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THE INFLUENCES OF THE BUILT ENVIRONMENT AND RESIDENTIAL SELF-SELECTION ON PEDESTRIAN BEHAVIOR

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ABSTRACT

Pedestrian travel offers a wide range of benefits to both individuals and society. Planners and public health officials alike have been promoting policies that improve the quality of the built environment for pedestrians: mixed land uses, interconnected street networks, sidewalks and other facilities. Whether such policies will prove effective remains open to debate. Two issues in particular need further attention. First, the impact of the built environment on pedestrian behavior may depend on the purpose of the trip, whether for utilitarian or recreational purposes. Second, the connection between the built environment and pedestrian behavior may be more a matter of residential location choice than of travel choice. This study aims to provide new evidence on both questions. Using 1,368 respondents to a 1995 survey conducted in six neighborhoods in Austin, TX, two separate negative binomial models were estimated for the frequencies of strolling trips and pedestrian shopping trips within neighborhoods. We found that although residential self-selection impacts both types of trips, it is the most important factor explaining walking to a destination (i.e. for shopping). After accounting for self-selection, neighborhood characteristics, especially perceptions of these characteristics, impact strolling frequency, while characteristics of local commercial areas are important in facilitating shopping trips.

Key words: attitude, derived demand, negative binomial regression, land use, travel behavior, walking

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1. INTRODUCTION

Pedestrian travel offers a wide range of benefits to both individuals and society (Gehl, 1987; Frank and Engelke, 2001; Litman, 2003). From a transportation standpoint, pedestrian travel may be accompanied by less vehicle travel and thus less traffic, air pollution, and other environmental impacts. From a public health standpoint, pedestrian travel means increased physical activity and thus improved health and reduced healthcare costs. Planners and public health officials alike have been promoting policies that improve the quality of the built environment for pedestrians: mixed land uses, interconnected street networks, sidewalks and other facilities. Whether such policies will prove effective has not been definitively established by research and thus remains open to debate.

A growing number of empirical studies have contributed to the debate about the relationship between the built environment and pedestrian behavior (e.g., Black et al., 2001; Cervero and Duncan, 2003; Cervero and Radisch, 1996; Frank and Pivo, 1995; Greenwald and Boarnet, 2001; Handy and Clifton, 2001; Hess et al., 1999; Shriver, 1997). These studies provide evidence of a correlation between the built environment and pedestrian behavior. For example, Cervero and Duncan (2003) found that land use mix is positively related to walking choice; and Hess et al. (1999) found that the completeness of sidewalk systems has a positive association with pedestrian volumes. On the other hand, these studies have also raised questions about the causal relationships that underlie these correlations and have provided hints that common conceptions of travel behavior do not fully apply to pedestrian travel. Two issues in particular need further attention. First, the impact of the built environment on pedestrian behavior may depend on the purpose of the trip, whether for utilitarian or recreational purposes. Second, the connection between the built environment and pedestrian behavior may be more a matter of residential location choice than of travel choice. These issues have fundamental implications for transportation policy and planning.

The purpose of this paper is to empirically explore the role of the built environment and residential self-selection in walking for its own sake (strolling) and walking for utilitarian purposes (to the store). For both types of pedestrian travel, the paper presents new analysis in the form of negative binomial models of data from a previous study (Handy et al., 1998) to address the following central questions: (1) Is residential self-selection important in explaining differences in pedestrian behavior? (2) Do built environment elements affect strolling trips and pedestrian shopping trips in different ways? The organization of this paper is as follows. The next section reviews the literature to provide further background for this study. Section 3 describes the data and variables used in this study and briefly discusses the modeling approach. Section 4 presents the model results for both types of pedestrian travel. The final section recapitulates the key findings and discusses policy implications of the results.

2. BACKGROUND

One reason the questions posed here have not yet been fully answered is that the derived-demand paradigm constrains our understanding of pedestrian behavior. The tenet that travel is a derived demand is embedded in travel behavior theory: the demand for travel is derived from the demand for activities and not from a desire for travel itself. However, this framework is less applicable to pedestrian travel, in that the purpose of many walking trips is the walk in and of itself rather than reaching a destination (Handy, 1996). Even if an individual chooses to walk to a destination, walking itself may be as important to her as the destination. Recently, the derived-demand idea has been systematically challenged by several studies that document positive aspects of travel itself (Mokhtarian and Salomon, 2001; Mokhtarian et al., 2001; Ory and Mokhtarian, 2005). These studies point to the importance of distinguishing between travel for its own sake (e.g., strolling and other forms of recreational walking) and travel for utilitarian purposes (e.g., walking to shop and walking to work) and to the possibility that the factors that influence these two categories of travel may differ significantly. However, most previous empirical studies on pedestrian behavior ignore this potential difference; exceptions include Handy (1996) from the travel behavior literature and Giles-Corti and Donovan (2002) from the physical activity literature. Based on descriptive and correlational analyses, Handy (1996) concluded that some built environment factors play a more important role in the choice to walk to a destination than to stroll.

