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The Role of Land Use in Travel Mode Choice

Evidence from Boston and Hong Kong

Ming Zhang

This article presents a study that analyzed the influence of land use on travel mode choice using survey data from Metropolitan Boston and Hong Kong. In Boston, the focus of inquiry was on whether land use would still matter for mode choice (and if so, to what extent) when mode attributes and traveler socioeconomic characteristics were taken into account. In Hong Kong, where the role of land use in mode choice is obvious due to the densely built environment, the focus was on whether land use completely explained the transit-dominated travel pattern. The empirical modeling confirmed that the role of land use in influencing travel was independent from travel time and monetary costs. Elasticity estimates show that the composite effect of land use on driving could be comparable in magnitude to that of driving cost. Yet being place specific, land use strategies are limited by the spatial extent to which they can be implemented. Land use strategies influence travel more effectively when complemented by pricing policies.

Ming Zhang is an assistant professor in the Department of Landscape Architecture and Urban Planning at Texas A&M University. He received an M.S. in transportation and a Ph.D. in urban and regional planning from MIT. His research and teaching interests include transportation planning, mobility/accessibility and urban form, and GIS.

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In the global search for effective policies to reduce driving and its associated undesirable environmental and social consequences, land use[1] is often considered to serve a mobility role. The basic idea is to "get the land use right" by designing an urban form with relatively high density, mixed use, and pedestrian friendliness so that alternatives to driving are promoted and demand for automobility can be reduced. Observing decades of discussion of social-cost-based transportation pricing, the advocates of "get the land use right" do not believe that true market pricing of transportation is a feasible way to manage travel growth. Thus, they promote land use as the second best solution (Cervero, 1991, 1996; Cervero & Landis, 1995). Examples of land use-based mobility initiatives include densification through infill development, transit-oriented development, neotraditional neighborhood design, and, more broadly, smart growth (Bernick & Cervero, 1997; Calthorpe, 1993; Cervero, 1989; Duany et al., 1991; Katz, 1994; Newman & Kenworthy, 1999; Urban Land Institute, 2000).

The efficacy of "get the land use right" for reducing driving, however, has often been questioned. Challenges have come from proponents of "get the price right." These observers note that the linkage between land use and transportation has weakened in the U.S. and other developed countries because of decreasing real costs of travel, existence of already well developed transportation systems, and structural shifts to an information-based economy (Dunn, 1998; Giuliano, 1995; Gordon et al., 1991). In this view, effective remedies for the problems associated with existing travel will come not from modifying land use, but from economic measures such as road pricing or general taxation to internalize the full costs of travel.

A key factor in their policy debate is properly identifying the mobility role of land use in people's travel decisions. The past decade or so has seen an explosion of articles investigating the relationship between land use and travel behavior. Nevertheless, even after many studies, results remain mixed on the existence, significance, and magnitude of these relationships.[2] For more informed policy-making, it is essential to improve our understanding of both the potential and limitations of land use in influencing travel behavior. Previous studies have indicated that improvements in policy research can be made in at least two directions. The first is to improve methodologies. A known weakness of existing studies is their methodological inadequacies, for example, lack of a sound theoretical foundation for analysis, incomplete specification of empirical models, and/or poor data quality (Badoe & Miller, 2000; Cervero, 2002; Crane, 1999; Handy, 1996b; Steiner, 1994). The second is to analyze the conditions under which land use influences travel. Although the two sides share a common goal to reduce driving, the debate between "get the land use right" and "get the price right" tends to fall into a dichotomy. The former holds that if getting the price right is infeasible, land use should be employed to do the job, whereas the latter maintains that if the price is right, employing land use to influence travel is neither necessary nor effective. This dichotomy implies a substitutionary relationship between the two approaches, leaving a gap in the research on policy analysis. Few studies have emphasized the complementary influences of economic and land use strategies.

This article aims to contribute to the policy debate with improved research and to enhance the literature with additional empirical evidence on land use/travel behavior relationships. It presents case studies of two cities, metropolitan Boston and Hong Kong, with empirical modeling of mode choices for work and nonwork travel. The study was designed to examine both the potential and the limitations of how land use affects travel. Therefore it asked related but different questions in each case. In Boston, the focus of inquiry was on whether land use would still matter for mode choice (and if so, to what extent) when travel costs and travelers' socioeconomic factors were taken into account. In Hong Kong, where the role of land use in mode choice is obvious due to the densely built environment, the focus was on whether land use completely explained the transit-dominated travel pattern. The next section reviews previous studies. This is followed by the research methodology, which gives the reasons for selecting these two cities.

Previous Studies

The relationship between land use and travel behavior is complex and multidimensional, because there are multiple attributes of land use intertwining with various aspects of travel behavior. Providing a site map to the complexity and multidimensionality, Table 1 cross-tabulates land use against travel variables, juxtaposing travel for work and nonwork purposes. The three center columns correspond to the three core dimensions of land use (Cervero & Kockelman, 1997): density, diversity, and design. The far left column lists seven major aspects of travel behavior. Corresponding to these seven aspects are aggregate travel patterns, which are policy concerns. As can clearly be observed, (1) one land use attribute may affect multiple aspects of travel; (2) one aspect of travel tends to relate to multiple land use attributes; and (3) the net effect of land use on travel is often unclear (Crane, 1996b). Empirically testing these complex relationships certainly demands substantial research. This study focused on one aspect of travel: mode choice.[3] Accordingly, the literature review concentrates on previous studies addressing the land use/mode choice linkage (For more comprehensive reviews, see Badoe & Miller, 2000; Crane, 1999; Ewing & Cervero, 2001; Handy, 1996b.)

A key component of the traditional four-step transportation demand model, mode choice analysis is itself a distinct area of research that has accumulated an extensive and sophisticated literature (e.g., Ben-Akiva & Lerman, 1985; Domencich & McFadden, 1975; Hensher, 2001). Typically, the analysis considers two classes of variables: (1) mode attributes such as travel times, costs, convenience, reliability, and comfort; and (2) traveler socioeconomic characteristics. Land use factors are often omitted, based on the assumption that the effects of land use on travel are captured in travel times and costs and have been taken into account by travelers in their long-term residential location decisions. Bringing land use into the mode choice equation challenges this assumption; it assumes instead that there are attributes of land use that are important to people's short-term mode choices that are not fully captured by travel times or costs. It is thus an empirical task to test whether the previously omitted land use factors are significant and, if so, to what extent. Conducting such tests in turn involves two tasks: measuring land use and performing tests with appropriate methods.

