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Residential Relocation and Commuting Behavior in Shanghai, China: The Case for Transit Oriented Development

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1. Introduction

Over the past decade, mainland Chinese cities have rapidly suburbanized. Fueling the centrifugal movement of people and jobs out of central cities has been rising disposable incomes which allow more housing consumption and not unrelated, private automobile ownership (Ingram, 1998). More and more, Chinese cities are mimicking the suburbanization trends and patterns of the post-World War II United States, the world's most car-dependent nation.

The sustainability implications of car-oriented suburbanization are cause for concern. Since 1978 when China's central government introduced its open-door policy of economic form, urban population has grown from 80 million to more than 560 million, an annual growth rate of 7.5% (Lin, 2002; Zhang, 2007). Vehicle ownership has increased at more than twice this rate. In Shanghai, the number of registered private automobiles jumped from 200,000 in 1991 to 1.4 million in 2002 (Zhang, 2007).

Urban China's swift pace of peripheral growth has predictably overwhelmed roadway networks. From 2000 to 2003, China's roads absorbed nearly 14 million additional vehicles – an average of almost 13,000 new cars and trucks per day (Appleyard et al., 2007). In central Beijing, the average travel speed on major arteries plummeted from 45 kph in 1994 to 12 kph in 2003 (Cervero, 2004B). Traffic snarls have in turn worsened air quality. A World Bank study shows that of the 20 most severely polluted cities in the world, 16 are located in China (Appleyard et al., 2007) . Threats to global pollution are further cause for alarm. Currently, the world's second largest greenhouse gas emitter, China is on a pace to surpass the U.S. in 2008 (Fraker, 2007).

Among the strategies being pursued to head off rising traffic congestion and worsening environmental conditions have been investments in urban rail systems. Many Chinese cities are approaching the size (roughly 5 million inhabitants) and density thresholds (15,000 inhabitants per square kilometer in the urban core) often thought necessary to justify high-capacity railway investments (Cervero, 1998; Fouracre and Dunkerley, 2003). Urban rail systems are currently found in 12 mainland Chinese cities. Plans call for expanding and upgrading existing rail systems and building new ones in 15 other Chinese cities. Bus Rapid Transit (BRT) systems are also being built or expanded in Beijing, Tianjin, Chengdu, Xian, and Kunming. The cities of Tianjin and Dalian also operate trams on central-city streets. Opportunities for creating sustainable city forms through bundling land development and railway investments in large Chinese cities are quite substantial and largely untapped. Today, increasing numbers of large, rail-served Chinese cities are looking to Transit-oriented development (TOD) as an alternative form of urbanism that reduces over-reliance on the private automobile.

This paper examines the effects of residential relocation to Shanghai's suburbs on job accessibility and commuting, focusing on the influences of proximity to metrorail services and neighborhood environments on commute behavior and choices. The policy implications of the research findings on the planning and design of suburban communities in large cities like Shanghai are addressed in the conclusion. Our research suggests that TOD has a potentially important role to play in placing China's large, rail-served cities on a more sustainable pathway.

2. Growth and Travel in Urban China

Today, the historical centers of Chinese cities are being given over to the office, retail, and government sectors, on land formerly occupied by working class families. Some households are being forcefully displaced by government takeover of land while others are willingly making the move, cashing in on their valuable central-city land holdings and with income in hand, seeking suburban locales with lower densities, less traffic and noise, and larger, more modern housing. Developers are responding. Newer, market-oriented housing developments are today springing up not only in large cities like Shanghai, Beijing, and Tianjin, but also smaller ones such as Chengdu (the capital of Sichuan Province), and Jinan (the capital of Shandong Province).

For most Chinese households relocating to the suburbs, the only option available is to reside in mid-to-high-rise towers situated on fairly isolated superblocks. While the interior of these projects offer shared courtyards, little motorized traffic, and relative safety and security, a signature feature is the separation from everyday "city life", in marked contrast from many households' previous residences – i.e., compact, mixed-use settings with most activities within walking distance, and if not, reachable by bicycle.

A study of Shanghai's first wave of auto-oriented suburbanization in the early 1990s documented the physical separation of workers from their jobs, resulting in increased reliance on motorized modes and correspondingly marked increases in daily travel-time expenditures (Shen, 1997). Travel surveys reveal the average trip length in Shanghai increased from 4.3 km in 2986 to 6.8 km in 2004 (SCCTPI, 2005). A recent study found that a move to Beijing's periphery lengthened commute times more than a move to the urban core, and that 'reluctant' movers averaged longer travel time increases (Yang, 2006). These experiences largely mimic those found in other countries. In a study of Glasgow, Scotland, Forbes and Robertson (1978) found that families relocated due to slum clearance ended up making significantly longer trips after moving to the urban edge. A study of housing decentralization in Mumbai found significant changes in both job accessibility and neighborhood quality following relocation (Takeuchi *et al*, 2006). Those who moved farther away from their jobs generally experienced welfare losses (as measured by compensating variation). Similarly, evidence from the United States reveals that people with lower incomes become less accessible and devote more time to commuting following suburban moves (Pucher and Renne, 2003; Clifton and Lucas, 2004; Holzer, 1991; Blumenberg, et al., 2002; Cervero, 2004A). Based on these experiences and in view of the urban transport sector's immense ecological footprint in urban China, the cumulative impacts of decentralization on commuting and car dependence needs to be closely gauged, as should ways of moderating increasing demands for motorized travel.

3 STUDY FOCUS, RESEARCH DESIGN AND SURVEY DATA

In the sections that follow, statistical models are presented that empirically estimate the influences of residential relocation on changes in job accessibility, modal choices, and commute durations. The city of Shanghai is used as a case context. Based on a survey of housing and transportation characteristics of sampled households at their prior residences and current suburban residences, the influences of factors like changes in accessibility and proximity of new suburban residences to metrorail services on commuting behavior are explored. Before turning to these research results, this section describes the case settings, sampling approach, and data collection instruments.

3.1 Study Setting

Shanghai, China's second largest city with some 15 million inhabitants, is a bustling, entrepreneurial, and increasingly westernized metropolis. With the largest international port in China, Shanghai is the nation's center for commerce, finance, trade, and technological innovation. The city's administrative area is a triangular region that covers 6,340 square kilometers, bordered by the Yangze River Delta on the northeast and southeast, and Jiangsu and Zhejiang Provinces in the north, west and south (Figure 1). Shanghai's urbanized area covers 2,643 square kilometers, with the urban core located near the river delta.

