Quantitative Insights into Urban Form and Transportation Solutions

An overview and synthesis of existing research related to The 8 Principles with emphasis on the Chinese experience

DRAFT

OCTOBER 16, 2014

This is a discussion draft. Reviewers of this document are encouraged to inform us of suggested additions by emailing Chris Busch (chrisb “at” energyinnovation.org) and CC Huang (cc “at” energyinnovation.org).

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EXECUTIVE SUMMARY

Introduction

This document presents an overview and synthesis of the quantitative research related to urban form and transportation with particular emphasis on evidence from China. Our goal is to highlight existing work that has used quantitative methods to analyze the problems and possible solutions. Our emphasis is on empirical studies that use real-world observations, though we discuss some future simulations too.

Our purpose. We hope that this work serves as a resource to others and that it helps clarify the importance and impacts of various urban planning practices. We hope that this paper spurs a larger and continuing conversation about urban form and transportation solutions. We are not aware of any similar existing survey of the literature as it relates to urbanization in China. While we have captured a broad array of studies, we are sure that additional work still exists. We would like to learn about any further work and request feedback regarding suggested additions.

Our findings. On balance, we find good evidence to support The 8 Principles approach (see text box at right), which is also referred to as *smart growth*. It is characterized by transit-oriented, bike-friendly, walkable, mixed-use, and compact cities that de-emphasize cars. In addition to surveying the research that has been done, this executive summary also includes our assessment of gaps that persist in the research.

Method

Given the importance of gaining support from investors and others in the community of developers, this survey gives particular attention to information relevant to expected returns on investment and other financial assessments. Oftentimes, it can be challenging or impossible to access proprietary information about business operations. Nonetheless, some clear indicators in this area do emerge. There is strong evidence of beneficial effects on real estate values for properties that are (1) located close to transit stations, and (2) located in more walkable neighborhoods.

In addition to investor concerns, a variety of other perspectives – from the public (e.g. air quality benefits), commuters, homeowners, and households - are presented on the impacts of development according to The 8 Principles. The survey catalogs broader economic, social, and environmental impacts of improved urban form and transportation.

This overview necessarily makes some choices about what to cover or exclude. While there is a plethora of studies, we have sought to include the most insightful and rigorous work. Sometimes simple analysis can provide powerful insights. In other cases, sophisticated techniques are needed to accurately disentangle complicated policy (or project) impacts that extend broadly over space and time.

Organization

The next section of this summary presents our synthesis of the literature and our estimation of priority gaps. It is in these areas that we are most actively seeking further information.

The body of the document opens with a table of contents that lists each study included, with live links enabling easy navigation directly to the full entry for the citation. For each entry, there is a brief description of the work, its geographic scope, and most important findings. In some cases, the relevant figures or tables are also included. For convenience, a table of figures appears after the table of contents above.

The findings are organized based on The 8 Principles from *Planning Cities for People*, a guide of urban form and transportation solutions to some of the most pressing challenges facing modern cities, including congestion, pollution, and urban sprawl. The 8 Principles are essential ingredients to sustainable, economically vibrant cities that deliver quality of life for people.

The 8 Principles

1. **Walk.** Develop neighborhoods that promote walking.
2. **Connect.** Create dense networks of streets and paths.
3. **Transit.** Build extensive, high quality transit. Make connections between modes.
4. **Cycle.** Prioritize city bicycle networks that offer protected lanes.
5. **Mix.** Zone for mixed-use neighborhoods.
6. **Densify.** Actively encourage greater density around major transit hubs.
7. **Compact.** Set growth boundaries to spur emergence of compact regions with short commutes.
8. **Shift.** Increase mobility by regulation parking and road use.

Highlights of Findings

The literature on urban form and transportation solutions is extensive. The most comprehensive work we are aware of is Calthorpe's analysis for *Vision California*. That work analyzes the impact of changing to a more compact and transit-oriented development pattern. The analysis ranges broadly across a variety of environmental, social, and economic outputs. In the Chinese context, we have found some well-executed studies of The 8 Principles in practice:

- Analysis of the revision of the Chenggong master plan, completed by Peter Calthorpe and The Energy Foundation (EF)
- The analysis of superblocks versus other neighborhood forms in Jinan, conducted by Jiang Yang, Massachusetts Institute of Technology (MIT) and EF's China Sustainable Cities Program
- The impacts of urban upgrades in Guangzhou and bike sharing programs, conducted by the Institute for Transportation and Development Policy (ITDP)