Kockelman (1997) suggested four measures to quantify the basic characteristics of land use: entropy index of land use balance, dissimilarity index of land use mixture, accessibility, and density. She then estimated five models—two of which were of mode choice—to explore the degree of association between land use and travel behavior in the San Francisco Bay Area. In her models, accessibility was statistically significant for decisions of personal vehicle and walk/bike modes. Population and job densities mattered only for vehicle choice. Land use balance and mixture also were significant in the walk/bike mode. In another study of 50 neighborhoods in the same region conducted by Cervero and Kockelman (1997), mode choice was regressed on land use intensity and design, which were derived from 12 input land use variables along with other socioeconomic variables. Both intensity and design were found to be significant.

A number of others have reported findings from separate studies in neighborhoods in the San Francisco Bay

	Core dimensions of land use			
Travel behavior	Density	Diversity	Design	Travel patterns
Driving choice	−	−	−	Modal split
Driving frequency	+/−	+	+	Total trips
Driving length and duration	−	+/−	?	VMT/VHT
Departure time	?	?	?	Peaking
Route choice	+/−	+/−	+/−	Road congestion
Trip chaining	−	+	+/−	Trip rate and distance
Tele-travel	+/−	?	?	All

Note: The symbols +, −, and ? indicate positive, negative, and unknown, respectively.

Table 1. Hypothesized relationships among three core dimensions of land use and travel.

Area. Friedman et al. (1994) and Cervero and Gorham (1995) found a higher percentage of nondriving in denser, traditional built environments than in more modern ones. Kitamura et al. (1997) also observed a positive correlation between residential density and the share of nonmotorized trips. Nonetheless, they found that personal attitudes had higher explanatory power than neighborhood characteristics. Handy (1996a) reported that a pedestrian-friendly environment encouraged walking for shopping travel; but people in the modern neighborhoods walked to stores as well, if the stores were located in easy walking distance. In this study, Handy offered an important observation: Land use made a difference in determining whether residents perceived walking as an option available to them. In other words, land use influences the choice set formation of travel modes feasible to the traveler. Choice set formation is the first and a critical stage of an individual's mode choice decision (Manski, 1977).

Frank and Pivo (1994) regressed shares of drive alone, transit, and walking mode choices on job and population densities using sample data from the Puget Sound (WA) area. They showed that job density mattered more at the trip destination while population density mattered more at the origin. A study by Ewing et al. (1994) in Palm Beach, Florida, reported findings similar to those in other areas: A larger share of nondriving travel is associated with denser land use development. Using a sample of 11 U.S. metropolitan areas and data from the 1985 American Housing Survey, Cervero and Wu (1997) modeled the probabilities of commuting mode choice as functions of the characteristics of trip origins and destinations. They found that mixed uses in the traveler's immediate neighborhood encouraged commuting by foot or transit. However, when trip distance was beyond approximately 300 feet, mixed uses appeared to induce commuting by automobile.

A limitation common to the above studies is that travel times and monetary costs were missing from the list of control variables, although some considered airline distances between trip origins and destinations. Crane and Crepeau (1998) controlled for trip distance and speed when testing the link between street network patterns and mode split. Using the travel diary and GIS data for San Diego, they estimated a set of probit regression models of mode choice for nonwork trips. From the analysis, they found no evidence that street network patterns mattered for decisions to drive vs. walk. The analysis did not test whether the street design at trip destinations had a measurable influence on mode choice.

In studying the effect of parking charges on mode choice for commuting to work in downtown Portland, Oregon, Hess (2001) also considered land use, which was measured by pedestrian friendliness and proximity to light rail. He found an expected significant influence for parking charges on decisions to drive alone or to take alternative modes, but none of the land use variables were significant.

A recent study by Cervero (2002) on the built environment and mode choice is among the few with analyses designed around behavioral frameworks and fully considered factors related to land use, generalized cost of travel, and socioeconomic attributes of travelers. In this study, Cervero framed the analysis around consumer choice theory and estimated utility-based models of mode choice in Montgomery County, Maryland. He showed that intensities and mixtures of land use significantly influenced decisions to drive alone, share a ride, or patronize public transit. Due to data limitations, however, the study did not distinguish between work and nonwork travel.

Identifying the link between land use and travel has also found a strong interest outside the U.S. A recent example is the study by Dieleman et al. (2002) using the Netherlands National Travel Survey. In the international context, perhaps the most influential and widely debated work is by Newman and Kenworthy (1989, 1999). Using a sample of 46 cities worldwide, they examined the relationships between urban form and auto use, based mainly on bivariate analyses. They expressed their study findings vividly in the graph of a logarithmic curve representing the negative correlation between urban density and auto use. On the curve, cities with lower density and higher auto use (such as North American and Australian cities) cluster at one end, Asian cities with higher density and lower auto use cluster at the other end, and European cities fall in between. Newman and Kenworthy concluded that low-density sprawl was the root cause of auto-dependent travel. Accordingly, they recommended densification as the most important policy to reduce driving.

Newman and Kenworthy's (1989, 1999) conclusion has invited a string of criticisms, mostly on methodological grounds: The studies failed to control simultaneously for the effects of socioeconomic, cultural, political, and historical factors on auto use (Gomez-Ibanez, 1991; Gordon & Richardson, 1989; Pickrell, 1999). Nevertheless, since Newman and Kenworthy's work, not much research has appeared with improved methodology in international settings.

The above review suggests a number of limitations in existing studies of land use and travel mode choice. First, many studies were conducted without a strong theoretical foundation, making it difficult to identify the sources of variations in the results and to generalize study findings for policy recommendations. Second, many studies included measures of land use but often omitted travel time, cost, and/or socioeconomic variables, making it impossible to single out the effect of land use on travel. Third, existing studies have focused more on the directions of land use effects on travel choice but paid less attention to the magnitude of the effects, although a few exceptions exist (e.g., Cervero, 2002; Cervero & Kockelman, 1997). Even fewer have compared land use effects with those of pricing. Furthermore, many have noted (e.g., Handy, 1996a) but few have tested in one integrated framework the variations of land use effects on mode choice for different travel purposes. Making progress in overcoming these limitations, several recent studies signify a new stage of research in the area (e.g., Boarnet & Crane, 2001; Cervero, 2002). This study of travel choice in Metropolitan Boston and Hong Kong reflects a continuing effort to investigate the linkage between land use and travel mode choice with refined methodologies.

Methodology

Why Boston and Hong Kong?