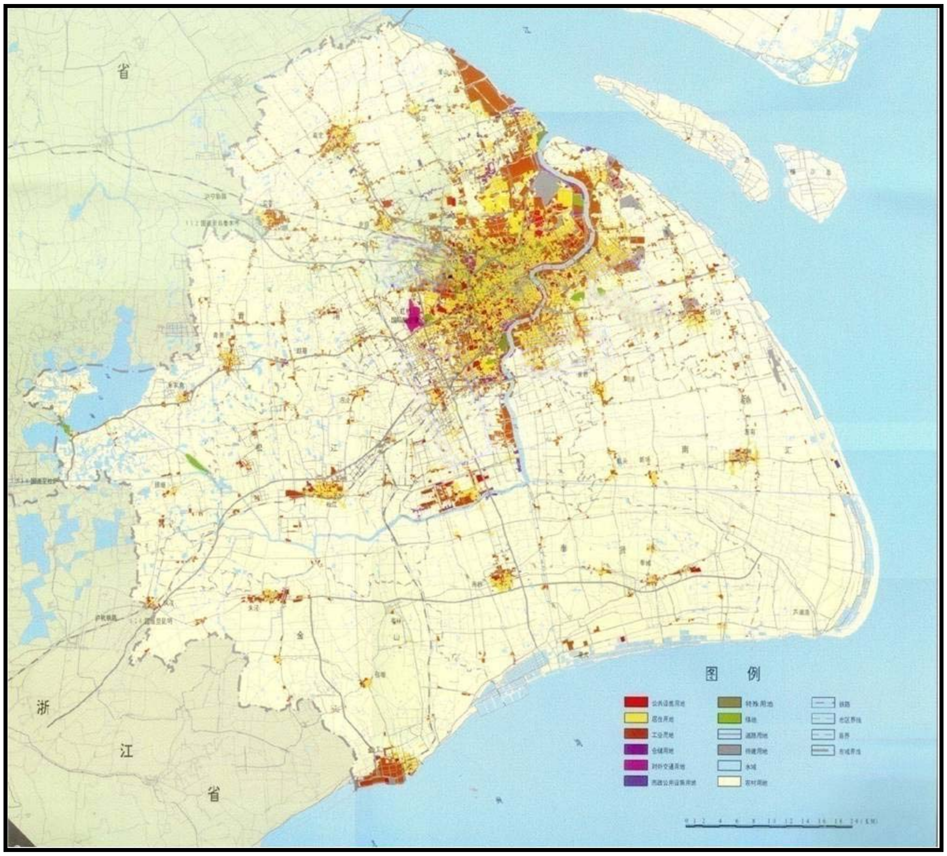

Figure 1. Shanghai Administrative Area

3.2 Sampling Approach and Survey Sites

A stratified sampling approach was adopted for conducting this research. First, three neighborhoods on Shanghai's outskirts – one directly served by metrorail and the others not – were selected. Then, six to seven housing projects (each 12 to 20 stories in height) were chosen in each district. In all, 20 housing projects comprised the sampling frame. In consultation with local planners, these 20 buildings were considered representative of housing and neighborhood environments in each of the districts. All of the selected housing developments were no farther than 1.5 kilometers from Shanghai's Outer Ring Road – a reference commonly used to demarcate the urban core from the outlying areas – and were no more than six years old. This meant that surveyed households surveyed consisted of relatively recent movers. Lastly, all household members 12 years of age and above residing in each of the selected buildings were asked to complete a self-reported survey on travel behavior and household attributes.

The 20 selected housing projects and their surroundings represented contrasting settings not only in terms of proximity to metrorail services but also levels of mixed-use activities. Additionally, they spanned a mix of housing types and household demographics. One quarter of the sampled units are government-subsidized housing set aside for relocated residents, or developments with both commodity and affordable housing; remaining developments consist of comprises market-based housing all ends of the price spectrum. All sampled developments were contained within superblocks and in general represented less walking-friendly, mixed-use environs than residents' prior neighborhoods.

Each of the three surveyed neighborhoods is briefly described below. Figure 2 shows the location of all three neighborhoods within the Shanghai region.

Jiangqiao

Jiangqiao is a residential community that straddles the Outer Ring Road to the northwest of downtown Shanghai, on land that was once designated in the Shanghai master plan as a greenbelt. Jiangquiao has limited retail shopping and only a few small grocery stores at the time of the survey. The area is served by a freeway which links to the Outer Ring Road but has no metrorail service. Conventional surface-street buses connect residents to the central city.

Meilong and Xinzhuang

These two rail-served communities are located at the southwest corner of the Outer Ring Road. Meilong lies inside and Xinzhuang is situated just outside of the ring

