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The impacts of built environment on home-based work and non-work trips: An empirical study from Iran

Roya Etminani-Ghasrodashti [a,*], Mahyar Ardeshiri [b]

[a] Department of Art and Architecture, Science and Research Branch, Islamic Azad University, Tehran, Iran
[b] Department of Architecture and Urban Planning, Beyza Branch, Islamic Azad University, Beyza, Iran

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ABSTRACT

This paper aims to explore the impact of built environment attributes in the scale of one quarter-mile buffers on individuals' travel behaviors in the metropolitan of Shiraz, Iran. In order to develop this topic, the present research is developed through the analysis of a dataset collected from residents of 22 neighborhoods with variety of land use features. Using household survey on daily activities, this study investigates home-based work and non-work (HBW and HBN) trips. Structural equation models are utilized to examine the relationships between land use attributes and travel behavior while taking into account socio-economic characteristics as the residential self-selection. Results from models indicate that individuals residing in areas with high residential and job density, and shorter distance to sub-centers are more interested in using transit and non-motorized modes. Moreover, residents of neighborhoods with mixed land uses tend to travel less by car and more by transit and non-motorized modes to non-work destinations. Nevertheless, the influences of design measurements such as street density and internal connectivity are mixed in our models. Although higher internal connectivity leads to more transit and non-motorized trips in HBW model, the impacts of design measurements on individuals travel behavior in HBN model are significantly in contrast with research hypothesis. Our study also shows the importance of individuals' self-selection impacts on travel behaviors; individuals with special socio-demographic attributes live in the neighborhoods with regard to their transportation patterns. The findings of this paper reveal that the effects of built environment attributes on travel behavior in origins of trips do not exactly correspond with the expected predictions, when it comes in practice in a various study context. This study displays the necessity of regarding local conditions of urban areas and the inherent differences between travel destinations in integrating land use and transportation planning.

1. Introduction

Travel challenges in developing countries are different from wealthier global. While recent studies suggest that car ownership rates in advanced economies have been peaked (Goodwin, 2012), motorization continues sharply in developing countries due to the economic growth and rising incomes. Recent research have estimated that the majority of vehicle use by 2050 will be found in developing countries, especially China, India and other Asian countries (United Nations Habitat,

* Corresponding author. Tel.: +98 09177113447.
E-mail addresses: roya.etminani@gmail.com (R. Etminani-Ghasrodashti), mahyarardeshiri@yahoo.com (M. Ardeshiri).

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2011). So policy proposals to reduce negative impacts of car dependency in developing countries could not thoroughly follow the same tools.

Multiple studies have investigated the subject of travel behavior to identify various factors which are determinants of daily trip patterns. In this regard, urban planners have been interested to understand the chief factors that can promote active travel patterns and decrease car-oriented behaviors in order to obtain sustainable urban transport. Considering the land use and transport planning as an integrated subject is the most prominent strategy adopted by several researchers in travel behavior studies (e.g., Newman and Kenworthy, 1989; Giuliano, 1995; Newman et al., 1995; Gordon and Richardson, 1997). The association between land use and travel behavior provides a wealth of empirical studies in North America and Europe. Based on their research methodology, the empirical studies on interaction between built environment and travel patterns have been divided into two main groups: comparative and analytical approach. The analytical approach which explores the correlations of land use and transport through multiple variables, has been studied as aggregated and disaggregated models. The aggregated models which are mostly performed to test the impacts of physical patterns on collective travel behaviors in a large geographical zone by using aggregated data (e.g., Pushkarev and Zupan, 1977; Frank and Pivo, 1994; Cervero and Gorham, 1995), were criticized due to their oversimplification of complex relationships between traffic behaviors and urban form (Gordon and Richardson, 1997; Kitamura et al., 1997). In order to eliminate cited limitations, a number of studies collected disaggregated data by individuals' trip diary and survey in the unit of households (e.g., Handy, 1996; Boarnet and Crane, 2001; Cervero, 2002; Naess and Jensen, 2004). This model usually provides a more comprehensive understanding of individuals' decision making on choosing special trip patterns. Since the 1990s town planning has dramatically shifted to employ particular built environment characteristics introduced by new urbanism policies (Duany and Plater-Zyberk, 1991) such as density, design and diversity to organize more sustainable trip patterns.

Whereas travel is traditionally considered as a derived demand, travellers are assumed to choose their travel patterns based on the cost and benefit of different ways to obtain their desired activities (Van Wee, 2002). So, built environment impacts individuals' travel patterns through altering the trip opportunities. Nonetheless, empirical studies on land use influences cannot fully resolve the issues of individuals' travel behavior, specifically since debates on residential self-selection have emerged (Bagley and Mokhtarian, 2002). Moreover, some studies argue that far from being completely determined by basic needs, travel demand is largely influenced by individuals' attitudes toward travel (Mokhtarian and Salomon, 2001).

Although integrated land use and transport strategies have gained extensive policy interest in North America, Europe, and Australia over the past two decades, there is some doubt about the implication of these policies in countries like Iran. Moreover, the differences in spatial characteristics in developing countries such as level of monocentricity, population densities, design and geographical locations (Cervero, 2013) make it difficult to implicate the land use as an efficient tool to control travel behaviors. Additionally, local governments application of biased versions of western land use strategies in metropolitan areas, accounts for more unorganized patterns of transportation.