Boston and Hong Kong are among the two end-groups on Newman and Kenworthy's (1989, 1999) logarithmic curve of land use/auto use relationships. Among the auto-oriented North American cities, Boston is a relatively friendly place for nondriving travel (see Figure 1). Its built environment and transportation services are relatively diverse (Levine et al., 2000). Such diversity offers a fairly large variation in land use attributes and in observed travel choice decisions, making Boston a methodologically appealing case for empirical analysis.

Hong Kong is the densest metropolis in the world. Featuring linear clustering and mixed development patterns, its land use provides a uniquely desirable setting for transit operations. In fact, Hong Kong is known as a transit-based city whose transit system consists of a variety of modes, mainly subway, light rail, tram, double-decker bus, regular bus, minibus, and taxi (see Figure 2). The system provides its residents with sufficient mobility and accessibility (Tong & Wong, 1997). Yet Hong Kong's environment is so unique that its land use can rarely be replicated anywhere else in the world.[4] Nevertheless, this extreme type of land use makes Hong Kong an interesting case; it offers an opportunity to study the flip side of prescribing land use as a policy to improve mobility. Hong Kong has almost all the physical attributes sought by the advocates of "get the land use right"—high density, mixed uses, and a nondriving-oriented environment. In fact, Hong Kong's land use reality goes well beyond any experience conceivable to North American cities. Still, does Hong Kong's land use pattern explain the whole story of its transit-dominated travel?

Given the sharp differences between Boston and Hong Kong in geography, culture, history, institutional settings, and indeed almost every aspect of life, issues of comparability naturally arise. In this study, Boston and Hong Kong are treated as two stand-alone cases, analyzed by means of the same analytical framework and methods. What links the two cases is the fundamental behavior of individual travelers in the two cities as they respond to changes in

Figure 1. The Harvard Square Station of Boston's subway system, 2000. One of the oldest in the U.S., the station area is also an attractive public gathering place with friendly walking and bicycle access.

the economic, physical, and transportation conditions in which they live, work, and travel. For these reasons, both case studies use a framework of disaggregate analysis.

Analytical Framework

The empirical analysis of mode choice in Boston and Hong Kong applies discrete-choice models developed from consumer choice theory (Ben-Akiva & Lerman, 1985; Domencich & McFadden, 1975). The choice theory suggests that decisions about mode choice are made on *a comparative, relative basis*. Any factors that change the *relative* attractiveness of travel modes will affect the traveler's mode choices.

Before choice modeling is presented, it is worthwhile to discuss, under the theoretical framework of consumer choice, how land use attributes enter into the utility functions of travel modes. Building such a causal link has been a notable challenge to empirical analysis in the field (Kockelman, 1997). The effects of land use on travel are better explained by identifying its differentiated impacts on modal supply in terms of quantity and quality or latent effects.

Land space itself is an important component of transportation supply. One task of land use planning and design is to allocate land spaces for transportation infrastructure that connects and organizes other land use activities (Kaiser et al., 1995). At the city and regional scale, land use planning and design typically specify types and layout of networks, road and intersection spacing, rights-of-way, and transit station sites. In area planning or subdivision design, laying out the circulation systems for vehicles and pedestrians is a key step. How land spaces are allocated across different transportation modes has a direct impact on modal supply. For example, allocating more land for parking

Figure 2. A street intersection in transit-oriented Hong Kong, 2000. Pedestrian paths are well integrated with adjacent stores and buildings.

benefits motor vehicle users (only). Adding a center, left-turn lane to the roadway helps improve through and turning traffic flows at the intersection but increases crosswalk width for pedestrians. Consequently, driving conditions improve, but walking becomes more difficult. Similarly, bus and bike modes become more attractive if the system includes exclusive busways and bike lanes.

At the micro scale, the design quality of the physical environment is part of the quality of modal supply, affecting the safety, comfort, and convenience of transportation services. Road cross-sectional design, intersection geometry, traffic signs and signals, and road surface pavement all affect the efficiency and safety of road use, and thereby the attractiveness of driving. Similarly, lighting, plantings, the width and pavement of sidewalks and pedestrian or bike paths or lanes, and the design features of bus stops or train stations all affect the supply quality of walk, bike, and transit modes (Untermann, 1984). Building setbacks, orientation of buildings to the street, and design of the street space connecting to the buildings all influence perceptions of the walking environment (Appleyard, 1981; Lynch, 1981). From the transportation service perspective, improved urban design with a more pedestrian- or bicyclist-friendly environment means improved quality for walkers or cyclists (Moudon et al., 1997).

Land use attributes in terms of density, balance and mixture of different uses, and street network patterns are surrogate measures of the built environment. To a certain degree they capture additional influences of some latent factors affecting people's travel mode choices. For example, density has a distance effect associated with all modes: Increased density results in reduced spatial separation, enhancing travel by all modes. However, nonmotorized modes benefit more from reduced spatial separation than motorized modes because the former are more sensitive to distance changes than the latter.[5] Similarly, reduced network connectivity (e.g., from a gridiron to a cul-de-sac street pattern) also creates a differentiated distance effect on motorized vs. nonmotorized modes.[6] These effects certainly go beyond travel times, and they are not reflected in cost variables, since typically there is no monetary cost assigned to travel on foot or by bike. Another dimension of density effects on travel is the psychological effect associated with road congestion, for example, uncertainty, discomfort, and fears of high accident risks. These are important qualitative factors influencing people's travel mode choices but are not fully accounted for by longer travel times. Apparently, the congestion from higher density tends to make driving less attractive but has little impact on modes that are protected from congestion, such as transit lines that are grade-separated from road traffic and nonmotorized modes.

Models and Data

The above qualitative discussion on land use/mode choice connections serves as a basis for the specification and interpretation of the choice models estimated in the study. The operational form of mode choice models used in this study takes a logit structure.[7] Three classes of explanatory variables were considered: travel costs (time and monetary), traveler socioeconomic characteristics, and land use variables (see Table 2).