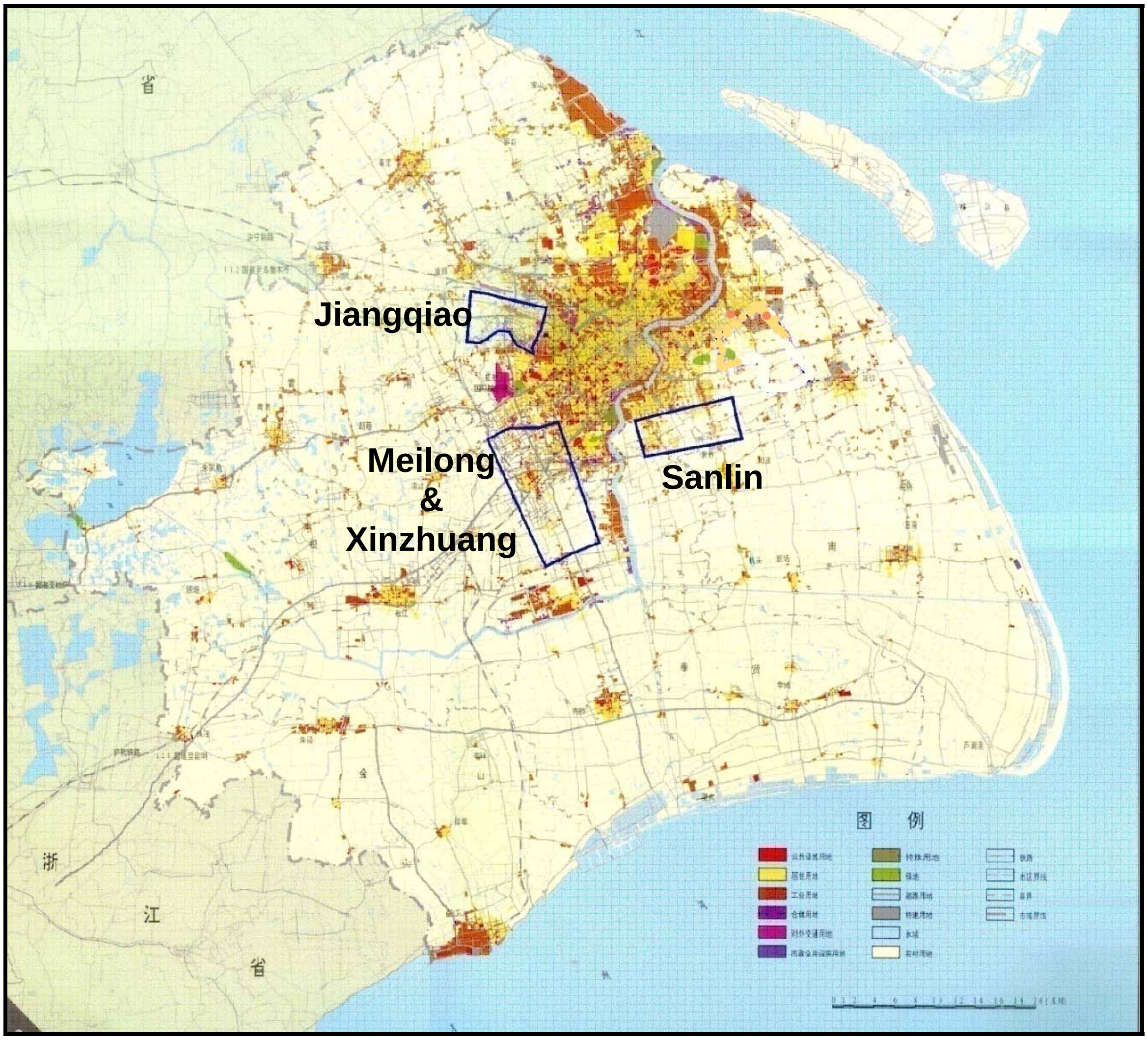

Figure 2. Three Surveyed Neighborhoods on the Periphery of Shanghai

road. Both neighborhoods are served by the Metro Line 1 (the Red Line) and Xinzhuang also by the suburban Line 5. Also, both neighborhoods have primarily market-based residential housing (i.e., no relocation housing). Meilong is the older of the two neighborhoods, featuring high densities, local retail uses, and good cycling infrastructure. Xinzhuang is also a mixed-use, transit-oriented neighborhood with somewhat lower densities. Both neighborhoods have minimal employment, so most working residents commute to the central city.

Sanlin

A mixed-use suburban town, Sanlin is located in the Pudong area (east of the Huangpu River). Over the past decade, the Shanghai government relocated over one million residents who previously occupied the riverside site of the 2010 World Expo, many of them to Sanlin. At the time of the survey, Sanlin had no metrorail station, thus residents reliedy mainly on bus transit for motorized travel. In 2009, a metroline is planned for Sanlin (South, 2006)

3.3 Data and Sampling Frame

Providing the data inputs for this research were responses to a before-and-after survey of 900 households (containing 2,840 inhabitants) that resided in the 20 housing developments across the three suburban districts. The survey instrument was pre-tested and following several revisions was administered by the municipality of Shanghai's survey division during a two-week period in October 2006. As noted earlier, the survey was designed to gather current and pre-move retrospective data on all household members' travel patterns, focusing on the commute trip.

Survey results were supplemented by other data to carry out the analyses. One, regional job accessibility indices were also computed – specifically, the number of jobs accessible to a household within one hour of network travel time, either via public transit or private automobiles. For details on the method applied in estimating job accessibility, see Day and Cervero (2007). Data were also compiled on neighborhood characteristics of respondents' current residences (e.g., average length of road links between intersections, number of bus lines within a 1000-meter radius of surveyed residences, and the ratio of road links to intersections within the 1000-meter radius). Thus changes in job accessibility and neighborhood characteristics as well as the presence of nearby metrorail services, controlling for household and person-level demographic variables, were used to predict changes in commute behavior.

4 EMPIRICAL RESULTS AND RESEARCH FINDINGS

This section first presents key descriptive findings from the before-and-after survey. This is followed by a path diagram that postulates statistical relationships between predictor and outcome variables of interest. The section closes with discussions of the modeling results *a propos* the core research questions.

4.1 DESCRIPTIVE STATISTICS

Below, descriptive findings from the survey are presented with regard to: previous residential location in metropolitan Shanghai; choice and tenure status; and changes in commuting expenditures and job accessibility. Statistics are presented for those who moved by choice and those who were required to relocate by government fiat (called "non-choice movers").

Location of Previous Residence

Figure 3 shows the previous locations of the 900 sampled households across the three surveyed neighborhoods. The figure also delineates four circular zones used to define prior residences: inner ring (from city core to the inner-ring road); middle ring (from inner-ring road to the middle-ring road); outer ring (from the middle-ring road to the outer-ring road); and outer-outer ring (beyond the outer ring road). The largest share (32%) of surveyed households previously resided between Shanghai's inner and middle ring roads, followed by residency inside the inner ring road (i.e., the historical city core, at 28% of the sample). Around a quarter of those surveyed previously lived