Far less is known on the subject of land use and travel planning in Iran, though new studies are moderately ascending. This paper aims to explore how built environment attributes in one quarter-mile buffer areas influence on home-based travel behaviors. We expanded travel patterns to both work and non-work destinations to investigate the effects of various urban form characteristics on the amount of weekly trips produced by individuals. To develop the study, micro-level travel data were obtained from a household survey conducted in 2014 and structural equation models were employed to explore travel behaviors while controlling socio-economic attributes for individuals' decision making. In the next section, related studies on travel behavior are reviewed. Section 3 expresses the methodology of the study. Section 4 indicates the data analysis and SEM results. The final section concludes the paper.

2. Built environment and travel behavior

There is a considerable amount of research on the link between built environment and travel behaviors in different countries by various contexts. In travel research the potential to adjust travel demand by modifying the built environment is explored through measures that are often named Ds. The original "three Ds" referred to density, design and diversity (Cervero and Kockelman, 1997), and were later completed by destination accessibility and distance to transit (Ewing and Cervero, 2001; Ewing et al., 2009). On the other hand, travel behavior outcomes have often been modeled as trip frequency (e.g., Zegras, 2007; Fan, 2007; Frank et al., 2007a,b; Cao, 2010), trip length (e.g., Boarnet et al., 2008; Boer et al., 2007), modal choice (e.g., Cervero, 2002; Chatman, 2003; Ewing et al., 2004; Zhang, 2004; Frank et al., 2007a,b) and vehicle miles traveled (VMT) (e.g., Bhatia, 2004; Frank and Engelke, 2005; Greenwald, 2009).

It is believed by the most studies that density often influences travel behaviors through reducing car ownership and VMT (e.g., Bhatia, 2004; Zhou and Kockelman, 2008) and leads to increased walking and transit trips (e.g., Bhatia, 2004; Greenwald, 2009). It has been pointed out that density certainly effects travel behavior due to the conditions of dense places that provide shorter distances among activity destinations, better access to public transport stations and more tendencies toward walking trips (Ewing and Cervero, 2010).

Another important dimension of built environment is diversity that is defined by the number of various land uses in a given area. Recent research has found that higher degree of mixed land uses result in less VMT (Kuzmyak, 2009), more choice of walking for work and non-work trips (Frank et al., 2008; Rajamani et al., 2003) and more transit mode choices (Cervero, 2002; Frank et al., 2009).

Design, which commonly refers to street network characteristics within an area, has been proven to decrease VMT per household (Ewing et al., 2009; Greenwald, 2009), increase walking/biking trips per person and transit mode choice for work and non-work trips (Soltani and Allan, 2006; Greenwald, 2009; Frank et al., 2009).

The other important land use attribute is destination accessibility, which is often defined as distance to central business districts, and has been strongly related to both motorized and non-motorized trips due to lower levels of car ownership and car dependency at central locations (Ewing and Cervero, 2010). The last explored D is distance to transit which indicates transit access and positively influences active travel behaviors (Boarnet et al., 2008).

Although several studies demonstrate the relationship between built environment and travel behavior, some conflicts exist on findings and conclusions of empirical evidence. It can be exemplified by studies that found subjective factors such as individuals' attitudes toward travel and residential neighborhoods, lifestyle and socio-economic factors are among the most determinants of travel behaviors (Mokhtarian et al., 2001; Van Acker et al., 2014). Moreover, inclination toward the impact of residential self-selection has notably shifted over the past years (e.g., Bagley and Mokhtarian, 2002; Cao et al., 2006). It means that individuals choose their residential neighborhood based on their travel preferences and habits. So controlling residential self-selection may count for descending built environment effects on travel behavior (Cao et al., 2006).

The literature on travel studies has mainly been performed in advanced countries, and little research has been conducted in Iranian cities. In one of the first studies conducted in the metropolitan area of Shiraz, the impacts of density on number of daily car trips have been explored. Results indicated that socio-economic variables were the main determinants of car trips and urban density was not only ineffective in reducing car use, but in areas with high levels of density daily car trips were increased (Soltani and Etminani Ghasrodashti, 2010). In a similar study, physical characteristics of traffic zones in Shiraz contributed to trip generation. The results demonstrated that socio-economic characteristics were again the most positive determinants of trip generation among the zones. In contrast, distance from central business district and distance from public transport facilities were negatively related with trip generation. Other physical factors such as land use mix and network connectivity were found not important in influencing trip generation (Soltani and Esmaeili, 2011). Nevertheless, in a study by Masoumi (2013), the influence of local accessibility on travel behavior in two compact and sprawl neighborhoods of Tehran were explored. Results revealed that the centralized neighborhood with more local accessibility to retail shops generates fewer shopping trips. Overall, compared to the increasing public attention given to organized land use and travel planning in line with each other, developing countries suffer from insufficient debates on this subject.

This study is developed in the special context of an Iranian city that unlike the developed countries, land use and transportation planning have not been considered as an integrated subject by urban policy makers. The model of this study contributes to the conceptual and methodological approaches explained above and attempts to recognize the trip behavioral differences in terms of investigating the explanatory power of built environment characteristics. According to the past studies, the effects of land use measures in buffer- based and TAZ based areas on travel behavior are significantly different (Lee et al., 2014). Hence, in order to reinforce the level of built environment influences on travel patterns, land use variables are measured in the scale of one quarter-mile buffer areas. As the effects of built environment differ by trip purposes, we considered frequency of both work and non-work trips by private car, transit and non-motorized modes. In addition, socio-economic characteristics of travellers contributed to controlling the models. Moreover, to understand the decision making process in choosing residential neighborhood, the impacts of residents' self-selection on their living areas will be taken into account.