Data were collected and merged from several sources to create a database for each city. For the Boston area, trip records were drawn from the 1991 Household Travel Survey (Central Transportation Planning Staff, 1993). Land use data included population, employment, street networks, and land uses by five classifications at the Transportation Analysis Zone (TAZ) level. Additional data obtained were the zonal travel time and cost matrices by different modes for the 787 TAZs in the metropolitan region. Excluding the

	Boston		Hong Kong	
Variables	**Mean**	**Std.**	**Mean**	**Std.**
Travel costs and supply[a]				
Trip distance (miles)[b]	7.4	7.4	—	—
Walk/bike time (minutes)[c]	37.3	44.9	—	—
Driving in-vehicle time (minutes)	16.8	12.9	40.2	17.3
Transit in-vehicle time (minutes)	23.8	21.5	—	—
Transit out-vehicle time (minutes)	27.6	12.9	—	—
Rail time (minutes)	—	—	53.6	28.2
Bus time (minutes)	—	—	46.1	23.8
Taxi time (minutes)	—	—	26.8	16.4
Driving costs (U.S. cents, one way)[d]	292	305	551.8	275.6
Transit costs (U.S. cents, one way)	268	215	—	—
Shared-ride costs (U.S. cents, one way)[e]	267	294	—	—
Rail costs (U.S. cents, one way)	—	—	96.4	54.9
Bus costs (U.S. cents, one way)	—	—	88.4	57.4
Taxi costs (U.S. cents, one way)	—	—	643.6	519.9
Percent workers with parking subsidy[f]	—	—	5.64	0.23
Traveler socioeconomic characteristics				
Age (years)	39	13	36	11
Proportion females	0.47	0.5	0.44	0.50
Household size (no. persons)	2.9	1.35	4	1.6
No. children under 5 in household	0.19	0.5	0.12	0.38
Proportion employed full time	0.77	0.42	—	—
Annual household income (U.S. dollars)	57,025	29,786	31,229	26,448
No. vehicles per household member	0.72	0.41	0.066	0.016
Proportion owned housing unit	0.65	0.48	—	—

Table 2. Sample descriptive statistics (continued on facing page).

observations with missing information in the merged database, the final data set for modeling contained 1,619 home-based work trips and 1,036 home-based nonwork trips.

The main data source for Hong Kong was the 1992 Travel Characteristics Survey (Hong Kong Transport Department, 1993). Zonal data included population, employment, and public and private parking supplies for the 274 TAZs in Hong Kong. Origin-destination matrices of zonal travel time and costs by all modes were extracted from the Hong Kong Regional Transportation Model (Hong Kong Transport Department, 2000). The final data set for modeling contained 20,246 home-based work trips and 15,281 home-based nonwork trips.

A few key figures highlight the sharp contrast between Boston and Hong Kong in land use and travel. In Boston, the population density (zonal average at trip origins) was 22 persons per acre, whereas in Hong Kong it was 263 persons per acre. In Boston, the modal shares of private transportation (drive alone and shared ride) for work and nonwork travel were 65.5% and 74.4%, respectively, while in Hong Kong they were 8.6% and 6.6%, respectively.

Results

The author estimated two sets of models for home-based travel in each city, one for work trips and the other for nonwork trips. Each set contained a base model and an extended model. The base model included variables typically considered in the analysis of mode choice (i.e., travel times, costs, and traveler socioeconomic characteristics). In the extended model, land use variables were added into the list of independent variables. To analyze how the effect of land use may vary for different trip purposes, the models in each city were estimated with an identical structure (see Tables 3 and 4).

	Boston		Hong Kong	
Variables	**Mean**	**Std.**	**Mean**	**Std.**
Land use and location				
Distance to nearest transit station at origin (1000 ft.)[g]	2.43	4.25	—	—
TAZ population density at origin (persons/acre)	22	31	263	199
TAZ job density at origin (jobs/acre)	17	74	80	108
TAZ population density at destination (persons/acre)	22	37	177	190
TAZ job density at destination (jobs/acre)	135	313	310	276
Connectivity: % non-cul-de-sac intersections at origins	0.66	0.09	—	—
Connectivity: % cul-de-sac intersections at destination	0.12	0.065	—	—
Entropy of land use balance at origin[h]	0.29	0.27	—	—
Entropy of land use balance at destination	0.39	0.28	—	—
Public parking spaces (per 1000 jobs)	—	—	20	40

a. Unless specified below, all time and cost data are taken from the regional transportation models for Boston and Hong Kong. Currency rate: 1 U.S. dollar = 7.8 H.K. dollars

b. Network distance between the centroids of trip origins and destinations.

c. Estimated trip time based on the formula: 1 / [1 + abs (age − 30) / 30] × (trip distance) / (speed), assuming a travel speed of 3 miles per hour for walking and 9 miles per hour for bicycling.

d. Generalized costs including tolls, parking costs, and estimated car operating costs in 1991 at 8.75 cents per mile (U.S. Department of Energy, 2002).

e. [Driving costs] / [Number of riders]

f. 1 if received any parking subsidy and 0 otherwise

g. Estimated airline distance from the city block of trip origins to the nearest bus stops or rail stations.

h. Entropy = $-\Sigma_j[Pj \times ln(P_j)] / ln(J)$, where P_j is the proportion of developed land in the jth use type and J is the number of land use categories considered. In this study, J = 3: residential, commercial, and industrial. Indexes are computed at the 800-meter grid cell.

Table 2. Sample descriptive statistics (continued).

	Work trip model				Nonwork trip model			
	Base		Expanded		Base		Expanded	
Variable (mode/s)[a]	**Coef.**	**t**	**Coef.**	**t**	**Coef.**	**t**	**Coef.**	**t**
Constant (walk or bike)	−0.0498	−0.09	−1.7461	−1.52	1.4684	2.85**	2.7258	2.30**
Constant (transit)	−0.3608	−1.32	−0.4445	−1.14	−0.4502	−1.34	−0.7394	−1.56
Constant (shared ride)	−1.1317	−3.94**	−0.5787	−1.75*	0.8625	3.79**	1.1987	4.07**
Travel costs and supply								
Walk or bike time	−0.0452	-2.10**	-0.0502	-2.27**	-0.0965	-4.32**	-0.0890	-3.92**
Transit trip time	−0.0473	-5.30**	-0.0396	-4.29**	-0.0523	-2.90**	-0.0442	-2.35**
Shared ride trip time	−0.0503	−3.76**	−0.0440	−3.16**	−0.0850	−3.22**	−0.0696	−2.54**
Drive alone time	−0.0657	−5.36**	−0.0593	−4.60**	−0.0859	−3.31**	−0.0720	−2.66**
Transit fare cost/income	−56.76	−2.75**	−40.24	−1.93*	−101.51	−2.78**	−92.27	−2.34**
Shared ride cost/income	−251.99	−8.83**	−224.93	−7.66**	−411.58	−9.30**	−382.48	−8.12**
Drive alone cost/income	−130.97	−8.41**	−110.07	−7.43**	−204.43	−7.45**	−171.31	−6.12**
Traveler socioeconomic characteristics								
Age <30 (walk or bike)	1.1769	3.14**	1.1802	3.07**	1.1873	3.66**	1.0950	3.29**
Full-time worker (drive alone)	−0.0077	−0.04	0.0515	0.28	0.5349	3.51**	0.5344	3.49**
Home owner (drive alone)	0.3751	2.60**	0.3374	2.27**	−0.0290	−0.18	−0.1063	−0.67
Female no children (transit)	0.3569	2.26**	0.3985	2.47**	0.2740	1.13	0.3482	1.38
Vehicles per worker (drive alone)	1.5053	8.01**	1.4559	7.70**	1.0056	4.73**	1.0893	4.80**
Vehicles per worker (shared ride)	0.9098	4.04**	0.8518	3.66**	0.6181	2.98**	0.6904	3.12**
Land use and location								
Trips to CBD (drive alone)	−1.3045	−6.75**	−1.0624	−5.13**	−0.4874	−1.35	−0.6650	−1.71*
Distance to nearest transit station (transit)	−0.0069	−0.35	−0.0015	−0.07	−0.1991	−2.82**	−0.1766	−2.47**
Pop. density at origin walk or bike, transit)			0.0082	2.48**			−0.0046	−0.92
Job density at origin (walk or bike, transit)			0.0008	0.68			−0.0011	−0.27
Pop. density at destination (walk or bike, transit)			0.0035	2.13**			0.0110	4.37**
Job density at destination (walk or bike, transit)			0.0009	2.94**			0.0002	0.34
% non–cul-de-sac at origin (walk or bike)			2.7056	1.84*			−2.1749	−1.41
% cul-de-sac at destination (drive alone)			3.6031	3.03**			2.6950	1.97**
Land use balance at origin (walk or bike, transit)			−0.2261	−0.72			−0.0131	−0.03
Land use balance at destination (walk or bike, transit)			0.0114	0.04			0.8427	1.95*