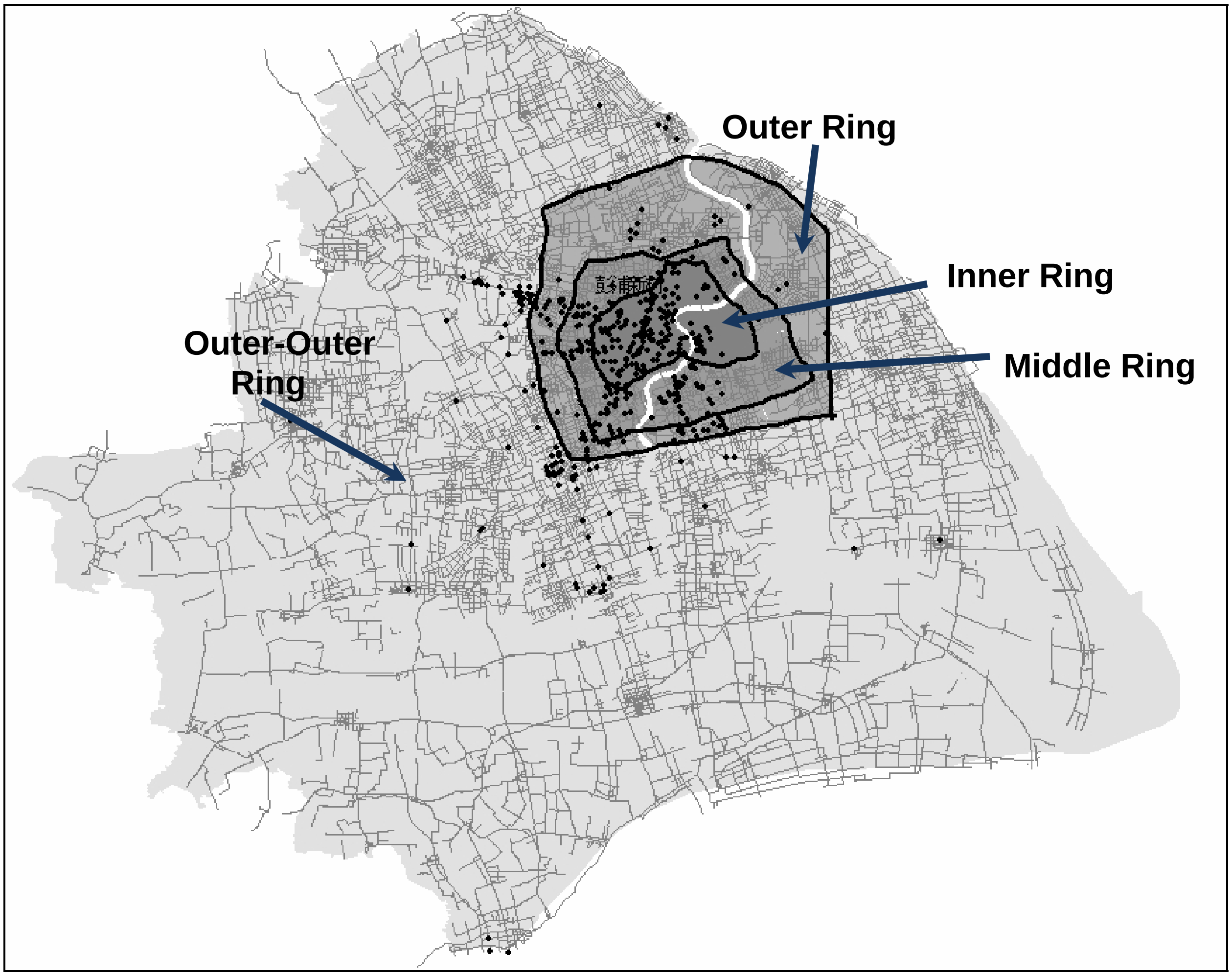

Figure 3. Location of Previous Residence in Metropolitan Shanghai Among 900 Surveyed Households

outside the outer ring road (i.e., even further out from the core than their current residence), and 14% resided between the middle and outer ring.

Choice Status and Tenure Length

The survey revealed that 51% of the sample left their previous residence by choice and had complete freedom in selecting their current residential location. Fifteen percent of the households, however, were forced to leave their previous location but freely chose the location of their new residence. And 34% of the sample had no choice about leaving their previous residence and had no other housing options aside from the one presented to them at the time of relocation.

Mover status was associated with household income. At their prior residences, choice movers averaged an annual household income of 68,027 RMB (in 2006 currency) compared to 39,715 RMB for non-choice movers (or around US$8,500 and US$4,960, respectively, based on exchange rates in 2006).

At the time of the surveys, three-quarters of the sampled households had lived in their current residence for three or fewer years. This contrasts with their prior residence, where the median length of tenure was more than 15 years.

Changes in Commute Expenditures and Regional Job Access

Outlays for commuting to work increased after moves, in terms of both travel time and cost. Among choice movers, the mean monthly expenditures for commuting rose 53 RMB per household worker after the move; for non-choice movers, it rose by 29 RMB. In terms of travel time, the trend was reversed: monthly travel time rose by 216 minutes monthly for choice movers and 605 minutes for non-choice movers. Valuing the time it took to get to work at one-third the household wage rate per worker, choice movers saw a monthly increase of 170RMB per worker in combined travel outlay and time costs, while non-choice movers averaged an increase of 115RMB.

Regional job accessibility decreased for most movers, particularly those who had no choice but to relocate. Non-choice movers averaged a decrease of 980,000 jobs that could be reached within one hour motorized travel time of their residence following the move, compared to a decrease of about 530,000 jobs reachable within an hour for choice movers.

4.2 MODELING APPROACH

The path diagram shown in Figure 4 guided the modeling of this research. It posits that changes in location – expressed by prior location (e.g., inner ring, middle ring) and proximity to rail services – explain changes in job accessibility, controlling for other factors (e.g., household income levels). Changes in location and accessibility in turn influence changes in commute mode, again controlling for other explanatory factors. Lastly, changes in all three factors – location, job accessibility, and commute mode – conspire to influence changes in commute time.

This path diagram posits a recursive (uni-directional) set of relationships, allowing single-equation, ordinary least squares (OLS) estimation to be used. Predictor variables that produced reasonably interpretable results consistent with expectations

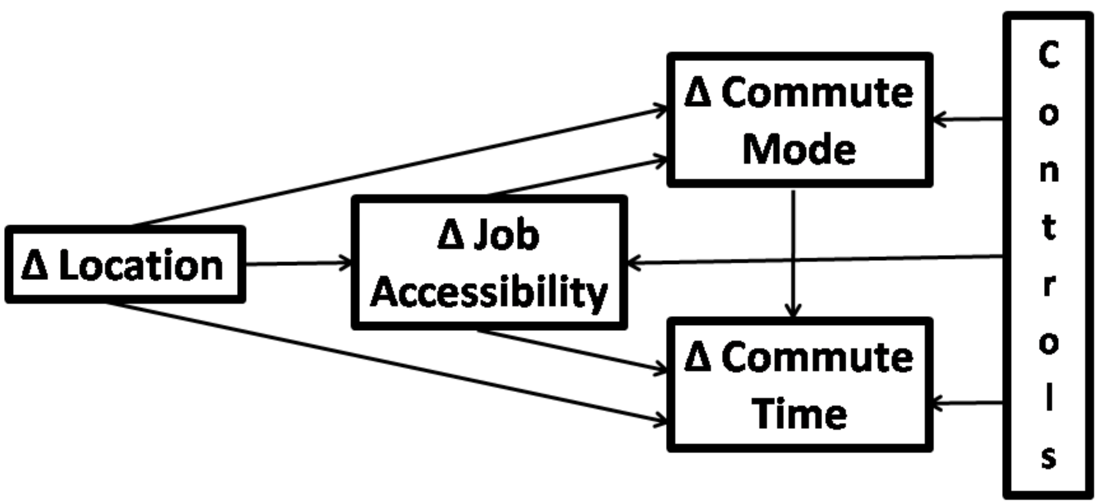

Figure 4. Path Diagram of Factors Influencing Changes in Job Accessibility and Commuting Behavior

and that shed light on the influences of policy variables of interest, such as proximity to rail services and neighborhood attributes, are presented in the models below.