Another part of the problem is a focus in travel behavior research on day-to-day choices about travel. In existing studies, researchers assume that the built environment influences the choice of mode for a particular trip by influencing the relative attractiveness of each mode – driving, transit, walking, etc. (Krizek, 2003). However, it is the residential location choice that determines what characteristics of the built environment the individual finds in her neighborhood. It is possible that individuals with a preference for walking consciously choose a neighborhood that is conducive to walking. In this case, the connection between the built environment and walking behavior can be explained by the influence of a preference for walking on the residential location choice. In other words, walking behavior is explained by prior "self-selection" into a certain kind of neighborhood rather than by the built environment of that neighborhood per se. Thus, simply comparing the differences in travel behavior observed in different neighborhoods, an approach broadly applied in empirical studies, is likely to lead to biased conclusions about the influence of the built environment (Boarnet and Crane, 2001).

Several empirical studies shed light on this self-selection issue. Kitamura et al. (1997) pointed out (using single-equation regressions) that the variation in travel demand for their San Francisco Bay Area sample owes more to attitudinal factors than to land use characteristics. Using structural equations modeling on the same data, Bagley and Mokhtarian (2002) found that with respect to direct and total effects, attitudinal and lifestyle variables had the greatest impact on travel demand among all explanatory variables, while residential location type had little influence on travel behavior. Handy and Clifton (2001) inferred that individuals who prefer walking to the store intentionally select residential neighborhoods consistent with their preference. These results lend strong support to the speculation that the observed relationships between the built environment and travel behavior are not direct causal links, but can be primarily attributed to interactions of these measures with other variables. Further, in a panel study, Krizek (2000) found that more than half of sample households chose to relocate either in areas close to their prior neighborhoods or in neighborhoods with similar land use traits, and that few changes in household travel behavior after residential relocation were observed. These findings indicate that individuals may select residential neighborhoods partly to match their travel preference, providing credible evidence for the self-selection effect.

However, our understanding on this issue is still immature (Boarnet and Crane, 2001; Handy, 2005). As an example, in the 1995 Nationwide Personal Transportation Survey, it was found that low income households were disproportionately likely to reside in high-density urban areas, and that they were much more likely to walk than their higher-income counterparts (Murakami and Young, 1997). Accordingly, the built environment may not be a causal factor itself, but rather act as a surrogate for a set of socio-economic factors that do affect travel behavior (Frank and Pivo, 1995). Further, in three studies of a newer sample of some 1,300 residents of the San Francisco Bay Area, Schwanen and Mokhtarian compared the trip frequency (2003), commute mode choice (2005), and mode-specific distances traveled (2005) of mismatched suburban and urban residents (those who preferred a more or less, respectively, dense/diverse neighborhood than the one they currently lived in) to their matched counterparts in both kinds of neighborhoods. In general they found that while suburban residents' travel behavior was similar whether they were matched or mismatched, mismatched urban residents' behavior fell between that of matched urban and matched suburban residents – more auto-oriented than the former but less so than the latter. These findings suggest that the built environment *does* in fact play a role, at least in constraining and possibly in shaping, one's underlying preferences. Unfortunately for the goal of reducing auto dependence, the role does not appear to be symmetric: urban-oriented suburban residents are less able to achieve their preference for non-auto travel than suburban-oriented urban dwellers are able to realize their preferences for auto travel.

3. METHODOLOGY

The data analyzed here were collected in a previous study (Handy et al., 1998). In this study, six middle-income neighborhoods in the Austin, TX area were selected based on their development era. Two traditional neighborhoods (Old West Austin and Travis Heights) were developed in the early 20th century; two early-modern neighborhoods (Cherrywood and Zilker) were developed between 1950 and 1970; and two late-modern neighborhoods (Wells Branch and Tanglewood) were developed after 1970. The era of development generally determines basic characteristics of neighborhoods. Pre-W.W.II neighborhoods are usually different from post-W.W.II neighborhoods in a variety of ways: rectilinear street grids, narrower streets, a greater mix of housing styles and sizes, occasionally neighborhood stores. The era of development is also correlated with the location in the region: the traditional neighborhoods lie just beyond the downtown area, the two early-modern neighborhoods are within a few miles of downtown, and the two late-modern neighborhoods are 10 to 15 miles from downtown.

The data came from a self-administered survey mailed in late May 1995 to 6,000 randomly selected households in these six neighborhoods. Ultimately, 1,368 surveys were completed and returned by a random adult member in the household, for a 23% response rate. This response rate is considered good since a mail survey administered to the general population is likely to result in a 10-40% response rate (Sommer and Sommer, 1997). However, any response rate less than 100% raises the possibility of non-response bias, or the possibility that the individuals who respond to the survey are systematically different from those who choose not to respond. As shown in Table 1, a comparison of the key characteristics between the respondents and the population shows that respondents who are male, have lived in the neighborhood longer, live in larger households, own more vehicles, and have higher incomes are somewhat overrepresented. Although changes between the 1990 census and 1995 survey may partly explain these differences, they may suggest a potential bias against pedestrian trips. However, since the focus of our study is on explaining the relationships of other variables to walking behavior rather than on describing the frequency of walk trips *per se*, this potential bias is not expected to materially affect the results (Babbie, 1998).