Table 3. Boston MNL models of mode choice for home-based trips (continued on facing page).

	Work trip model		Nonwork trip model	
	Base	Expanded	Base	Expanded
Model output statistics				
No. observations	1,619	1,619	1,036	1,036
Log-likelihood at initial	−1,668.5	−1,668.5	−1,133.0	−1,133.0
Log-likelihood at final	−969.84	−947.87	−824.83	−806.37
ρ^2	0.419	0.432	0.272	0.288
$\bar{\rho}^2$	0.408	0.416	0.256	0.265
Model improvement test ($-2[\mathscr{L}$(base model) $- \mathscr{L}$(expanded model)])	χ^2 = 43.94, d.f. = 8, $p \leq 0.001$		χ^2 = 36.92, d.f. = 8, $p \leq 0.001$	
Choice alternatives and sample shares (%)	Walk or bike	4.1	Walk or bike	9.8
	Transit	30.4	Transit	15.8
	Shared-ride	9.6	Shared-ride	37.9
	Drive alone	55.9	Drive alone	36.5

a. For a further description of model specification and estimation, see article note 7.
* $p < 0.10$ ** $p < 0.05$

Table 3. Boston MNL models of mode choice for home-based trips (continued).

The following sections present modeling results and findings, centering on four questions that have both policy and methodological importance for studying land use/travel behavior links.

1. Does the inclusion of land use variables significantly improve the model's explanatory power (i.e., do the magnitude and significance of the estimated coefficients change considerably as a result of including land use variables)?

Notably, the goodness-of-fit of both Boston models (see Table 3) and both Hong Kong models (see Table 4) improved after the inclusion of land use variables. For example, for work trips in Boston, the proportion of explained variation in mode choice increased from 0.419 in the base model to 0.432 in the expanded model. Statistical tests confirmed the significance of the improvements.[8]

In Boston's base model for work trips, all estimated coefficients of the price variables (i.e., travel times and costs) had the expected negative signs. Young workers were likely to walk or bike to work, whereas female workers with no children preferred public transit (bus, subway, or commuter rail). Those who owned houses and had more vehicles per worker in the household were more likely to drive alone to work. A downtown-bound worker was less likely to drive alone than a suburb-bound worker, in part because there are better transit services into central Boston and driving in downtown Boston can be quite difficult. Distance to the nearest transit station was not a significant factor in the commuter's decision to take transit to work. This is likely because suburban commuters often drive or receive a ride to park-&-ride facilities and take transit (mostly rail) from there to work places in inner Boston.

Hong Kong's work trip model performed similarly well. All price variables had the expected signs and were significant. Female workers without children and young people preferred taking public transportation to driving, a behavior similar to that found in Boston. The existence of a parking subsidy encouraged people to drive (Hess, 2001). Also similar to the Boston case, when there were more vehicles per person in a household, members of the household were more likely to drive to work than to take transit. Furthermore, individuals with a driver's license were more likely to drive than to use nonauto modes.

Notably, adding land use variables to the models did not change the signs of travel time, travel cost, and socioeconomic variables. In general, these variables also retained their significance to predict mode choice, suggesting that land use has an independent influence on mode choice. These findings are consistent with previous studies in other cities (e.g., Cervero, 2002; Cervero & Kockelman, 1997). There were a few exceptions to this observation. In Bos-

	Work trip model				Nonwork trip model			
	Base		Expanded		Base		Expanded	
Variable (mode/s)	**Coef.**	**t**	**Coef.**	**t**	**Coef.**	**t**	**Coef.**	**t**
Constant (rail)	2.2860	5.29**	2.5350	3.82**	6.0570	5.53**	8.8760	3.80**
Constant (bus)	3.7590	8.67**	4.0120	6.03**	8.1420	7.42**	10.960	4.69**
Constant (driving)	−2.6980	−18.88**	−2.8060	−18.40**	−1.2980	−9.20**	−1.3800	−8.63**
Travel costs and supply								
Rail trip time	−0.0290	−20.65**	−0.0291	−20.73**	−0.0332	−14.82**	−0.0330	−14.68**
Bus trip time	−0.0569	−32.48**	−0.0571	−32.60**	−0.0654	−23.85**	−0.0652	−23.69**
Driving time	−0.0174	−6.59**	−0.0128	−4.31**	−0.0118	−3.11**	−0.0029	−0.70**
Taxi time	−0.0463	−8.33**	−0.0451	−7.93**	−0.0559	−10.06**	−0.0491	−8.61**
Rail cost/income	−4756.0	−7.13**	−4597.0	−6.87**	−3072.0	−6.13**	−3093.0	−6.14**
Bus cost/income	−3642.0	−5.27**	−3476.0	−5.02**	−3528.0	−6.53**	−3556.0	−6.54**
Driving cost/income	−2519.0	−11.60**	−2371.0	−10.95**	−1956.0	−7.37**	−1752.0	−6.68**
Taxi cost/income	−8013.0	−15.31**	−7811.0	−14.99**	−240.3	−2.55**	−176.6	−1.95*
Traveler socioeconomic characteristics								
Age <30 (rail and bus)	0.9026	5.67**	1.1870	4.79**	0.7768	3.45**	1.3380	3.19**
Female no small children (rail and bus)	0.8022	4.54**	1.0780	4.08**	−0.3245	−1.64*	−0.5316	−1.68*
Parking subsidy (drive)	0.8493	10.36**	0.8390	10.21**	0.2372	2.28**	0.2351	2.24**
Vehicles per person (drive)	6.4880	39.11**	6.5280	38.92**	5.8230	25.92**	5.8870	25.92**
With driver license	2.0690	24.43**	2.0670	24.37**	1.9240	21.99**	1.9690	21.98**
Land use and location								
Public parking supply (drive)			4.2600	3.39**			1.1700	0.90
Population density at origin, (rail and bus)			0.0004	0.55			0.0029	2.19**
Job density at origins (rail and bus)			0.0051	4.38**			0.0017	1.31
Population density at destination (drive)			−0.0003	−1.09			−0.0004	−1.08
Job density at destination (drive)			−0.0001	−1.72*			−0.0004	−3.62**
Public transportation (structure coefficient)[b]	0.3799	−16.37**	0.2872	−16.70**	0.3135	−16.28**	0.2080	−17.52**