4.3 CHANGES IN JOB ACCESSIBILITY, MODE CHOICE, AND COMMUTE DURATIONS

This section presents the core findings of the research. Models are presented that account for the influences of relocation as well as proximity to metrorail and neighborhood attributes on changes in job accessibility, commute duration, and mode choice.

Changes in Job Accessibility

It was expected that many households in the sample experienced poorer access to jobs in the region and that this in turn resulted in longer commute durations. It was also hypothesized that relative to lower income households and non-choice movers, more-affluent and choice-mover households would be better able to self-select into more accessible locations.

Table 1 presents a best-fitting OLS model for predicting changes in regional job accessibility – specifically, the number of jobs that can be reached within one hour via highway and transit networks -- following moves to Shanghai's periphery. The "outer ring" served as the reference category for the three "prior residence" dummy variables, thus model coefficients should be interpreted with respect this location. As expected, movement from more central areas to the periphery reduced job accessibility the most, followed by a relocation from the middle ring. However, movement to the Metrorail-served neighborhoods of Meilong and Xingzhuang helped to offset this decline (presumably because of comparatively fast rail access to potential job destinations). And moving to within 1 km of a metrorail station within the Meilong and Xingzhaung

Table 1. Model for predicting changes in Job Accessibility Index (in 1,000,000s) from prior to current residence, Surveyed Household

Location Variables	**Coef.**	**Std. Error**	**Prob.**
Prior Residence: Inner Ring (0-1)	-15.54	.887	.000
Prior Residence: Mid-Ring (0-1)	-9.44	.833	.000
Prior Residence: Outer-Outer Ring (0-1)	7.92	.793	.000
Moved: Inner Ring to Rail-Served Meilong/Xingzhuang (0-1)	4.21	1.173	.000
Moved: Mid-Ring to Rail-Served Meilong/Xingzhuang (0-1)	.85	.411	.039
Moved Near Metro: To within 1000m of Metro Station (0-1)	1.93	.786	.014
Control Variables			
Household Income: Current Residence, in 2006 RMB (100,000s)	1.32	.339	.000
Automobile Ownership: Automobiles per Worker in Household, Current Residence	1.67	.928	.072
Job Change: 2nd wage-earner (0-1)	1.35	.727	.064
Non-Choice Move: (0-1)	-.971	.579	.094
Constant	-4.46	.79	.000
Summary Statistics R Square = .678 F (prob.) = 141.73 N = 685			

neighborhoods offset accessibility losses even more. All else being equal, the model suggests that someone moving from the inner ring to one of the three neighborhoods near the Outer Ring Road had 1.55 million fewer jobs that could be reached via the highway and transit network within one hour's time. If the relocation was to the rail-served Meilong-Xinzhuang district, the decline was tempered: 1.13 million fewer jobs within one-hour motorized travel time. And if the relocated residence was within one km of a station on Metro Line 1, the drop was further moderated: 940,000 fewer jobs within an hour's time by car, train, or bus.

Consistent with expectations, automobile availability at the current residence enhanced job accessibility. Given it is far easier and less costly to own and park a car in Shanghai's suburbs than central city, car ownership moderates job accessibility losses just as proximity to rail transit does. The model further shows that household income at current residences and job changes among the second (and typically lower salary) wage-earner were associated with positive changes in accessibility, however compulsory relocation was not. The finding that accessibility to jobs throughout the region declined for non-choice movers is of some concern given that prior residential location and levels of metrorail access were statistically controlled in the model. That is, regardless of where their prior residence was within the region and whether or not they relocated to the rail-served neighborhoods, non-choice movers suffered declines in job accessibility whereas choice movers did not.

Changes in Mode Choice

The analyses presented in this section are not mode-choice models in the strict sense. This is because fully specified mode-choice models require some measures of costs (e.g., travel times) for specific trips among competing modes, an important component of utility. However, neither the precise origin of previous residences nor the precise locations of major trips were known from the retrospective surveys that allowed comparative travel times among available modes to be calculated for specific trips. Accordingly, the analyses in this section are presented less as predictive mode-choice models and more as explorations of factors associated with changes in commute mode based on attributes of the trip maker as well as attributes of the surrounding neighborhood of the current residence (including proximity to Metrorail, street connectivity, and the job accessibility index).

Analyses of change in mode were conducted only for the household head and only cases where the work trip at the prior location was either non-motorized (i.e., by foot or bicycle) or by bus. Figure 5 shows the distribution of mode changes across four modal types: NMT (Non-Motorized Transport), Bus, Metrorail, and Automobile. Four options, of course, involved no changes – e.g., rode bus before and after ("Bus to Bus" in the figure). Indeed, most of the surveyed heads (58.8%) stayed with the same commute mode before and after their moves. The most common modal set was "Bus to Bus" – 27.2% of surveyed household heads, followed by "Auto to Auto", and "Metro to Metro". Among those switching modes, the most common changes were "NMT to Bus" (8.2%) followed by "Bus to Metro" (8.0%). There were no instances of surveyed commuters shifting from "Metro to NMT", "Metro to Bus", or "Auto to Bus". Surprisingly, a few (0.6%) of household heads gave up a car and switched to cycling or walking to work after the move to the outskirts.

The Mode Change models presented below examine the influences of neighborhood environmental factors as well as traveler attributes for the following types of commute switches: NMT to Bus (8.2% of cases); NMT to Metro (2.5%); NMT to Auto (2.5%); Bus to Metro (8.0%); and Bus to Auto (6.1%). The other commute-mode changes were too small in incidence to estimate models.