3. Methodology

3.1. Study area and data sources

The present study used data from a survey in 2014 from 22 residential areas in the metropolitan of Shiraz, Iran. Shiraz is located in the northwest of Fars Province, with an area of 17,889.1 Hectares and 416,141 households (Shiraz Municipality, 2014). Shiraz is among the main economic hubs in the southern region of Iran and is one of the most prominent centers of historical-tourism and natural environment that has attracted large numbers of permanent and temporary migrants in recent years. According to previous research, more than 50% of residents use their private vehicles for daily trips and this is the main reason behind the increasing air pollution (Soltani and Esmaeili, 2011). Although the history of urban planning[1] in Shiraz is short, it appears that its master plans did not take the environmental issues into consideration. During 2000–2005 Shiraz faced sprawling development with the conversion of large plots of vegetation into built-up areas. Therefore, the urban texture has changed from a compact to a dispersed or sprawled pattern. Nevertheless, the growth of Shiraz cannot be characterized as complete sprawl (Sabet Sarvestani et al., 2011).

Although the municipality of Shiraz is among the largest institutes in Iran, little attention has been paid to sustainable transportation planning and traffic improvement. Recent studies reveal that the percent of transportation planning fond in Metropolitan of Shiraz has been decreased from 48% in 2007 to 22% in 2012 (Soltani, 2014). In addition, the public trans-

[1] The first comprehensive master plan of Shiraz was provided by Tehran University, Department of Architecture, in1966; the second was produced by Naghshe-Jahan Pars Consultants, in 1989.

port budget has been shifted from 28% to 11% in that same time period. The increasing share of road projects implicates the car-oriented tendencies toward transportation planning by policy makers in Shiraz.

In present study, the study areas were selected in a way that cover a variety of urban forms (from organic urban forms in traditional neighborhoods to modern and sprawl developments) and different socio-economic variables (Cao et al., 2006). The 22 study areas were chosen as a one quarter-mile buffer area, because buffer-based land use measures are more practical and include more reliable statistical significance compared to TAZ-based variables (Lee et al., 2014). We selected buffer areas through corridor and central neighborhoods. A corridor neighborhood here is defined as a linear area in which service-commercial uses and retail stores are concentrated through a main arterial street. Central neighborhoods are mixed and non-mixed residential areas. Our buffers were selected among these two kinds of neighborhoods. The priority of selecting the buffers was municipal regions, property prices and traffic zones of Shiraz.

The survey collected attributes on socio-economic as well as features of work and non-work trips made by individuals in a typical week. A total of 900 heads of household who were mostly male (78%) participated in the survey. Most of the respondents (50.2%) were middle-aged between 41 and 64 years. According to the employment status, 44.8% were full time workers, 5% were part-time workers, 28.2% were unemployed, 19.2% were retired and 2.8% were students. The mean of car ownership in sample population was 1.13.

3.2. Built environment attributes

Basic spatial data was geocoded by using a Geographical Information System (GIS). As discussed before, various land use attributes were considered for built environment measurements. The dimensions of built environment around the neighborhood are measured by density, design, diversity and local accessibility to transit in the one quarter-mile buffer areas. The variables of these dimensions are computed at trip origins in order to understand land use effects on home-based travel behaviors. For both trip destinations, distance to closest employment sub-center and main CBD have been included as regional accessibility.

Following the literature, this study employs two variables for density: residential density and job density. Residential density is described as the number of residents per net residential area of each buffer and job density is calculated as the number of commercial-service activities (jobs) per square km of total buffer area. The diversity of built environment is measured by entropy index. Entropy measure which indicates single-use environments at low values and more varied land uses at higher values (Ewing and Cervero, 2010), quantifies the degree of balance across various land uses. Among the 11 land uses in the detailed plan of Shiraz (revision of detailed plan, 2014), seven land use types are considered for evaluating the mixed uses, including, residential, commercial and services, parks and green spaces, educational, public (health and sport), cultural-religious, and roads. According to the low portion of industry and agricultural areas in the case study, these land uses are eliminated in the analysis. Information is obtained from detailed plan and recalculated at the scale of buffers in ArcGis 10.2 according to the equation.

$$EI_i = -\left(\sum_{j=1}^{J} Pj \cdot \ln Pj\right) / lnJ$$

In this equation, Pj refers to the ratio of each of the land uses in buffer areas and J is the sum of various kinds of land uses (Lee et al., 2014).

The design measurement in this study is explained as street density and internal connectivity. Street density, which indicates number of linear miles of street per square mile of land, is calculated by dividing the total street length per unit of area by the area. A higher value of street density would reveal more streets and further connectivity in road network. Internal connectivity indicates the density of intersection calculated here as the number of street intersections divided by the number of intersections plus cul-de-sacs. The maximum value is 1.0, while the higher numbers refer to higher levels of connectivity. It is assumed that the probability of walking trips increases by greater connectivity of street networks (Tresidder, 2005). The last measurement of the built environment that is extracted from household survey is local accessibility to transit. This variable is defined as distance from home to the closest bus stop and intersection.[2] Moreover, to understand the influences of regional accessibility on individuals travel behavior, distance to closest employment sub-center and distance to historical CBD of Shiraz[3] is extracted from the center of each buffer area. Table 1 indicates the built environment attributes of 22 surveyed buffer areas. According to this table, land use attributes are different in the various study samples. While some urban neighborhoods of our study are more compact with higher levels of density and diversity, suburban neighborhoods have been developed in a sprawl way with long distance to facilities and public transport. Fig. 1. represents a ¼ mile buffer area as the sample.