Table 4. Hong Kong NL models of mode choice for home-based trips (continued on facing page).

ton's work trip model, the level of significance of transit cost decreased from 99% to 90%, indicating a certain degree of substitutability between land use attributes and transit cost in explaining mode choice. In Hong Kong's nonwork trip model, driving cost became statistically insignificant when land use variables were included.

2. Does land use still matter to mode choice when travel time, cost, and traveler socioeconomic factors are controlled for?

For work trips in Boston, after travel time, travel cost, and socioeconomic factors were controlled for, higher population densities at both trip origins and destinations were significantly associated with higher probabilities of commuting by transit or nonmotorized modes. Higher employment densities at trip destinations increased the likelihood of taking nondriving modes. But employment densities at trip origins did not show statistical relevance to people's decisions on travel means to work. Increased network connectivity at trip origins tended to encourage walking, biking, or taking transit, but with marginal statistical significance. Yet decreased network connectivity at trip destinations resulted in a greater likelihood of driving alone. The entropy measures of land use balance had no

	Work trip model		Nonwork trip model	
	Base	**Expanded**	**Base**	**Expanded**
Model output statistics				
No. observations	24,026	24,026	15,281	15,281
Log-likelihood at initial	−33,307	−33,307	−21,184	−21,184
Log-likelihood at final	−19,664	−19,633	−12,115	−12,097
ρ^2	0.4096	0.4105	0.4281	0.4290
ρ^{-2}	0.4091	0.4098	0.4273	0.4279
Model improvement test (−2[$\mathscr{L}$(base model) − $\mathscr{L}$(expanded model)])	χ^2 = 61.6, d.f. = 5, $p \leq 0.001$		χ^2 = 36.4, d.f. = 5, $p \leq 0.001$	
Choice alternatives and sample shares (%)	Rail	36.8	Rail	24.7
	Bus	51.8	Bus	64.9
	Drive	8.6	Drive	6.6
	Taxi	2.7	Taxi	3.8
	Public transp.	88.6	Public transp.	89.6

a. For a further description of model specification and estimation, see article note 7.

b. The t-statistic for the pseudo mode of public transportation (i.e., structure coefficient) refers to the null hypothesis of the coefficient equal to one: t = (0.3799 – 1) / 0.03787 = −16.37

* p <0.10 ** p <0.05

Table 4. Hong Kong NL models of mode choice for home-based trips (continued).

influence on mode choice for commuting to work. Intuitively, whether or not there is a balance of residential, commercial, and industrial land use near work places is irrelevant when the purpose of travel is for work only. Land use balance may matter to travel for nonwork or all purposes; travelers may chain their trips to take advantage of trip origin and destination diversities (Srinivasan & Ferreira, 2002).

In Hong Kong, the higher level of parking supply increased significantly the probability of driving to work, a behavior pattern similar to that observed in American cities (e.g., Kitamura et al., 1997; Pickrell & Shoup, 1975; Shoup, 1995, 1999; Willson, 1995). The probabilities of commuting to work by rail or bus increased with job densities at trip origins. The negative signs of population and job densities at trip destinations in association with the car mode suggest that, when travel time, costs, and other factors were controlled for, people working in places where job and population densities were higher were unlikely to commute by driving. Nevertheless, only job density attained a marginal statistical significance.[9]

3. How does the influence of land use on mode choice vary for work vs. nonwork travel?

Results from the choice models for work and nonwork travel showed the varying effects of land use attributes on mode choice for different trip purposes, confirming the general expectation (e.g., Handy, 1996a). For nonwork travel in Boston (see Table 3), population density at the trip origin and job density at the destination no longer mattered, although they did for commuting to work. Network connectivity at the destination remained important to driving decisions at a reduced but still significant level. In contrast, network connectivity at the origin lost its marginal significance for the work commute and even changed sign from positive to negative (although insignificant) in the nonwork trip model. Land use balance was not important to commuting but significantly affected the likelihood to travel for nonwork activities by walking, biking, or transit. The role of several socioeconomic factors also changed. For example, females with no children no longer preferred transit to other modes for nonwork travel. In contrast to the performance of land use variables, travel time and cost variables had consistent, negative effects on mode choice for all purposes of travel.

Hong Kong's models show a similar pattern of variable performance. Specifically, travel time and cost variables retained their negative signs and in most cases their statistical significance. Females with no children did not prefer bus or rail for nonwork travel, although they did for work trips. Parking supply also became insignificant for nonwork travel. Similarly, for nonwork activities, the probabilities of taking rail or bus did not necessarily increase with job densities at trip origins. Two land use variables changed from statistically insignificant for work trips to significant for nonwork trips. These were population density at the origin for rail and bus travel and job density at the destination for driving.