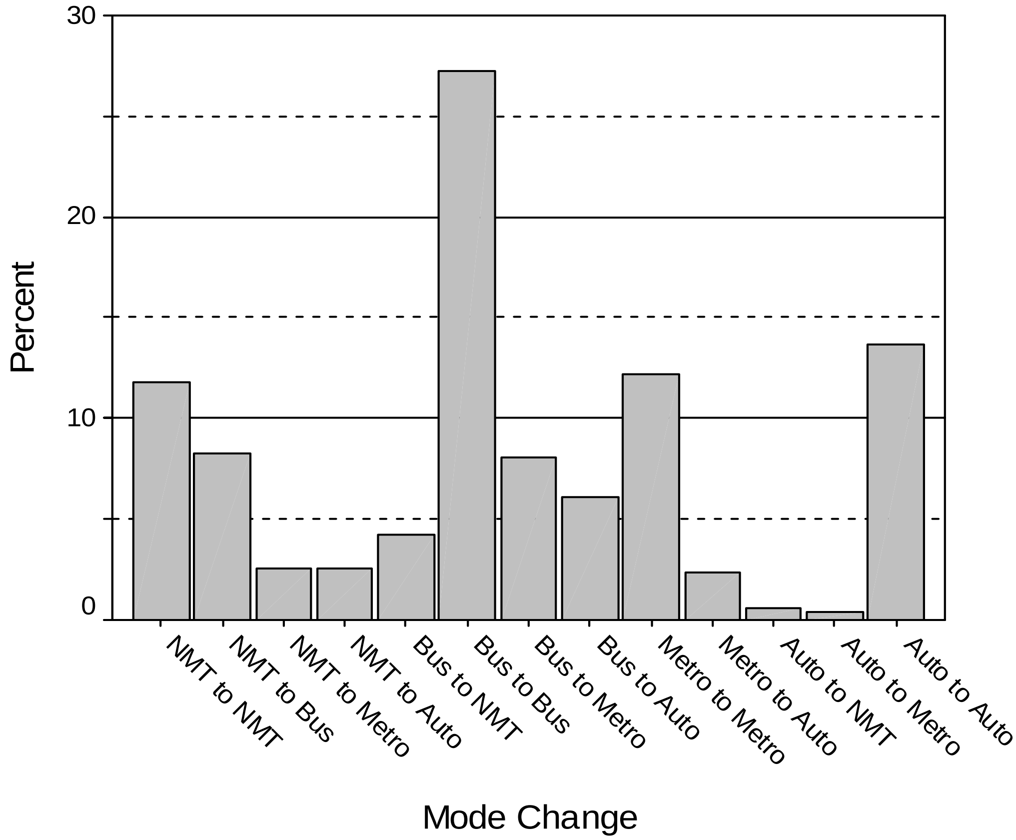

Figure 5. Distribution of Mode Changes, Before and After Moves

In the models that follow, binomial logistic regression equations are estimated. The variable entry process involved including transportation and accessibility variables (e.g., automobile ownership and changes in job accessibility) as well as location (e.g., ring of prior residence, proximity to metro station) and neighborhood attributes (e.g., local road and connectivity levels within 1000 meters of residence). Variables with reasonably significant predictive powers as well as signs that matched expectations were retained. Then statistical controls were added, based mainly on attributes of the surveyed commuter and his or her household. Again, we acknowledge these are not fully specified mode change models in that information on changes in other measures of utility, notably data on travel times among competing modes, were not available.

Nonetheless, the models that follow, we believe, shed light on how changes in accessibility, location, and neighborhood setting influence changes in work-trip travel in a setting – the dense suburbs of China's megacities – where data limitations have historically restricted the ability to conduct quantitative analyses.

Mode Change Models: Non-Motorized to Motorized Transport

Table 2 presents three binomial logit models that predict commute mode changes from Non-Motorized Transport (NMT) at the prior residence to three means of motorized travel: Bus, Metrorail, and Automobile. The left-hand panel of Table 2 reveals enhanced job accessibility via both highway and transit networks worked against changes from NMT to bus commuting, controlling for other factors. One can surmise that improved motorized accessibility promotes switches to speedier modes – i.e., private car and metrorail vis-à-vis bus transit. Similarly, moving to a residence within one km of a metrorail station deterred NMT-to-bus shifts. Interestingly, high street connectivity promoted switches to bus transit. One might expect grid-like street patterns (which average high ratios of nodes-to-links) to encourage more walking and cycling, all things being equal – e.g., continuing to use NMT after the move. This might be the case for shopping and non-work travel, however this is less likely for commute trips since many are made over longer distances and to destinations outside on one's immediate neighborhood. Instead, the positive sign on the street connectivity variable could mean connectivity facilitates walking access to local transit stops, inducing more bus commuting, at least at the margin. Lastly, a job change was positively associated with NMT-to-bus switches, possibly because the wider reach and finer grain network of bus services (versus both NMT and rail transit) promoted bus commuting at a new job location.

The middle panel of Table 2 presents a fairly streamlined binomial logit model

Table 2. Factors Associated with Commute Mode Change from Non-Motorized Transport, Household Head

	NMT to Bus			NMT to Metro			NMT to Auto		
	Coef.	Std. Error	Prob.	Coef.	Std. Error	Prob.	Coef.	Std. Error	Prob.
Transportation & Location Attributes									
Change in Job Accessibility Index: Road and Transit networks, in 100,000s	-.810	.225	.000	--	--	--	.502	.312	.107
Moved: Inner Ring to Rail-Served Meilong/Xinzhuang (0-1)	--	--	--	2.304	1.012	.023	--	--	--
Moved Near Metro: To within 1000m of Metro Station (0-1)	-1.862	1.043	.074	2.564	1.361	.060	--	--	--
Road Length: Centerline meters within 1000m of Current Residence	--	--	--	--	--	--	-.014	.006	.015
Street Connectivity Index: # Nodes/# Links) within 1000m of Current Residence	5.060	2.121	.017	--	--	--	--	--	--
Controls									
Change in Household Income: 2006 RMB (100,000s)	--	--	--	--	--	--	1.340	.801	.072
Automobile Ownership: Automobiles per Worker in Household, Current Residence	--	--	--	--	--	--	1.636	.909	.095
Job Change (0-1)	.792	.47	.092	--	--	--	--	--	--
Non- Choice Move (0-1)	--	--	--	1.504	.876	.086	--	--	--
Constant	-9.901	2.69	.000	-7.639	1.261	.000	-.175	1.91	.927
Summary Statistics									
Nagelkerke R Square			.202			.272			.259
Chi-Square (prob.)			44.69 (.000)			20.81 (.000)			21.47 (.000)
N			674			761			674

on NMT-to-Metrorail commute mode-changes following a move. Clearly, location matters. Moving from the inner-ring to a rail-served neighborhood (i.e., Meilong/Xinzhuang) increased the odds of rail-commuting, and moving to a residence within 1km of a metrorail station increased it even more. Non-choice movers were also more likely to make a NMT-to-rail switch, possibly reflecting some degree of transit-dependence and captivity.