[2] We are aware that local accessibility is defined by Handy (1996) as distance from home to closest store. Although we calculated the distance from home to closest intersection and bus station as local accessibility and not as 5th D (distance to transit), in some cases distances from home to these destinations (Km) are short, but some barriers prevent easy access to them. So distance in minute is more appropriate to conduct accessibility. Moreover, to decrease the overlapping of accessibility with diversity, we consider closest intersection and bus stop instead of closest store.

[3] In this paper the cultural-historical region of Shiraz is considered as the CBD of city.

Table 1
Summary of built environment attributes of 22 study areas.

Built environment measures at buffer-based scale	Minimum	Maximum	Average	SD
Entropy index	0.35	0.98	0.49	0.10
Street density	1.80	4.93	3.07	0.90
Internal connectivity	0.46	1	0.68	0.13
Residential density	0.192	0.571	381.30	112.14
Job density (jobs /km^2)	38	1186	254.95	265.57
Distance from home to closest bus stop (min)	1	5	1.62	0.744
Distance from home to closest intersection (min)	1	60	10.02	6.95
Distance to closest sub-center (km)	0.30	12	4.78	2.93
Distance to main CBD (km)	3.20	20	8.125	4.95

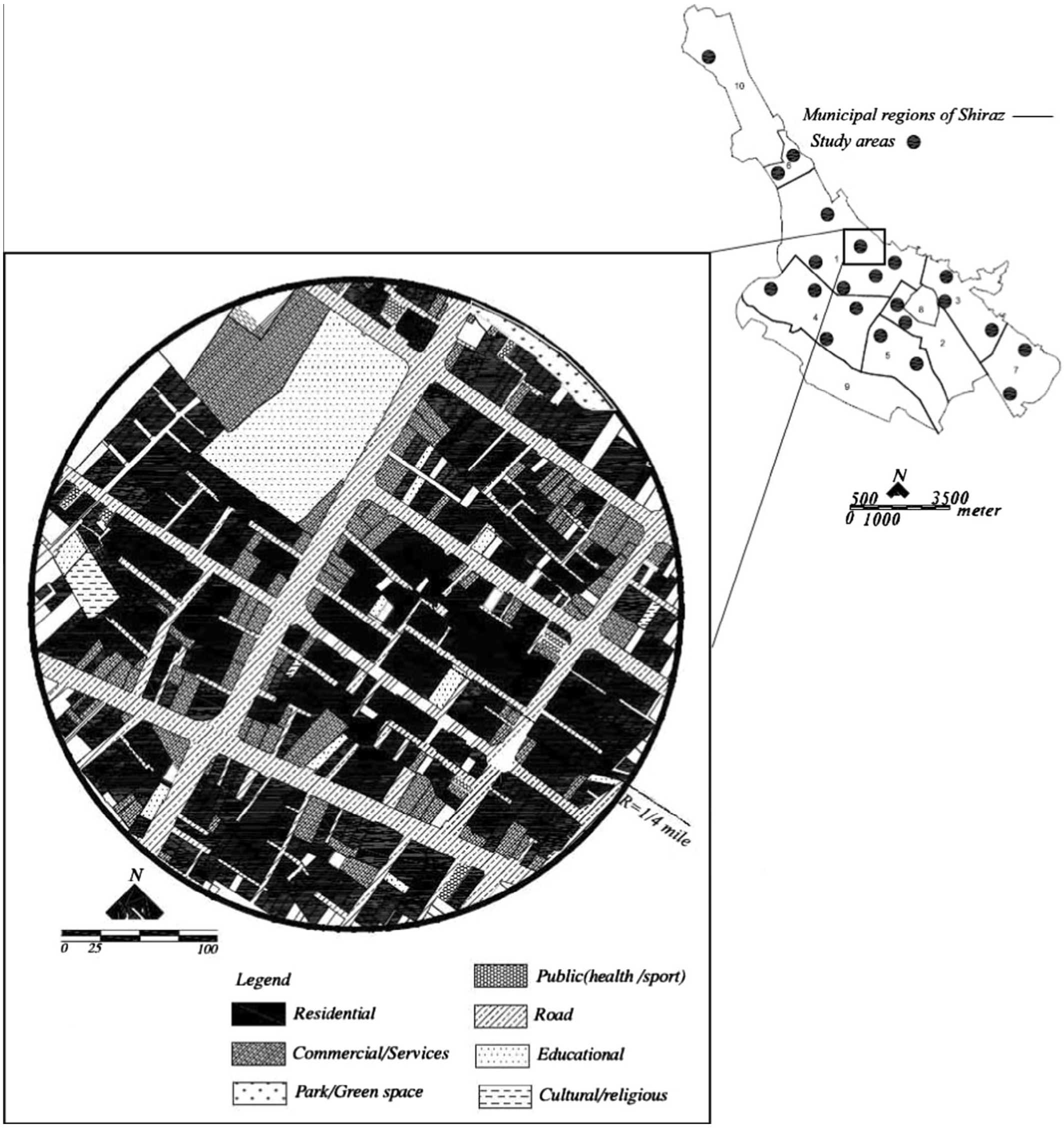

Fig. 1. A sample of selected study areas.