4. What are the magnitudes of the effects of land use on mode choice compared with those of driving costs?

To answer this question, elasticity, which is widely used for policy sensitivity analysis, was estimated. It is computed as the percentage change of one variable in response to a 1% change of another variable. Table 5 reports probability-weighted average elasticity estimates for mode choice with respect to land use variables and to driving costs for all travel modes in Boston and Hong Kong. Several observations follow. First, the magnitudes of the elasticity estimates were relatively small, with an absolute value of less than 0.3.[10] For example, in Boston elasticity of driving probability with respect to population density was about −0.04 for both work and nonwork trips. This means that doubling Boston's current net population density would decrease driving probability by about 4%, all other factors being held constant. Second, in absolute terms, the elasticity of driving probability with respect to driving cost was greater than the elasticities with respect to each of the three land use attributes. However land use attributes could change simultaneously through planning and design, for example, having higher density along with more balanced land use and improved network connectivity. Consequently, *the combined land use elasticities of driving probability are similar in magnitude to those of driving cost.*[11] This suggests that the influence of land use on decisions about driving is potentially as strong as that of pricing. Third, estimated elasticity values for Hong Kong were in the same range as for Boston, in spite of dramatic differences between the two cities in land use, cultural background, and economic and social settings.

Discussion and Conclusions

The modeling outcome reported above answers affirmatively the question of whether land use still matters for travel mode choice when the effects of travel time, cost, and socioeconomic factors are taken into account. Results showed that, for both work and nonwork trip purposes, land use explained additional variations in mode choice when controlling for price variables. Overall, for Boston travelers, land use features at trip ends mattered more for mode choice than at trip origins. These results support the idea of clustering development at activity centers with multiple uses and well connected streets (e.g., Cervero, 1989). With respect to the policy debate on the link between land use and travel, the study provides supporting evidence for concluding that there are potential transportation benefits for reducing drive-alone travel through planning and design practices promoted by the New Urbanists and the smart growth advocates.

Conclusions and Policy Implications

The study has shown that travel cost variables affect mode choice in a uniform direction across all modes. In most cases, these variables carry consistent statistical significance across different trip purposes. In contrast, the link between land use variables and mode choice demonstrates no such uniformity. The finding brings both encouraging and challenging news to those who have faith in the mobility role of land use. On the one hand, those land use variables that did show statistical significance worked in the same direction, encouraging nondriving mode choices. On the other hand, land use variables displayed a varying degree of significance for mode choice, depending on whether they were measured at trip origins or destinations and whether they related to work or nonwork travel.

The results reflect the spatial nature of modifying land use as a place-based, location-specific policy strategy.[12] Travelers' responses to changes in land use vary depending on how much weight they put on land use in their travel decisions, which in turn depend on where they travel from and to, and for what activities. Implications of the results are twofold. Land use strategies do offer the potential to influence travel. Yet the extent to which land use can affect travel is commensurate with the spatial extent to which these strategies can be implemented. The neighborhood-level design strategies would expect potential transportation benefits at the neighborhood scale. If planners aim at achieving transportation objectives by the land use approach at the regional level, they should seek changes in the regional spatial structure accordingly.

It is important to emphasize that the *composite* effect of changes in land use (i.e., densification along with increased land use balance and network connectivity) on driving probability can be comparable in magnitude to the effect of increased driving cost, although estimated elasticities

	Elasticity estimates							
	Work trips				Nonwork trips			
Boston	**Transit**	**Drive**	**Walk or bike**	**Shared ride**	**Transit**	**Drive**	**Walk or bike**	**Shared ride**
Population density	0.118	−0.044	0.105	−0.071	0.126	−0.040	0.060	−0.033
Job density	0.090	−0.031	0.026	−0.044	0.004	−0.001	−0.004	0.0003
Land use balance	—	—	—	—	0.121	−0.043	0.118	−0.043
Connectivity	0.083	−0.091	0.072	0.299	0.044	−0.195	0.047	0.153
Driving cost	0.229	−0.144	0.113	0.252	0.183	−0.227	0.062	0.120

	Work trips			Nonwork trips		
Hong Kong	**Transit**	**Drive**	**Taxi**	**Transit**	**Drive**	**Taxi**
Population density	0.005	−0.039	−0.026	0.014	−0.110	−0.128
Job density	0.011	−0.077	−0.118	0.006	−0.070	−0.024
Driving cost	0.023	−0.242	0.019	0.014	−0.191	0.012

Notes: Elasticities reported above are probability-weighted average individual elasticities for each mode (see Ben-Akiva & Lerman, 1985, p. 113). For nondriving modes, for the driving cost effects, the figures indicate the cross-elasticities of mode choice probabilities. Connectivity elasticity is measured by a 1% *decrease* in the share of cul-de-sac intersections.

Table 5. Elasticity estimates of mode choice probabilities in Boston and Hong Kong.

of driving probability with respect to *individual* aspects of land use are relatively small. This finding should send a strong message to inform the debate on the effectiveness of land use for influencing travel. In the search for policy strategies to address the transportation, environmental, and social concerns associated with growing vehicle travel, the potential of land use should not be dismissed, but needs to be further explored.[13]

Lessons from Hong Kong

What can be said from the Hong Kong case that is relevant to the North American policy debate? The evidence of travel choice revealed from the disaggregate modeling illustrates a behavioral commonality among individual travelers in the two cities. Whether traveling in Boston or Hong Kong, the individual as an economic entity responds in similar, rational ways to costs of travel, personal and family responsibilities, and spatial constraints.

What factors have driven Hong Kong to the far right on Newman and Kenworthy's (1989, 1999) logarithmic curve of land use/auto use relationship? A known factor is Hong Kong's exceptional natural and built environments that support its efficient multimodal transit system. Another key factor is Hong Kong's strong fiscal and regulatory control over owning and using the private automobile (Dimitriou, 1994; Hau, 1999). In Hong Kong, the after-purchase costs of owning and using private automobiles are among the highest in the world. Expenses for vehicle operation and registration are typically 4 to 10 times higher in Hong Kong than those in the Boston area.[14] Parking also is extremely difficult and expensive. Many in Hong Kong can afford to buy a car but cannot find or afford a place to park it.

Pertinent implications of the Hong Kong experience lie in the fact that Hong Kong's land use offers desirable attributes for nondriving travel, but the city still needs a strong fiscal policy to restrain the growth in demand for auto use. This means that *land use is necessary but not sufficient to influence travel.* This implication is essential to the current policy debate. If the advocates of "get the land use right" want to make land use a more effective mobility tool, complementary policies such as transportation pricing should be adequately incorporated. If the advocates of "get the price right" want to improve the feasibility of implementing pricing policies to reduce driving, providing viable travel options is the place to start—which requires deliberately planned and designed nondriving-friendly land uses. The two form a pair of tactics that are more feasible and effective in combination than either implemented alone.