The final model of Table 2, shown in the right-hand panel, reveals that enhanced job accessibility over both highway and transit networks encouraged NMT-to-automobile changes. This further suggests the dominant influence of highway networks in the suburbs of Shanghai – i.e., the ability to move swiftly by private car encourages mode changes from the slowest modes (NMT) to the fastest (automobile), even when controlling for changes in income. Rising income itself promoted NMT-to-automobile switches as did more cars per household worker. This finding is consistent with recent research that found household income and car ownership to be significant predictors of car versus NMT commuting based on intercept surveys of pedestrians in four suburban neighborhoods of Shanghai (Pan et al., 2007).

Mode Change Models: Bus to Other Motorized Transport

Table 3 presents models of mode-changes from the slowest means of motorized travel – conventional bus transit – to faster motorized modes: metrorail and private automobiles. Among those who regularly rode buses to their job sites at their prior residence, the likelihood of switching to metrorail significantly increased if they moved to the rail-served districts of Meilong and Xinzhuang. Among neighborhood variables, dense street networks near one's current suburban residence deterred bus-to-rail mode-changes, possibly due the prevalence of bus routes in dense street settings. Another deterrent was car ownership, which tended to draw former bus riders to automobiles.

Table 3. Factors Associated with Commute Mode Change from Bus Transit, Household Head

	Bus to Metro			Bus to Auto		
	Coef.	Std. Error	Prob.	Coef.	Std. Error	Prob.
Transportation & Location Attributes						
Change in Job Accessibility Index: Road and Transit networks, in 100,000s	--	--	--	1.434	.301	.000
Prior Residence: Inner Ring (0-1)	--	--	--	1.486	.583	.011
Prior Residence: Outer-Outer Ring (0-1)	--	--	--	-3.135	.871	.000
Moved: Inner Ring to Rail-Served Meilong/Xinzhuang (0-1)	1.135	.403	.005	--	--	--
Road Length: Centerline meters within 1000m of Current Residence	-.009	.003	.001	--	--	--
Controls						
Automobile Ownership: Automobiles per Worker in Household, Current Residence	-2.142	.867	.013	2.231	.605	2.231
Education Level[a]	.381	.171	.026	.602	.246	.015
Age: Years	--	--	--	-.063	.023	.007
Constant	-.590	1.185	.618	-2.702	1.346	.045
Summary Statistics						
Nagelkerke R Square			.200			.425
Chi-Square (prob.)			48.66 (.000)			80.87 (.000)
N			688			688

[a] Education Level (completed): 1 = junior high or less; 2 = high school; 3 = junior college; 4 = undergraduate college; 5 = graduate college

Education level, on the other hand, encouraged former bus commuters to begin taking rail to work. This could reflect the influence of Shanghai's radial metrorail routes that efficiently deliver suburbanites to central-city office jobs.

Lastly, the right-hand panel of Table 3 shows the factors the prompted former bus users to commute via private car following their move to the outskirts. Increased job accessibility via road and transit networks encouraged the changeover to car commuting, ostensibly reflecting the impacts of improved highway connections. While a move from the center city correlated with bus-to-car switches, moving to the sampled residences near the Outer Ring Road from areas farther out (i.e., the "outer-outer ring") had the opposite effect. Automobile ownership and education levels were also associated with bus-to-car switches whereas age had a deterring effect.

Changes in Commute Durations

What factors influenced changes in commute times? Table 4 presents best-fitting OLS models for predicting changes in monthly commute time expenditures, estimated for both household heads and the second adult wage-earner. For both individuals, enhanced job accessibility was associated with shorter commutes, controlling for other factors. In the case of the household head (normally the primary wage-earner), every additional 100,000 jobs that could be reached by the motorized network following the move was associated with 157 fewer minutes getting to work – or around 7 minutes per day assuming a 22 day work month. Commute time reductions attributable to accessibility gains were even greater for the second adult wage-earner.

As significant in explaining changes in commute durations were mode changes. Interestingly, changes from non-motorized to motorized commutes were associated with longer durations, most like a product of jobs being fairly close at many workers' prior residences and much farther away at their present ones. That is, the speed advantages of motorized commuting were likely eclipsed by the longer distances that

Table 4. Models for predicting changes in monthly travel durations for work trips, from prior to current residence, household heads and second adult wage-earners

	Household Head			Second Adult Wage-Earner		
	Coef.	Std. Error	Prob.	Coef.	Std. Error	Prob.
Accessibility & Mode Predictors						
Change in Job Accessibility Index, road and transit networks, in 100,000s	-157.16	38.02	.000	-240.36	62.53	.000
Mode Change: NMT to Bus	609.22	155.36	.000	1381.67	193.45	.000
Mode Change: NMT to Metro	797.39	303.66	.009	--	--	--
Mode Change: NMT to Automobile	745.24	329.86	.024	-751.09	430.46	.082
Mode Change: Bus to NMT	-922.69	190.21	.000	-692.34	210.91	.001
Mode Change: Bus to Bus	609.22	155.36	.065	--	--	--
Automobiles per worker (in household, current location)	--	--	--	387.44	246.24	.117
Controls						
Age, Years	8.98	3.59	.013	-15.86	5.80	.007
Changed Job Location (0-1)	-292.13	98.13	.003	-549.63	182.25	.003
Relocated, No Choice (0-1)	208.48	85.13	.015	327.36	138.31	.018
Constant	-340.21	163.80	.038	406.295	270.83	.134
Summary Statistics						
R Square	.251			.218		
F (prob.)	14.03 (.000)			11.98 (.000)		
N	386			354		

commuters had to cover following their moves, resulting in lengthier overall commutes. The one exception was for second wage earner who switched from NMT to private car. Since these individuals are often secondary wage-earners who limit their job searches to close-by destinations, for them, private automobility generally conferred net travel-time savings (though this effect was moderated some by the positive sign on the automobile ownership variable). Also of interest, the reverse relationship appears to have held for those who switched from bus commuting at their prior residence to walking or cycling at their current one – i.e., household heads who switched from bus to walking or cycling experienced around 922 minutes monthly time savings getting to and from work (or around 42 minutes per day, assuming a 22-day work month).

