130.87	118	151	33	15.195	230.896
	Average Distance to Facilities	0.128	0.044	0.218	0.174	0.073	0.005
Khyber Block	Intersection Density	2.740	2.575	2.876	0.301	0.110	0.012
	Link-Node Ratio	1.667	1.488	1.789	0.301	0.079	0.006
	Street-Length Density	0.123	0.109	0.128	0.020	0.005	0.000
	Job Commuting Distance	3.566	0.733	8.712	7.979	2.632	6.926
	Population Density	444.789	444.789	444.789	0	0	0
	No. of Bus Stops	1	0	3	3	1.422	2.022
	Average Distance to Bus Stop	0.285	0.000	0.854	0.854	0.405	0.164

Raza Block	No. of facilities	83.37	70	104	34	12.817	164.280
	Average Distance to Facilities	0.132	0.039	0.200	0.161	0.048	0.002
	Intersection Density	1.265	1.216	1.369	0.153	0.051	0.003
	Link-Node Ratio	1.062	1.039	1.146	0.107	0.043	0.002
	Street-Length Density	0.101	0.091	0.109	0.017	0.006	0.000
	Job Commuting Distance	7.062	2.311	18.470	16.159	4.243	18.003
	Population Density	205.097	205.097	205.097	0	0	0
	No. of Bus Stops	2.46	2	3	1	0.502	0.252
	Average Distance to Bus Stop	0.698	0.579	0.837	0.258	0.129	0.017
	No. of facilities	43.91	18	60	42	16.376	268.169
Satluj Block	Average Distance to Facilities	0.742	0.349	1.033	0.684	0.245	0.060
	Intersection Density	1.499	1.428	1.581	0.153	0.052	0.003
	Link-Node Ratio	1.634	1.472	1.780	0.308	0.107	0.011
	Street-Length Density	0.197	0.146	0.227	0.082	0.035	0.001
	Job Commuting Distance	8.391	2.222	16.819	14.597	4.255	18.101
	Population Density	244.634	244.634	244.634	0	0	0
	No. of Bus Stops	3	3	3	0	0	0
	Average Distance to Bus Stop	0.567	0.567	0.567	0	0	0
	No. of facilities	68.46	60	75	15	5.949	35.396
	Average Distance to Facilities	0.541	0.424	0.709	0.285	0.107	0.011