Future Directions

This study can be extended further in several directions. To test all the propositions discussed in the methodology section about how land use influences mode choice through its differentiated impacts on mode supply, it is necessary to collect and incorporate into the models detailed land use information at a level finer than TAZs. It is even more important to understand how travelers perceive and evaluate the qualitative attributes of the built environment in their mode choices. With the help of advanced analysis techniques (e.g., Ben-Akiva et al., 1997), it is possible to explicitly account for latent effects on mode choice of density, mixed use, and design quality of the built environment. Another direction to extend this research is to address self-selection issues through combined modeling of travelers' residential locations and mode choices.[15]

In closing, the evidence from travel mode choices in Boston and Hong Kong demonstrates both the potential of land use in influencing travel *and* the importance of having pricing strategies in place in order to make land use more effective. In the search for policy solutions to the growing demand for driving, the debate between "get the land use right" and "get the price right" should focus not on which one is more effective, but on how the two can be integrated as complementary policies.

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Notes

1. This study uses the terms *land use*, *urban form*, and *the built environment* interchangeably. They all refer to the physical environment in which people live, work, and travel.

2. For example, at the regional scale, some studies have identified a strong correlation between urban density and auto use (e.g., Kenworthy & Laube, 1999; Newman & Kenworthy, 1989, 1999; Pushkarev & Zupan, 1977). Others, however, have found little evidence to connect compact urban form with reduced travel (e.g., Giuliano & Small, 1993; Wachs et al., 1993). At the micro level, studies have shown modest to strong influence of built-environment attributes on travel mode choice, vehicle miles of travel, and trip distances (e.g., Cervero, 2002; Cervero & Kockelman, 1997; Frank & Pivo, 1994). Yet others have reported negligible effects of urban form on travel when behavioral variables such as travel times, costs, and traveler socioeconomic characteristics were taken into account (e.g., Boarnet & Crane, 2001; Boarnet & Sarmiento, 1998; Crane & Crepeau, 1998).

3. Studying mode choice is of particular policy interest. Most undesirable travel outcomes are linked to the dominant use of the private automobile. If the share of car trips—particularly those made by single-occupant vehicles—could be reduced, problems such as congestion, environmental degradation, and energy consumption would be eased to a significant extent.

4. Singapore may be the only exception.

5. Because traveling an additional tenth mile is more difficult on foot or by bike than by car, the marginal cost (in the generic sense) for overcoming spatial separation is greater for nonmotorized modes than for motorized modes. For an illustrative explanation, see Figures 4–6 in Crane (1996a).

6. In fact, there are other attributes of the built environment that matter more than the geometric difference between gridiron and cul-de-sac. When Clarence Stein and Henry Wright (Stein, 1966) promoted the cul-de-sac/curvilinear network in their design of Radburn, New Jersey, there were also other key elements, namely, separation of pedestrians from automobile traffic and superblocks. In principle, cul-de-sacs protect a neighborhood from through traffic and provide quiet and safety, while curvilinear streets provide variety and changing street vistas. Their strength over the traditional gridiron system depends on the provision of parallel, separated circulation systems designated for pedestrians or bicyclists. In decades of suburban development, however, the only part of the Radburn language that was institutionalized was the cul-de-sac/curvilinear network. The other central component, the pedestrian/bicycle circulation system linking public spaces and facilities, has been largely neglected. When pedestrians and bicyclists are put into a cul-de-sac/curvilinear network that is designed primarily for the auto, they are certainly worse off than when they are in a grid system.

7. The general form of logit models is:

$$P(i) = e^{\beta' X i} / \sum_{j \varepsilon c} e^{\beta' X j}$$

where $P(i)$ is the probability of a traveler choosing mode i from a feasible choice set C and X is a vector of explanatory variables. Vector β includes parameters to be estimated to capture the direction, significance, and magnitude of corresponding X in influencing travel mode choices. After several model specification tests, the Boston models took a conventional multinomial logit (MNL) form, whereas Hong Kong's models had a nested logit (NL) form. In Boston's MNL models and Hong Kong's NL models, travel time and cost variables were specified uniquely to corresponding modes. Hence, the models estimated different time and cost coefficients for different modes. Specifying these variables in such a mode-specific structure assumes that the marginal effect of travel time and cost on mode choice varies across different modes. An alternative approach is to specify and estimate a time or cost coefficient that assumes that the marginal effect of travel time and cost is the same across all modes. This study took the former approach to maintain consistency with the theoretical discussion in the methodology section. For more discussions on model specifications with mode-specific vs. mode-generic variables, see Ben-Akiva and Lerman (1985, p. 75). For detailed model specification tests and estimations related to this study, see Zhang (2001).

8. The model improvement is tested based on the likelihood ratio test with the test statistic given by −2[L(base model) −L(expanded model)], which is asymptotically distributed as χ^2 with degrees of freedom equal to the difference in number of parameters between the base and the expanded model. For further details, see Ben-Akiva & Lerman (1985, p. 91).

9. Only rather coarse measures of land use density at the zonal level were available for Hong Kong. Lack of more detailed information on Hong Kong's built environment restricted how well the models captured the link between land use variables and choice behavior.

10. In general, these elasticity estimates are smaller in magnitude than those reported in previous studies of land use impacts on travel behavior (e.g., Cervero, 2002; Cervero & Kockelman, 1997), mostly because in those studies, elasticities were computed at the sample mean or mode.

11. These estimates are partial elasticities and therefore they are additive. For example, the combined land use elasticity of driving probability is $(-0.044) + (-0.031) + (-0.091) = -0.166$

12. This is similar in magnitude to the driving cost elasticity (−0.145). In contrast, pricing may be characterized as a people-based strategy. The uniformity shown by the cost variables influencing travel choice makes it technically simple and direct to suggest pricing as a policy instrument —for example, increasing drive costs in order to reduce driving demand. The degree to which such policies can achieve their objectives depends much on the political feasibility of implementing them.

13. These elasticity values are estimated with a sample of cross-sectional data from the Boston area. Whether the same or similar estimates can be obtained from other cities will require specific analysis of those cities. In addition, the elasticity estimates suggest the *potential* effects. Feasibility of implementing land use changes is a critical but different issue that goes beyond the scope of this study.

14. In Hong Kong, major categories of after-purchase costs for privately owned vehicles include the First Registration Tax (FRT), Annual License Fee (ALF), insurance, and fuel costs. In 2000, the FRT on average was 50% of a vehicle's value (Hong Kong Transport Department, 2000), compared to a 5% sales tax in the Boston area. For a mid-size car, the ALF was approximately US$1,000. In addition, the price of unleaded gasoline in Hong Kong was US$5.40 per gallon, about four times the U.S. average.

15. For an example of studying trip frequency, see Boarnet and Sarmiento (1998).

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