[Insert Table 1 here]

The dependent variables in the two individual models are the frequencies for strolling and for walking to the store in the last 30 days. In the data, 1,059 respondents took at least one stroll around their neighborhood, and the mean frequency of trips for strollers was 12.0; 594 respondents walked from their home to a local store or shopping area at least once, and the average frequency of walking to the store for walkers was 5.6. These figures show that the majority of walking trips are recreational and hence do not reflect purely a derived demand. Table 2 presents some descriptive sample statistics on the amount of walking by neighborhood. ANOVA tests demonstrate that there is no statistically significant difference in mean strolling behavior in different neighborhoods, but the frequencies of walking to the store are significantly different.

[Insert Table 2 here]

The explanatory variables consist of neighborhood characteristics (objective assessments as well as respondents' perceptions about the neighborhood), residential preference, and demographics. To capture the objective neighborhood characteristics, various sources, including analysis of GIS databases, hardcopy maps, aerial photos, and data collected through site visits, were used. Tables 3 and 4 present the objective assessments of these neighborhoods (refer to Handy et al. (1998) for a complete overview of these neighborhoods). Generally, most households in the traditional and early-modern neighborhoods are located within walking distance of local commercial areas, and commercial development in the traditional neighborhoods tends to be pedestrian-oriented, with pedestrian entrances, full sidewalks, and high levels of sidewalk shading. Interestingly, residential streets in the late-modern neighborhoods have full sidewalks while the traditional and early-modern neighborhoods only have partial sidewalks along streets. These characteristics were measured at the level of the neighborhood rather than the household. In addition, the street network distance from home to the nearest commercial area for most households was objectively measured at the household level using the network skim capabilities of a travel demand modeling program.

[Insert Table 3 here]

[Insert Table 4 here]

The survey included a series of questions asking residents about their evaluation of the neighborhood on several built environment characteristics. To simplify the analysis of the contribution of these factors to explaining travel choices, we grouped the survey questions into six factors describing physical qualities within the neighborhood and three describing physical qualities of local commercial areas (Table 5). We based these groupings on the results of a confirmatory factor analysis. The measures for each factor are an average of responses on a five-point scale to the appropriate survey questions and were structured so that the correlations between the factors and the frequency of walking were expected to be positive. These factors represent the feelings and perceptions of the residents about the physical qualities of their neighborhood and should be more closely tied to choices about travel than would be an objective assessment of these qualities.

[Insert Table 5 here]

One section of the survey asked respondents about the relative importance of a variety of factors potentially influencing their choice of residential neighborhood, on a five-point scale from "not at all important" to "extremely important". These factors include affordability of living unit, quality of living unit, quality of schools, investment potential, having stores within walking distance, attractiveness of neighborhood, level of upkeep in neighborhood, closeness to work, and closeness to friends and family. The importance ratings on these factors are considered measures of the individual's predisposition toward those characteristics of a residential neighborhood. The factor measuring the importance of having stores within walking distance can be used as an indicator of self-selection: to what degree did respondents select a neighborhood because of the opportunity to walk that the neighborhood affords? We would expect that respondents for whom having stores within walking distance was important would, in fact, walk more. An ANOVA test confirms this hypothesis, with a significant positive association between the importance of this factor and frequency of walking. Although conceptually this factor relates more clearly to utilitarian walking, it might also provide an indication of an intrinsic preference for neighborhoods conducive to walking; we would expect this factor, however, to be a more significant predictor of utilitarian walking than recreational walking.

Finally, the survey also contained a list of demographic variables that may help to explain travel behavior. These variables include gender, age, employment status, the presence of a pet, auto ownership, household income, household size, and the number of children in the household. These variables may affect the travel options available to individuals; for example, an elderly person may not physically be able to carry goods home and thus may not consider the option to walk.

Negative binomial regression was used to analyze the relationship of built environment variables, the self-selection variable, and socio-demographic characteristics with both strolling frequency and the frequency of walking to the store. Linear regression techniques have been widely used to analyze travel demand (e.g., Frank and Pivo, 1995; Kitamura et al., 1997; Krizek, 2003). Linear regression analysis requires model residuals to conform to the normal distribution (Neter et al., 1996). However, distributions of trip frequencies are often seriously skewed to the left, and hence greatly deviate from the normality assumption. The data used in this study follow this pattern (Figure 1). In this situation, linear regression analysis is not an appropriate tool for modeling trip frequencies. Instead, because trip frequencies are always non-negative integer values, Poisson regression and negative binomial regression, frequently used to model count data, are potential alternatives.