This review identifies some patterns in the research literature. Based on both Chinese and international experience, there is good evidence that:

- **Investment in public transit increases property values nearby**: There is fairly conclusive evidence across a range of geographies on this point.
- **Done right, there are many benefits to density:** Denser cities tend to have better transportation sector performance in energy and environmental terms (lower greenhouse gas emissions, lower energy consumption, lower vehicle kilometers traveled). There is also strong evidence that denser cities are more productive. Many scholars attribute innovation-inducing properties to dynamic urban areas, and there is some statistical evidence for this.
- **Congestion costs are potentially high in dense areas, but can be managed**: Economic activity naturally leads to more travel demand, passenger mobility, and freight transport. The economic costs of congestion can be significant, but good management with a high-quality public transit system, support for walking and biking, and car control strategies can alleviate these costs. Adequate green space is another crucial aspect to delivering quality of life for people living in dense cities.
- **Mixed-use, transit-oriented development improves public health outcomes:** Failure to mix land-uses (e.g. single-use neighborhoods, such as purely residential) and higher car ownership have been found to increase the risk of obesity and even colon cancer, while more commuting via walking and biking were found to improve public health results.
- **Both bike share programs and protected bike lanes are effective in increasing biking:** The spontaneous bottom-up spread of bike share systems, absent a significant national policy push, has been impressive. This positive development deserves to be supported through upgrades to bike path networks.
- **Compact development is cost-effective**: Capital, operation, and maintenance costs of urban infrastructure and public service provision are generally lower with compact and transit-oriented development strategies.

On balance, we find strong evidence of benefits outweighing costs, but it should be acknowledged that there are costs to dense urbanization when done poorly: traffic congestion, air pollution, and noise assaults on the human senses.

Gaps Assessment

While this survey has gathered a large literature, there are still gaps in our knowledge, especially when it comes to China-specific research. We seek suggestions for other work that should be included. We currently see the following priority gaps in the literature:

- **Air quality benefits, ideally with cost analysis:** While we have found some studies of air quality benefits (GHG emissions and local air pollutants) in China's cities due to urban form and transportation improvements, we have found very few that estimate the cost of such measures. The only examples we are aware of are ITDP assessments of GHG reductions due to BRT system introduction, which include cost and municipal finance assessment.
- **Information from the developer perspective:** We would be particularly interested in case studies from developers that help shed light on profit impacts due to sustainability upgrades.
- **Case studies that combine public and private (e.g. investor) perspectives to evaluate new developments or redevelopments in the Chinese context:** What are the impacts on urban infrastructure costs in China of smaller, more connected, blocks in contrast to the default pattern of superblocks and large arterial street grids? Also, on a more granular level, what are the cost impacts of one-way couplets, mixed-use land developments, walkability efforts, and bike lanes?
- **Understanding the bike-rail connection:** The studies we have collected suggest a somewhat nuanced interaction. In congested areas, bike-share and motorized public transit can act as substitutes.

Introducing bike share serves to siphon off some motorized transit riders. This was the case in Washington, D.C., where the bike share programs alleviates congestion on public transit in the city center. In another study from Nanjing, based on data from the entire transit system and not just those in the suburbs or the city center, we found that bike parking increased transit use. We would like to further understand the relationship between biking and taking public transit and how these two transportation modes can best work together.

- **Clarifying the connection between commercial activity and more walkable and bike-friendly neighborhoods:** We could use more evidence of the commercial and economic effects of making neighborhoods more conducive to walking and biking. We have one rigorous hedonic study that finds that walkability increases home values for the U.S., but have not found any Chinese examples with similar statistical rigor. We have some anecdotal evidence that downgrading car privileges, such as transforming a small parking lot into a plaza, increases sales at nearby businesses despite their initial concerns. Also, a tantalizing line of thinking is that greater density is particularly beneficial for service industry development. Given the Chinese leadership's interest in service sector growth as an aspect of economic rebalancing, this could be important.
- **Better characterization of the public health benefits from decreased congestion**: There has been some good work on the economic cost of time lost due to traffic congestion. We have yet to find much quantification of the public health benefits of transportation solutions that reduce congestion.
- **Measuring the result of increased density on characteristics such as labor productivity for Chinese cities:** Since Chinese cities have levels of density that are incomparable to U.S. cities, we would like to know how productivity is affected, given factors that are specific to China. There are unique Chinese factors that might mean different effects on productivity levels (i.e. high migrant labor population, prevalence of state-owned enterprises, a higher proportion of workforce employed in industrial sectors). The Urban China Initiative Sustainability Index[1] finds gains attributable to density at up to 8,000 people/square kilometer, after which the relationship becomes insignificant. However, we remain unaware of much other work on density and productivity in the Chinese context.
- **Disentangling the relationship between housing and transportation costs as percent of income in China:** We have done some analysis that shows higher housing costs in denser areas are more than balanced out by lower transportation costs. This serves to rebut the concern that dense, compact cities will lead to welfare losses due to higher housing costs. We are interested in studies of these dynamics for China.
- **Understanding if price premiums for properties next to public transit stations tend to increase or decrease over time:** Evidence from Beijing shows that values of properties next to BRT stations grow at a faster rate, but we have only found one study in China indicating this. We have found a range of stories about positive real estate value effects due to proximity to transit. It would also be productive to explore these economic dynamics over time.