3.3. Travel behaviors: home-based work and non-work trips

As previously discussed, travel behavior is defined as home-based work and non-work trips. Individuals were asked to report their weekly trip frequencies from home to job destinations by various modes of travel (private car and alone, private

Table 2
Sample travel behavior and socio-economic characteristics ($n = 900$).

Variables	Mean	Std. Deviation
Travel behavior variables		
No. of HBW trips by car	2.96	2.88
No. of HBW trips by transit	1.32	2.31
No. of HBW trips by non-motorized vehicle	0.45	1.45
No. of HBN trips by car	29.98	28
No. of HBN trips by transit	13.56	22.91
No. of HBN trips by non-motorized vehicle	19.43	28.04
Household characteristics		
No. of children under 18 in household	0.80	0.87
No. of people above 18 in household	2.71	1.21
No. of workers in household	1.56	0.88
No. of private cars in household	1.13	0.78
Job characteristics		
No. of full-time jobs	0.56	0.53
No. of part-time jobs	0.40	0.56
Time spent to get to work	22.86	23.29
	23.36	20.95
Individuals characteristics		
Sex(1 = male)	0.78	0.215
Age	44	11.53
Income ($)	550	262
Maximum desired distance for walking	23.36	20.95

Note: HBW = home-based work, HBN = home-based non-work.

car with others, walking, biking, bus, taxi, job service and agency vehicle). About 44% of respondents drive alone, 15% drive with others, 10% walk, 1% use bicycle, 11% use bus, 7% take taxi, 9% use job service and 3% use an agency vehicle to travel to work. Total work trips are calculated by summing weekly individual use of various modes and it is then reduced to three main categories including: private car, public transport and walking/cycling. These home-based trips to work are characterized by the following frequencies: 62.5% trips by car, 28% by transit (public transport) and 9.5% non-motorized trips (walking/cycling trips). Moreover, frequency of home-based non-work trips was measured as other measurement of travel behavior in our models. Respondents were asked to report the number of their non-work trips from home to different destinations for service-shopping and leisure activities in a typical week by six travel modes; private car and alone, private car with others, bus, taxi, walking and biking. These six modes of trips have been summarized to three main modes (private car, public transport and walking/cycling). About 41% of home-based non-work trips were taken by car, 26% by transit and 33% were non-motorized trips (see Table 2).

3.4. Other variables

To explore the determinants of travel behavior in work and non-work trips from home, some other endogenous variables have been entered in the models. Our household survey also supported data on variables such as socio-demographic and job characteristics (see Table 2). Individual characteristics include sex of respondent (0 = female, 1 = male), age, monthly income, maximum desired distance for walking to get to a certain destination by individuals (min), and job characteristics of individual encompassing number of full-time jobs, number of part time jobs, time spent to get to work by individuals (min). Household characteristics are defined as number of children under 18, number of people above 18, number of workers and number of private cars in household.

4. Data analysis

The variables discussed in the previous section, will now be entered as input in structural equation models (SEM). Structural Equation Model is one of the most beneficial techniques used in the study of travel behavior. SEM comprises two or more equations which represent the hypothesized relationships among variables and allow us to estimate endogenous relations between variables (Bagley and Mokhtarian, 2002; Golob, 2003). These features allow SEM to explore direct, indirect and multiple relationships and also to investigate reverse associations.

In this paper, we not only focus on the associations between built environment and home-based trips, but we also explore the differences of these associations between work and non-work trips. We assume that non-work trips are influenced more by built environment attributes compared with work-trips. In work-only trips, land use features of the workplace should impact on commuting decisions, and workplace attributes should have a very straightforward influence on travel behavior (Van Acker and Witlox, 2010). We are aware that individuals who work in central and denser places are more eager to use non-motorized modes and transit and use the private car less (Silva et al., 2012). However, due to the special context of our study, the built environment of living areas appears to be more crucial in determining travel behaviors. Since the job locations are sprawled throughout the city of Shiraz, finding a job demands a high sense of flexibility by individuals and self-decision of individuals, their preferences and desires do not often influence their current job places; so we assume that the land use characteristics of the workplaces have minor impact on travel behavior of respondents.

Since the equations will be estimated by minimizing the distinctions between the model-implied covariance matrix and the empirically-computed covariance matrix for the data, the evaluation depends not only on the model but also on the estimation method. One of the most common estimation methods is maximum likelihood (ML) which requires the normal distribution of endogenous variables (Harrington, 2009). The other three applied methods have been used by Amos 22. Package to estimate models including: Asymptotically distribution-free (ADF), generalized least squares (GLS), and un-weighted least squares (ULS). ADF method works better in estimation of standard errors and does not require normal data. Although the results of four estimation methods were similar, ML was, in all models, the method with the lowest mean discrepancy.

We also tested the models for the quality of their specifications by using some fitting indices. These fitting indices involved χ^2 test value divided by the model degrees of freedom, normed fit index (NFI), comparative fit index (CFI) and root-mean square error of approximation (RMSEA). The brief summary of goodness-of-fit based on estimation methods for two sets of models on three travel modes for work and non-work trips have been indicated in Table 3. These values compare approximately well to standard values which must be less than 2 for χ^2/df, more than 0.95 for NFI and CFI and less than 0.1 for RMSEA (Bentler and Bonett, 1980; McDonald and Marsh, 1990; Browne and Cudeck, 1993).