[Insert Figure 1 here]

In Poisson regression, it is assumed that the dependent variable Y (the frequency of walk trips in this study) is Poisson-distributed given the explanatory variables $X_1, X_2, \ldots, X_p$. This means that the probability of observing Y = *k* trips is governed by the Poisson distribution function:

$$P(Y = k \mid X_1, X_2, \ldots X_p) = \frac{e^{-\lambda}\lambda^k}{k!}, \quad k = 0, 1, 2, 3\ldots, \qquad (1)$$

where the conditional mean λ is an exponential function of the explanatory variables. That is,

$$\lambda = \exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p). \qquad (2)$$

The fitted value of Y for the *i*th case, $\hat{Y}_i$ (i = 1, 2, …, N), is denoted $\hat{\lambda}_i$.

Poisson regression assumes mean-variance equality. However, this property is frequently violated in empirical data. Figure 1 illustrates that there is some evidence of overdispersion (variance > mean) in this sample. Alternatively, the negative binomial regression model captures the overdispersion effect by introducing an unobserved effect into the conditional mean, λ, of the Poisson model (Greene, 2002):

$$\lambda = \exp(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p + \varepsilon), \qquad (3)$$

where exp(ε) has a gamma distribution with mean 1 and variance α (also called the dispersion parameter). The resulting probability density function can be written as:

$$P(Y = k \mid X_1, X_2, ...X_p) = \frac{\Gamma(k + \alpha^{-1})}{k!\Gamma(\alpha^{-1})} \left(\frac{\alpha^{-1}}{\alpha^{-1} + \lambda} \right)^{\alpha^{-1}} \left(\frac{\lambda}{\alpha^{-1} + \lambda} \right)^{k}, k = 0, 1, 2, 3..., \tag{4}$$

Its mean is λ and its variance is $\lambda+\alpha\lambda^2$ (called a type 2 negative binomial regression or Negbin2 by Cameron and Trivedi (1986)). Poisson regression is a special case of negative binomial regression (α = 0). If the estimated dispersion parameter is statistically significantly larger than zero, a Poisson regression model is not appropriate for the data. A likelihood ratio test is also commonly used to test for overdispersion (Cameron and Trivedi, 1998). Cameron and Windmeijer (1996) proposed several R^2s as goodness-of-fit measures based on various definitions of residuals. They recommended using the deviance R^2 to evaluate the aptness of the model:

$$R^2_{DEV,NB2} = 1 - \frac{\sum_{i=1}^{N} \left\{ y_i \ln\left(\frac{y_i}{\hat{\lambda}_i} \right) - (y_i + \hat{\alpha}^{-1}) \ln\left(\frac{y_i + \hat{\alpha}^{-1}}{\hat{\lambda}_i + \hat{\alpha}^{-1}} \right) \right\}}{\sum_{i=1}^{N} \left\{ y_i \ln\left(\frac{y_i}{\bar{y}} \right) - (y_i + \hat{\alpha}^{-1}) \ln\left(\frac{y_i + \hat{\alpha}^{-1}}{\bar{y} + \hat{\alpha}^{-1}} \right) \right\}} \ . \tag{5}$$

This statistic measures the proportionate reduction, due to the explanatory variables in the model, in deviance of the log-likelihood of the constant-only model from the maximum possible log-likelihood. Limdep 8.0 was used to calibrate the two models. As shown in Tables 6 and 7, the estimated dispersion parameters for the two models are significantly larger than zero, and the likelihood ratio test confirms that the negative binomial model is significantly better than the Poisson model for this study.

4. RESULTS

Models for the two types of walking are presented in Tables 6 and 7. The deviance R^2s for the two models are 0.131 and 0.379, respectively. We are not aware of any criteria used to evaluate the goodness of deviance R^2s for negative binomial regressions. However, in an ordinary least squares context, these would be considered typical-to-good levels of fit for models on disaggregate cross-sectional data (Greene, 1997). It is interesting that the deviance R^2 of the model for pedestrian shopping frequency is much larger than that for strolling frequency. This result suggests that the survey more effectively captured factors that explain pedestrian shopping trips than factors that explain strolling trips. For both types of trips, two questions are of interest: how important is self-selection in explaining walking behavior, and what role do neighborhood characteristics play once self-selection has been accounted for?

4.1 Strolling Trips

The parameter estimates for strolling frequency in the last 30 days provide important evidence on these questions. First, individuals who rate having stores within walking distance as more important in their decision to live in their current neighborhood stroll more frequently. This result suggests that strolling frequency is in part explained by an intrinsic preference for neighborhoods conducive to walking; it thus lends support to the self-selection hypothesis.