Several of the control variables shown in Table 4 are also of interest. Those who moved their job locations following residential moves tended to experience substantial declines in commute durations – for some, job and residential sites were likely co-located as a consequence of residential relocation so as to temper changes in commute times. On the other hand, workers who had no choice but to move their residences tended to experience significant increases in commute times – nearly 10 and 15 minutes a day for household heads and second wage-earners respectively (assuming 22 commute days per month).

5 Conclusions

The findings presented in this paper underscore the potential mobility – and by extension, environmental – benefits that could accrue from successful integration of urban development and rail-transit investment in large Chinese cities. Notably, our research found that moving near a suburban rail station significantly moderated the travel-consumption impacts of relocation, especially from the central city to the outskirts. Notably, households that relocated in a neighborhood served by Shanghai's metro-rail system and lived within one kilometer of a metrorail station had substantially higher access to jobs (and most likely other destinations as well) following the move than similar households in otherwise comparable non-rail settings. Living near a suburban metrorail station was also associated with commute-mode changes from NMT and bus transit to rail commuting. The enhanced accessibility associated with living in a rail-served community also correlated with reductions in the time spent getting to and from work, controlling for other factors.

These research findings suggest that transit-oriented development (TOD) holds considerable promise for placing rapidly suburbanizing Chinese cities on more sustainable pathways. The co-occurrence of rapid decentralization and rail investments presents unprecedented opportunities to orient more development to rail catchment areas, complemented by secondary transportation systems that provide good feeder access and egress to stations. Such bundling of railway and housing development would likely increase transit ridership and moderate automobile travel by materially increasing regional accessibility to jobs and other activities.

While proximity to suburban rail stations produced, on balance, positive mobility dividends, we note that many of the variables reflecting neighborhood attributes – such as street connectivity, road density, and availability of local retail shops – did not emerge as significant predictors in most of the models. That is, proximity to regional rail networks had far stronger influences on commuting behavior than neighborhood street designs and land-use patterns. We believe this is more of a reflection of the fairly homogeneous nature of superblock-style residential designs on the outskirts of cities like Shanghai, regardless of whether buildings are near metrorail stations or not, than a statement of how urban design might impact travel behavior. We suspect, however, more and better examples of high-quality walking and cycling environments as well as supportive mixed land uses in the vicinity of metrorail stations would have produced more significant statistical relationships. Experiences in Hong

Kong and other large rail-served East Asian megacities demonstrate that high-quality walking environments and integrated urban designs are associated high transit ridership levels and reduced car dependency (Tang et al., 2004; Cervero and Murakami, 2008). Far more attention, we believe, needs to be given to integrating surrounding communities with China's suburban metrorail stations through improvements in pedestrian designs and the introduction of bikeway connectors, such as practiced in Bogotá, Colombia in concert with the TransMilineo BRT system (Cervero, 2005).

To a large extent, there has been a disconnect between transit investments and urban development in much of suburban China to date. Beijing, for example, currently operates four rail transit lines (with several more under construction or in planning phases), with a total track length of 114 km. Beijing's rail transit expansion has been accompanied by a real estate boom. Yet there has been little effort so far to link urban development and railway expansion. Housing projects have followed Beijing's rail transit networks, but jobs and businesses have not (Zhang, 2007). Many new communities developed along rail corridors have become veritable bedroom communities, not unlike that found on the outskirts of Shanghai. Skewed commuting patterns have resulted (Zhang, 2007). A study of three residential new towns in Beijing's rail-served northern suburbs found as many as nine times the number of rail passengers heading inbound in the morning peak as heading outbound (Lin and Zhang, 2004). Moreover, poor integration of station designs with surrounding development has led to chaotic pedestrian circulation patterns and long passenger queues at suburban stations like Xizhimen on Beijing's Line-2 (Zhang, 2007).

The absence of station-area master planning has also led to substandard development. A case in point is Beijing's Sihui interchange station on Lines 1 and 8 between the 3rd and 4th ring roads (Cervero and Murakami, 2008). There, a massive concrete slab was built over the 40-hectare depot site next to the station, enabling the Beijing City Underground Railway Company to lease 700,000 m^2 of air-rights to developers. No design or development standards, however, were set as part of the lease agreement. To economize on the cost of a thousand-plus apartments built atop the site, only one footbridge was built to the Sihui subway station. Overcrowded sidewalks and queues at the station entrance have severely detracted from the station environment, resulting in land prices that are below tracts farther from the station. The poor-quality environment surrounding the Sihui station underscores the importance of a master planning entity that oversees project development and ensures a functional relationship unfolds between the public and private realms of station settings.

Urban environments and local amenities matter to residents of China's suburban new towns. Says Zhu Minyu, 50, a recent relocatee to the Sanlin neighborhood (South, 2006):

> At first I found living here really inconvenient, boring and lonely. It has taken me quite a while to adjust. I used to bump into people I knew all the time on Huaihai Road, but here in Sanlin, the streets are mostly empty…. If I do go downtown, I can't stay after the buses stop at 10 pm because catching a taxi home is too expensive.

Beijing's officials seem aware of past design shortcomings and are seeking to change course. In concert with master planning for the 2008 Olympic Games and beyond, Beijing's municipal government established the following transportation development guideline:

> The public transportation system will also be fully exploited as a functional instrument in guiding Beijing's urban development. Urban land development with transit-oriented development (TOD) will be employed to rationalize Beijing's layout and provide reliable transportation supporting facilities for the development of scattered groups and small towns in the suburbs (Beijing Transport Research Development Center, 2008).

An important challenge in cities like Beijing and Shanghai is to think of TODs as more than nodes in isolation. TOD planning and finance needs to be tied to a larger regional plan, one that casts TODs as part of a network, what might be called "transit oriented corridors" (TOCs) (Cervero, 2007) in a "city wide transport strategy" (Pan and Zhang, 2006).

More than a decade ago, Shen (1997) discussed tempering motorized travel demand in large Chinese cities like Shanghai by advancing land-use plans that enhance accessibility (access to locations) without increasing mobility (ease and speed of travel). Since then, Shanghai and other large Chinese cities have witnessed enormous increases in "mobility-enhancing" infrastructure, namely superhighways and metrorail investments. It is perhaps now time to heed this advice, and bring destinations closer to outlying communities. When conceptualized as part of a strategic regional planning effort, international experiences show that an integrated network of TOCs can sum to a "Transit Metropolis", arguably the most sustainable pattern of urbanization in megacities of the world (Cervero, 1998).

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