4.1. Home-based work trips

The first structural equation model has standardized total effects of travel frequency in work trips. This model investigates the impacts of built environment variables along with socio-economic factors on the number of home-based work trips by three modes of mobility (see Table 4). In order to understand both direct (mediate) and indirect (unmediated) effects of exogenous and endogenous variables, the value of effects has been standardized. Results indicate that work trips from home influence by built environment attributes in terms of some measurements.

According to Table 4, residential and job densities in residential places significantly affect respondents travel behaviors. It means that respondents who live in the dense neighborhoods use more public transport and non-motorized modes to travel to work due to the existence of transit options. While residential and employment density at trip origin rises, the probability of choosing transit and non-motorized modes increases. Although entropy index in buffer areas has a slight positive effect on the likelihood of traveling to work by transit, its influence on non-motorized trips is in conflict with our expectations. Hence, land use diversity in buffer areas results in more travel to work by public transport and less by walking/cycling.

Though street density has not resulted in any significant impact on travel behavior of individuals, internal connectivity counts for fewer car trips and more use of public transport and non-motorized modes by respondents. Distance from home to closest bus stop merely impacts on more car trips and does not significantly influence other modes. Among regional accessibility measurements, distance to closest sub-center has a positive influence on car trips and negative impact on non-motorized options. As the distance of neighborhood from sub-centers intensifies, individuals tend to walk or cycle to work less. After residential density, this variable is among the most significant factors of built environment on work trips in our study. The effects of socio-economic factors on work trips are more or less in accordance with our expectations. Females are less likely to drive to work, and more eager to use public transport and non-motorized modes. This result is associated with findings from recent research that shows males have greater tendency toward using private vehicles to travel to work and thus produce more travel distance (Silva et al., 2012; Ma et al., 2015). Also, old adults use transit less for work trips. As it was expected, maximum desired distance for walking has a slight influence on non-motorized trips. Besides, the further a workplace is, the more transit trips and the fewer walking/cycling trips performed by the respondents. In addition, household characteristics including number of people under and above 18, number of workers and number of private cars meaningfully effect on commuters' decision toward work trips. Existence of more adults in the households decrease the possibility of driving a car to work and leads to more use of public transport (Lee et al., 2014). Individual travelers with greater access to vehicles in family rely significantly on driving to work and they are less interested in using transit and non-motorized trips.

4.2. Home-based non-work trips

Another structural equation model was utilized to explore non-work trips from home to different destinations (see Table 5). Variables that are related to individuals' work attributes (number of full time and part time jobs and time spent

Table 3
Goodness-of-fit measures.

Models	Standard values			
	$\chi^2/df < 2$	NFI > 0.95	CFI > 0.95	RMSEA < 0.1
Model 1: HBW trips	2.04	0.96	0.98	0.068
Model 2: HBN trips	1.94	0.98	0.99	0.062

Table 4
Model estimation results for HBW trips (standardized total effects).

	HBW trips		
	No. of car trips	No. of transit trips	No. of non-motorized trips
Built environment attributes			
Residential density	−0.012	0.161**	0.095**
Job density	−0.060*	0.005	0.096**
Entropy index	−0.011	0.066*	−0.076*
Street density	0.019	−0.049	0.017
Internal connectivity	−0.089**	0.075*	0.085**
Distance from home to closest bus stop	0.056*	−0.051	−0.036
Distance from home to closest intersection	0.029	−0.014	−0.052
Distance to closest sub-center	0.083**	−0.037	−0.119***
Distance to CBD	0.005	−0.008	−0.036
Individuals characteristics			
Sex	0.127***	−0.081**	−0.116***
Age	0.033	−0.084**	0.039
Income	0.024	−0.035	−0.050
Maximum desired distance for walking	−0.009	−0.033	0.075*
Job characteristics			
No. of full time jobs	−0.048	0.70*	0.053
No. of part time jobs	0.004	0.019	0.014
Time spent to get to work	0.042	0.194***	−0.177***
Household characteristics			
No. of children under 18 in household	−0.028	0.067*	−0.044
No. of people above 18 in household	−0.106***	0.129***	−0.017
No. of workers in household	−0.043	0.070*	0.020
No. of private cars in household	0.299***	−0.327***	−0.112***

* Significant $\alpha = 0.1$.
** Significant $\alpha = 0.05$.
*** Significant $\alpha = 0.01$.

Table 5
Model estimation results for HBN trips (standardized total effects).

	HBN trips		
	No. of car trips	No. of transit trips	No. of non-motorized trips
Built environment attributes			
Residential density	−120***	.025	128***
Job density	0.007	0.137***	0.086**
Entropy index	−0.223***	0.025	0.090**
Street density	0.150***	−0.023	−0.114***
Internal connectivity	0.097**	−0.016	−0.127***
Distance from home to closest bus stop	0.011	−0.059	−0.001
Distance from home to closest intersection	0.059	−0.077*	−0.028
Distance to closest sub-center	0.208***	−0.235***	−0.062
Distance to CBD	0.125***	−0.114***	−0.018
Individuals characteristics			
Sex	0.059	−0.078**	−0.085**
Age	0.043	−0.044	0.082**
Income	0.103***	−0.076*	−0.023
Maximum desired distance for walking	−0.097**	0.050	0.125***
Household characteristics			
No. of children under 18 in household	0.036	0.091**	0.004
No. of people above 18 in household	−0.023	0.154***	0.124***
No. of workers in household	0.105***	0.138***	0.036
No. of private cars in household	0.194***	−0.236***	−0.119***

* Significant $\alpha = 0.1$.
** Significant $\alpha = 0.05$.
*** Significant $\alpha = 0.01$.

to get to work) have been eliminated from this model. Among density measurements, residential and job densities significantly effect on travel behavior. Respondents residing in the neighborhoods with higher residential density and more accessibility to commercial and service activities are more likely to produce non-motorized trips and use more public transport for shopping and recreational destinations.