[Insert Table 6 here]

Second, after accounting for this self-selection factor, we also found that four neighborhood characteristics are associated with strolling frequency. Therefore, although self-selection accounts for some variation in strolling frequency, elements of the built environment do impact strollers' behavior, and (according to the standardized coefficients) some elements play a more important role than the self-selection factor in explaining the variation in strolling frequency. Interestingly, these four variables are exclusively related to individuals' perceptions of physical qualities within the neighborhood as pedestrians. The absence of objective measures of neighborhood characteristics implies either that individuals' perceptions of pedestrian environments are more important than objective neighborhood characteristics in explaining pedestrian behavior or that the aggregate neighborhood characteristics used here are not good indicators of the influences of the built environment on individuals' strolling choices.

Several demographic characteristics were also significant. Older people are more likely to stroll around the neighborhood, a result that may be attributable to changes in activity patterns and preferences with age. On the other hand, full-time workers stroll less frequently, presumably due to time constraints. The model also suggests that the presence of pets and children (under 5 years old) in the household constitute two major motivations for strolling. A comparison of standardized coefficients shows that having a pet to walk is the most important factor affecting the frequency of strolling trips, and that each built environment factor provides a moderate contribution to inducing strolling trips.

4.2 Walking to the Store

The model for the frequency of walking to the store is presented in Table 7. Again, the residential preference for stores within walking distances – the self-selection factor – positively affects the frequency of walking to the store. In terms of standardized coefficients, this is the most important observed influence on pedestrian behavior. Therefore, residential self-selection plays a substantial role in explaining pedestrian shopping behavior: residents who chose their neighborhood because of the opportunity to walk to the store walk to the store more frequently. This result suggests that an intrinsic preference for walking, rather than the neighborhood environment itself, explains walking behavior.

After the self-selection factor has been accounted for, the characteristics of local commercial areas are also important in generating pedestrian shopping trips. A higher traffic volume in the commercial streets tends to reduce pedestrian trips. This is plausible since both Appleyard (1981) and Gehl (1987) show that greater traffic volume makes for a less inviting street for pedestrians. On the other hand, providing connections for pedestrians between the street and stores encourages pedestrian shopping trips. All three store-related factors, representing the respondents' perceptions of the local commercial areas as both pedestrian and consumer, enter the model: the higher respondents rated these factors, the more frequently they walked. Only one factor representing perceived neighborhood characteristics was significant in the model: the (low) traffic factor (for which scores are high when the individual is comfortable walking without sidewalks and disagrees that there is too much traffic in the neighborhood) is positively associated with utilitarian walking frequency.

In addition, distance to the nearest store is highly significant in predicting frequency of walking to the store, consistent with the finding of others (e.g. Giles-Corti and Donovan, 2002; Handy and Clifton, 2001; Limanond and Niemeier, 2004). Specifically, a one-mile increase in the distance reduces walking frequencies by about 2.97 trips per month (compared to an average of 2.90 utilitarian walking trips per month across all respondents) for an individual whose characteristics are taken at the sample mean. The distance to the nearest store is likely to be shortest in neighborhoods with mixed land uses and an interconnected street network; these characteristics may thus encourage walking to the store. The significance of several characteristics of local commercial areas and limited appearance of neighborhood characteristics suggest that built environment elements at the destination outweigh elements of the residential neighborhood in shaping utilitarian pedestrian behavior: stores must be of interest to local residents, within walking distance, and safely accessed on foot or residents are unlikely to walk there.

Several demographic characteristics are also significant. This model also shows that respondents who have children (under 5 years old), or are women, older, richer, or full-time workers tend to walk to the store less frequently than others. Most of these characteristics are associated with greater time pressures, while age may reflect mobility limitations or possibly safety concerns. It is worth noting that age as well as the presence of children has opposite impacts on strolling frequency and pedestrian shopping frequency, while full-time workers are less likely to conduct both types of walking.

5. CONCLUSION AND IMPLICATIONS

As one of a series of studies of Austin neighborhoods regarding the impact of land use on pedestrian behavior (Handy, 1996; Handy and Clifton, 2001), this paper empirically explores the influences of built environment factors and residential self-selection on both types of pedestrian travel: travel for its own sake (strolling) and travel for utilitarian purposes (walking to the store).

A comparison between the two models yields interesting insights into pedestrian behavior. First, both models suggest that residential preference plays an important role in individuals' travel choices, and pedestrian shopping trips are more likely to be explained by residential self-selection. Consequently, the ability to manage travel behavior by shaping the built environment may be limited by the apparently sizable share of households that favor automobile-oriented neighborhoods. On the other hand, over one quarter of the respondents in this survey indicated that being able to walk to a store was important in their choice of neighborhood. If, as others have argued, the market, under the constraints of city planning, provides a surplus of low-density and auto-oriented development (Levine, 1998; Levine and Inam, 2004; Boarnet and Crane, 2001), policies should then encourage more pedestrian-oriented developments in order to satisfy the demand for walking-oriented development and provide sufficient opportunities for walking.