Entropy index in the buffer areas; that shows a weak relationship with home-based work trips; has a notable impact on non-work trips. Respondents of diverse neighborhoods with mixed land uses tend to use private car less and walk or cycle more to obtain service-shopping and leisure activities.

In this model, the impacts of design measurements on individuals' travel behavior are significantly in contrast with research hypothesis. It was assumed by default that high street density leads to high connectivity (Tresidder, 2005) and great street connectivity shortens access distances and provides more routes for public transport (Ewing and Cervero, 2010). In this study, neighborhoods with high street density affords more appropriate roads for car users, more congestion and lack of pedestrian safety and gradually low tendency toward walking/cycling trips. This analysis could be applied for internal connectivity too. Internal connectivity that is defined as intersection density provides short blocks with more walkability (Ewing and Cervero, 2010). Nevertheless, in our study internal connectivity results in fewer walking/cycling trips and more car uses. Respondents of neighborhoods with higher street connectivity are less interested in non-motorized trips, perhaps due to the traffic issues and perceptions of unsafe pedestrian roads. The impacts of regional accessibility is similar to past empirical research; distance from home to closest sub-center and CBD are related to more non-work trips by car and fewer transit choices.

In a similar manner, males are less interested in traveling by public transport and non-motorized trips. Contrary to HBW model, old respondents are more likely to use non-motorized modes for non-work trips. People with high incomes call for more trips by private cars and maximum desire toward walking has a negative influence on automobile mode. One of the most crucial factors of travel behavior is again car ownership. Respondents with more vehicles in their family use considerably fewer public transport options.

4.3. Relationship between residential self-selection and built environment attributes in the origin of trips

Since self-selection is associated with the importance of the relations between travel behavior and land use attributes, it is crucial to consider the impacts of respondents' decision making on selecting their residential neighborhood. It is assumed that residents intentionally choose to reside in the neighborhoods in accordance with their socio-economic characteristics. So, in both structural equations the interrelations between endogenous variables has been modeled too. Table 6 indicates the associations between socio-economic characteristics of respondents and their neighborhood attributes in the model of non-work trips. As the endogenous factors are the same for home-based work and non-work trips; we just consider the interrelations for home-based non-work trips. The standardized effects show that some of the built environment variables are significantly influenced by socioeconomic factors, thus it reveals the importance of self-selection effects due to the socio-economic differences between individuals. This result mentions the fact that different people reside in various places and travel in dissimilar manners. For instance, individuals with more monthly income tend to live in the neighborhoods with less residential and job densities; they are more likely to reside in places with longer distance to sub centers and CBD; So, the decision making of higher income people are in line with their travel behaviors. Male heads which indicated further lower tendency toward transit use and walking/cycling trips, have a stronger probability to live in the neighborhoods with lower residential and job density, with less mixed-land uses and higher street density and finally farther distance from CBD.

Table 6
Standardized total effects of decision-making on residential neighborhood in non-work trips.

	Residential density	Job density	Entropy index	Street density	Internal connectivity	Distance from home to closest bus stop	Distance from home to closest intersection	Distance to closest sub-center	Distance to CBD
Sex	−0.079*	−0.081*	−0.090**	0.086*	0.061	−0.030	0.085**	0.070	0.128***
Age	0.090**	0.019	0.012	−0.020	−0.028	−0.075*	0.055	0.001	0.000
Income	−0.133***	−0.211***	0.067	−0.038	0.083*	0.071	0.041	0.159***	0.139***
Maximum desired distance for walking	0.006	0.025	0.002	0.025	−0.127***	0.028	0.045	0.000	−0.022
No. of children under 18 in household	0.169***	−0.061	0.089**	−0.51	0.016	−0.026	0.032	−0.119***	−0.132***
No. of people above 18 in household	−0.029	0.040	0.075*	−0.011	0.009	0.040	−0.113***	0.025	−0.098**
No. of workers in household	0.026	0.142***	0.071	−0.058	0.002	0.024	0.053	−0.078**	−0.020
No. of private cars in household	−0.027	0.058	0.006	0.077*	0.073*	−0.023	−0.044	0.029	−0.017

* Significant $\alpha = 0.1$.
** Significant $\alpha = 0.05$.
*** Significant $\alpha = 0.01$.

In a similar manner, elder adults tend to dwell in higher residential areas, since they are more concerned about non-motorized trips. Moreover, as the number of children in families increase, the likelihood of living in dense places with mixed-land use, shorter distance from sub-centers and CBD is reinforced. It could arise from the fact that families with more children are assumed to select the residential neighborhoods in places with higher accessibility to service providers and educational centers that are concentrated in diverse centers and close to public transport systems. Families with more workers are more likely to live in residential areas with higher job density and closer to sub-centers. Many of them actually reside near sub-centers that provide more appropriate services and greater access to transportation networks. Households with more car ownership indicate greater tendency toward living in neighborhoods with higher street density and internal connectivity. As mentioned previously, high street density equips more road facilities to families with more private cars.