Second, neighborhood characteristics, especially respondents' perceptions of those characteristics, greatly impact strolling frequency, while characteristics of local commercial areas are more important in encouraging shopping trips. This result implies that strolling trips and shopping trips are influenced by different dimensions of the built environment. For strolling trips, the pedestrian environment at the origin (home) is important. For utilitarian trips, the pedestrian environment at the destination appears to be at least as important as that at the origin. The distance to local commercial area, an outcome of the layout of the street network and the mix of land uses, also significantly affects walking frequency. Pedestrian-oriented designs at the destination and accessibility to potential destinations are important facilitators of utilitarian walking; conversely, long distances to destinations and poor connections for pedestrians are likely to discourage utilitarian walking. Future studies should assess the built environment in residential and commercial areas in more detail to provide a better understanding of specific design strategies that may be effective in encouraging walking.

Third, the appearance of the traffic-related variables in both models is worth noting. Individuals are more likely to stroll around or walk to the store when fewer vehicles travel residential and commercial streets. Transportation planning efforts that aim to improve vehicle mobility may thus deter pedestrian travel by increasing vehicle traffic on local streets. Conversely, traffic calming programs designed to reduce traffic speeds and discourage through traffic in residential areas may help to encourage pedestrian travel.

An overview of average frequencies for both types of pedestrian travel in these neighborhoods shows that strolling trips account for the majority of total walking trips made by respondents. Traditionally, travel-diary surveys focus on travel to a destination rather than travel as an activity in and of itself. Pedestrian trips without a clear destination may be omitted entirely (Handy et al., 2002). Therefore, the impacts of the built environment on facilitating pedestrian travel tend to be underestimated. On the other hand, even if such trips are completely captured in the survey, the impacts of built environment elements on pedestrian behavior may be distorted and misinterpreted, given that strolling trips and utilitarian trips are influenced by different dimensions of the built environment. Further, older people as well as those who have children under 5 years old are more likely to stroll around but less likely to walk to a store, a pattern that suggests that the effects of demographic characteristics on pedestrian travel may be canceled out or underestimated if the two types of trips are combined. Therefore, to accurately obtain and explain pedestrian behavior, the two kinds of trips should be differentiated in surveys.

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Table 1 Sample Characteristics and Neighborhood Population Characteristics

	Traditional		Early Modern		Late Modern	
	Old West Austin	Travis Heights	Cherrywood	Zilker	Wells Branch	Tanglewood
Neighborhood population characteristics – 1990 census						
Population	4,311	5,666	4,137	4,741	5,005	5,650
% male	52%	51%	50%	50%	50%	50%
Median age	30.7	31.7	33.7	33.3	28.6	28.7
Avg years in unit	5.3	7.4	10.5	9.2	3.2	4.6
Avg vehs/HH	1.4	1.5	1.5	1.4	1.9	1.9
Persons/HH	1.59	1.94	2.02	2.02	2.53	2.65
Median income	$21,910	$24,551	$28,206	$25,359	$38,862	$34,873
Survey respondent characteristics [a]						
Number	281	245	226	220	204	192
% male	54%	50%	57%	58%	55%	55%
Median age [b]	43.3	43.8	44.0	46.5	42.0	44.3
Avg years in unit	8.6	9.3	12.4	11.2	6.2	9.1
Avg vehs/HH	1.6	1.8	1.6	1.8	1.9	2.4
Persons/HH	2.1	2.1	2.1	2.2	2.6	2.7
Median income [c]	$50,749	$53,377	$42,749	$48,469	$59,146	$69,889

[a] Differences between neighborhoods significant at 1% level for all characteristics except gender

[b] For adults

[c] Estimated based on reported income ranges

Source: Handy et al. (1998).

Table 2 Overview of Walking Trips

	Traditional		Early Modern		Late Modern	
	Old West Austin	**Travis Heights**	**Cherry-wood**	**Zilker**	**Wells Branch**	**Tangle-wood**
Strolling trips						
Average trips/30 days for all respondents	10.95	9.99	10.13	8.36	8.61	8.23
Percent strolling at least once/30 days *	84%	82%	78%	76%	83%	73%
Average trips/30 days for strollers	13.12	12.23	13.06	11.06	10.32	12.03
Walks to the store						
Average trips/30 days for all respondents *	6.29	2.03	2.06	1.68	0.72	0.91
Percent walking at least once/30 days *	79%	45%	48%	39%	22%	21%
Average trips/30 days for walkers *	8.01	4.55	4.28	4.33	3.36	4.40

* Differences between neighborhoods significant at the 5% level.

Source: Handy (1996).