5. Conclusion

This paper aimed to contribute to the extensive debates on the existence of the relationship between travel behavior and built environment characteristics. Considering home-based travels in one quarter-mile buffer areas, the individuals' decision making on trip patterns has been explored in a micro scale level. Although the scholarly inclinations toward the relationships among travel behavior and built environment led to the wealth of studies in this field, most of them ignore the differences between trip destinations of urban travellers. In this paper, we subjected various trip purposes for the influences of trip behaviors. Sampling the metropolitan of Shiraz, Iran, as our case study, we investigated work and non-work trips through two separated SEM to explain the travel pattern mechanisms in a developing country by using disaggregated survey data and Gis-based land use measurements. Chief findings of the research are as follows.

Results from HBW model indicate that elasticity of residential density toward using public transport is greater in work trips (e.g., Zhang, 2004; Fan, 2007; Greenwald, 2009). This effect of density on transit trips is certainly due to shorter distances to public transport service and greater access to bus stations in study areas. Since density is an interposing variable, its influences are mostly biased by other characteristics of dense places such as diversity in land uses, street design and centralization of activities in dense places that all result in shortening distances and stimulate people to travel by transit and walking (Ewing and Cervero, 2010). In HBN model the residential density has targeted non-motorized trips. These disparities in the impacts of residential density on work and non-work travel patterns are due to the fact that respondents are more likely to walk or bike for optional trips. Moreover, in HBN model, the influence of job density on respondents' travel behavior is higher than residential density.

Similar to past studies (e.g., Kuzmyak, 2009; Frank et al., 2009), results from HBN trips in our study indicate the decisive influence of entropy index in decreasing car trips and increasing walking/cycling. It concluded that diverse dimension of built environment accounts for more sustainable modes as a response to greater accessibility to various service-shopping and leisure activities. Nevertheless, in HBW trips, mixed-land use influences are in conflict with previous research; mixed-land use in residential areas reduces individuals' non-motorized trips to work.

An important finding of this paper is related to the effects of design measurements on travel behavior. Although multiple studies emphasized the role of street density and connectivity on reducing the use of private vehicle and increasing more sustainable modes (Frank and Engelke, 2005; Hedel and Vance, 2007; Boarnet et al., 2008; Frank et al., 2009), in this study the influences were found to be reverse. High street density and connectivity is associated with high level of car use for HBN trips. This result is due to the fact that street density provides more road facilities to drivers and improves their car trips in a quicker approach rather than other travel modes. Moreover, internal connectivity which is defined as more intersections than dead-end roads, supplies better opportunities for individuals to drive within the neighborhood through cross-cut streets and encourages them to use more vehicles. Hence, design measurements contribute to the significant reduction in non-motorized trips by individuals.

The SEM analysis additionally analyzed the associations between socio-economic attributes and home-based travel behaviors. Among the household characteristics, number of cars in family is the most important determinants of travel behaviors. Residents tend to use less public transport for both HBW and HBN trips when they possess more private vehicles in the family. So, it can be concluded that apart from built environment characteristic, socio-economic features affect travel behavior from top of the hierarchy of respondents' decision making.

Furthermore, we considered the subjective influences of individuals' self-selection on travel behaviors in SEM model for non-work trips, and found that respondents with special socio-demographic attributes live in the neighborhoods with regard to their transportation patterns. For instance, higher residential density were related to less non-work car trips per week; respondents with higher incomes were more likely to use private car to non-work destinations; and finally individuals with higher income were more willing to reside in the neighborhoods with lower residential density. This result could be originated from the fact that low residential density buffers in our study samples were mostly placed in urban areas with high land prices that attract high income people to reside in. It is believed that socio-economic factors are among the most important determinants of individuals' lifestyle (Kitamura, 2009). Some researchers argued that objective socio-economic characteristics should be considered as a fundamental part in travel-related self-selection and the dual relationships between socio-economic factors and lifestyle contribute to forming various travel patterns (Van Acker et al., 2014). So, socio-economic characteristics such as income, age and number of workers in the family have resulted in performing a particular lifestyle and accordingly specific travel patterns.

The findings of this paper reveal that although built environment attributes of home-based trips significantly influence individuals travel behaviors, some of the relationships cannot exactly confirm the previous study's results. Street design factors; known as the land use attributes that can stimulate more trips by public transport and non-motorized modes; have indicated equivocal influences. This mismatch between our results and the rich literature reveals the necessity of paying attention to the structural distinctions in urban areas in developing countries and investigating new design measurements in compliance with the local condition of the built environment.

Coordinating land use and transportation based on approved policies by the western countries (e.g., smart growth and compact city) must be challenged in developing countries. It has been argued that, the excessive use of natural environments in cities and the less participation of inhabitants in planning are responsible for differences of mobility challenges in developing countries (Cervero, 2013). Additionally, understanding the factors that influence individuals' travel behavior in sustainable patterns require a vast investigation of individuals' lifestyle contexts and the systems within which different individuals' lifestyles are performed (Etminani-Gahsrodashti and Ardeshiri, 2015). Hence, it should be mentioned that since the impacts of land use policies on mobility patterns are a context-related subject, putting these polices into practice should be adapted to local conditions of urban areas and in line with cultural and social characteristics of different societies.

In this study, individuals' satisfaction toward public transport systems has not been regarded. Since the quality and efficiency of public transport are among the main determinants of individuals' transit trips, it is necessary to consider the affordability of mass transit along with built environment design in further developments. Finally, it should be considered that individuals' environmental concerns about transportation modes could have a significant influence on the proportion of individual sustainable trips. Hence, increasing the level of public knowledge toward travel behavior could notably improve the efficiency of policies designed to integrate land use and transportation planning.

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