Table 3 Street Characteristics of Neighborhood and Commercial Area

	Traditional		Early Modern		Late Modern	
	Old West Austin	**Travis Heights**	**Cherry-wood**	**Zilker**	**Wells Branch**	**Tangle-wood**
Neighborhood street system						
Land Area (sq. mi.)	0.75	0.99	0.50	0.82	0.64	1.00
Street Miles	17.7	22.9	11.7	18.8	14.5	17.6
Street Miles/Land Area	23.6	23.2	23.4	22.9	22.7	17.6
Est. Street Area (sq. mi.)	0.09	0.11	0.06	0.11	0.10	0.13
Street Area/Land Area	12%	11%	12%	13%	16%	13%
%T-Intersections	71%	77%	77%	69%	89%	76%
Intersections/Street Mile	9.2	7.0	13.2	7.5	10.6	6.2
Cul-de-sacs/Street Mile	1.2	0.8	1.2	0.6	1.8	2.1
Blocks/Land Area	94.7	98.5	82.0	89.0	75.0	45.0
Access Points/Land Area	41.3	27.3	42.0	31.7	7.8	16.0
Commercial street						
Street name	West Lynn 12th st.	South Congress	38 1/2 st.	S. Lamar	Wells Branch Pkwy	Slaughter Manchaca
% of HHs within walking distance of commercial street	95%	60%	80%	60%	15%	15%
Location of entrances - pedestrian or auto	P	P	P/A	A	A	A
Traffic volume - vehicles per day	4,460	28,500	12,220	38,000	18,200	18,090
Share of road w/sidewalk - full/partial/none*	F/F	F/F	F/N	P/P	F/F	P/N
Level of sidewalk shading - high, medium, low	H	H	M	M	L	L

* Full (F), partial (P) or none (N) on each side of road, ex. F/F means full sidewalks on both sides.

Source: Handy et al. (1998).

Table 4 Residential Street Characteristics

	Traditional				Early Modern				Late Modern			
	Old West Austin		Travis Heights		Cherry-wood		Zilker		Wells Branch		Tangle-Wood	
	10th	Lorraine	East Side	Alta Vista	Cherrywood	E. 37th	Hether	Jessie	Surrender	Margelene	Monarch	Curlew
Street characteristics												
Street width (feet)	26	26	26	26	26	26	30	30	40	36	36	40
Level of shade [a]	H	H	H	H	M	M	M	M	L	L	L	L
Share of road w/sidewalk [b]	P/P	P/N	N/N	P/N	P/P	P/P	F/N	N/N	F/F	F/F	F/F	F/F
Housing characteristics												
Avg. front door setback (ft)	30	30	30	40	50	34	30	40	50	66	50	48
% w/front porches	75%		75%		50%		50 - 75%		0 - 25%		0 - 25%	
Design variation [a]	H		H		M		M		L		L	

[a] High (H), medium (M), or low (L).

[b] Full (F), partial (P), or none (N) on each side of street, ex. F/F means full sidewalk on both sides.

Source: Handy et al. (1998).

Table 5 Perceived Design Factor Definitions

Factor	Perceptions
Within the neighborhood	
Safety	I feel safe walking during the day I feel safe walking at night
Shade	Trees provide ample shade I'm comfortable walking in hot weather
Houses	There are interesting houses I like to look at houses when I walk
Scenery	Trees provide ample shade There are interesting houses
Traffic	I'm comfortable walking without sidewalks (There's too much traffic in neighborhood)
People	I see neighbor when walking I see other people when walking I like to see people when I walk
Local commercial areas	
Stores	Local stores meet my needs The quality of local store is high
Walk advantage	The closest store is a reasonable walking distance (It is hard to park at local stores)
Walk comfort	(I have to walk along busy streets to access local stores) (I have to cross a busy street to access local stores) I am comfortable walking around local shopping areas I feel safe walking from my house to local stores

Note: parentheses indicate that the scale was reversed in computing the factor score

Source: Handy et al. (1998)

Table 6 Strolling Frequency Model

Variables	Unstandardized Coefficient	Marginal Effects [a]	Standardized Coefficient [b]	p-value
Constant	-0.405	-4.002	2.152	0.177
Residential Preference				
Stores within walking distance important	0.110	1.085	0.141	0.000
Neighborhood Characteristics				
Perception of safety	0.225	2.224	0.125	0.000
Perception of shade	0.158	1.560	0.183	0.000
Perception of traffic	0.071	0.704	0.073	0.063
Perception of people	0.146	1.446	0.108	0.003
Demographics				
Pet to walk	0.686	6.785	0.308	0.000
Age	0.008	0.075	0.095	0.026
Full-time worker	-0.234	-2.319	-0.101	0.015
Presence of kids (< 5 years) in the household	0.301	2.973	0.103	0.014
Dispersion parameter α	1.180			0.000
Number of observations	1182			
Log-likelihood (Negbin2, constant only)	-3888.173			
Restricted log-likelihood (Poisson)	-7271.825			
Model log-likelihood (Negbin2)	-3792.371			
Likelihood ratio test (Negbin2 vs. Poisson)	6958.909			0.000
Deviance R^2	0.131			

[a] Marginal effects represent the change in the dependent variable given a unit change in a particular explanatory variable (i.e., the first-order derivative). According to a personal communication with Bill Greene (April 20, 2005), the effects shown here are the individual-specific effects averaged over the sample. This is contrary to the message generated by Limdep, which incorrectly indicates that they are the effects calculated for a single "representative" individual, i.e. for a person having average values on all explanatory variables. The two methods of estimating an average marginal effect can differ considerably for non-linear functions such as we have here; see Section 2.5 of Train (1986) for a discussion of this point in the context of discrete choice models.

[b] To compare the importance of explanatory variables with different measurement scales, all explanatory variables (except the constant term) were standardized. The dependent variable was not standardized since negative binomial regression requires the dependent variable to be a count value (non-negative integer). The model was then re-estimated.

Table 7 Walk to the Store Frequency Model

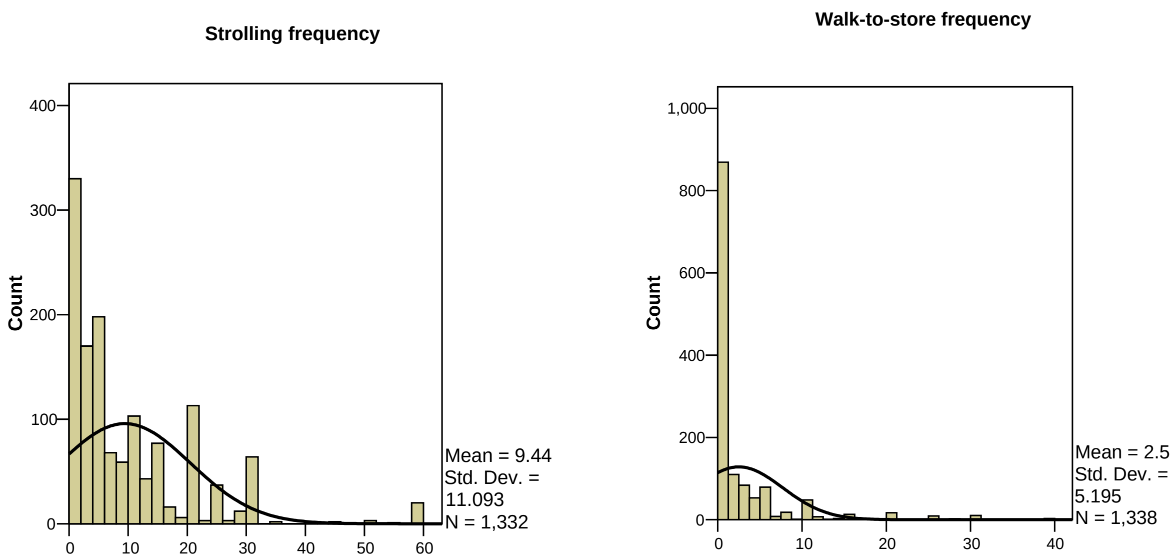
Variables	Unstandardized Coefficient	Marginal Effects [a]	Standardized Coefficient [b]	p-value
Constant	-1.618	-4.888	0.415	0.000
Residential Preference				
Stores within walking distance important	0.332	1.004	0.430	0.000
Store Characteristics				
Traffic volume (thousand vehicles per day)	-0.013	-0.040	-0.108	0.064
Pedestrian connections	0.880	2.658	0.392	0.000
Perception of stores	0.198	0.597	0.209	0.000
Perception of walk advantage	0.310	0.935	0.284	0.000
Perception of walk comfort	0.209	0.632	0.180	0.004
Neighborhood Characteristics				
Perception of traffic	0.149	0.451	0.157	0.011
Miles to the nearest store	-0.983	-2.970	-0.312	0.000
Demographics				
Female	-0.224	-0.667	-0.112	0.041
Age	-0.013	-0.038	-0.153	0.009
Full-time worker	-0.317	-0.957	-0.133	0.016
Presence of kids (< 5 years) in the household	-0.360	-1.088	-0.130	0.027
Household income	-0.100	-0.302	-0.134	0.015
Dispersion parameter α	1.674			0.000
Number of observations [c]	837			
Log-likelihood (Negbin2, constant only)	-1662.020			
Restricted log-likelihood (Poisson)	-2301.616			
Model Log-likelihood (Negbin2)	-1490.750			
Likelihood ratio test (Negbin2 vs. Poisson)	1621.732			0.000
Deviance R^2	0.379			

[a] Marginal effects represent the change in the dependent variable given a unit change in a particular explanatory variable (i.e., the first-order derivative).

[b] To compare the importance of explanatory variables with different measurement scales, all explanatory variables (except the constant term) were standardized. The dependent variable was not standardized since negative binomial regression requires the dependent variable to be a count value (non-negative integer). The model was then re-estimated.

[c] The variable, miles to the nearest store, has 339 missing values, leading to a sharp reduction in the number of observations.

Fig. 1. Strolling Frequency and Walk-to-store Frequency.



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