[1] For more information, please see: http://www.urbanchinainitiative.org/en/

Summary of Findings Table

	Location	Finding	Source
URBAN FORM			
General Urban Form	China (*Beijing*)	Economic output is decreased by sprawl. A study of the Beijing metro area estimates that urban congestion and environmental damages reduce the area's economic output by 7.5 to 15 percent.	Creutzig and He, 2009
	China (*Chenggong*)	Redesign of the new Chenggong district in Kunming according to The 8 Principles will lead to reduced fuel use and other benefits: • 72 percent reduction in air emissions • 59 percent reduction in greenhouse gas emissions • 67 percent reduction in passenger vehicle kilometers traveled	Energy Foundation and Calthorpe, 2011
	China (*Jinan*)	Superblocks mean higher energy use than other neighborhood forms. • 33 percent of superblock residents' trips are by car versus eight percent for other urban form types • Superblock residents also use 2.75 times the amount of transportation energy • These travel-mode and energy-use effects persist even when controlling for income and location, e.g. distance to city center *(link to graphic)*	Energy Foundation, 2011; Jiang, ND.
	China	Improved urban form would reduce GHG emissions in China from the transport sector by 29 percent over business-as-usual with similar reductions in vehicle kilometers travelled and in fuel use.	He et al., 2013
	U.S. (*California*)	Smart growth in California would lead to the following benefits by 2050: • 67 percent less land consumed • 19 percent lower capital infrastructure costs • 18 percent lower operations and maintenance costs • 16 percent increase in local government revenues • 38 percent lower air pollutant emissions (GHGs and local pollutants) from transportation • 27 percent savings in health costs in 2035	Vision California, 2011
	U.S.	Each quartile increase in land-use mix is associated with a 12.2 percent reduction in the likelihood of obesity on average and the trend can be seen across gender and ethnicity groups.	Frank et al., 2004
Density	China (*Shenzhen*)	Taller buildings command higher economic benefits per square meter in Shenzhen *(link to graphic)*.	Wang et al, 2011
	Japan	Higher density areas are correlated with better access to stores, medical and other public services *(link to graphic)*.	Kaido and Kwon, 2008
	International	Higher density cities have lower GHG emissions per capita – the best example is Seoul which has about 325 habitants per hectare and one of the lowest per capita emissions levels *(link to graphic)*.	Baeumler and Ijjasz-Vasquez, 2012
	U.S.	Higher density means higher labor productivity – productivity increases from two to six percent when density doubles. Cervero found that a six percent increase in employment density is associated with a one percent increase in mean labor worker productivity.	Cervero, 2011; Abel et al., 2012; Ciccone and Hall, 1996
	Canada (*Fort St. John*)	Using medium density and mixed-use planning helps households gain $2,353 annually from lower O&M and government will gain $294 annually from each household.	The Sheltair Group
Compact	U.S. (*Portland, Oregon*)	Compact design can lead to eight percent less driving. In Portland, compact design leads to seven percent less transportation costs per household.	Ewing et al, 2007; OECD, 2011.
	US (*Utah*)	Compact design can help government revenue: • For Utah, preventing sprawling development saved the region about $4.5 billion • There are estimates that $12.6 billion could be saved by containing sprawl, $110 billion could be saved with more compact road infrastructure • Another estimate says that if 1/3 of US future growth was directed toward	Transportation Research Board, 2000; Burchell, 2000; Ewing et al., 2007

		central cities, the U.S. would save $250 billion over next 25 years, equivalent to $2,500 per household	

TRANSPORTATION

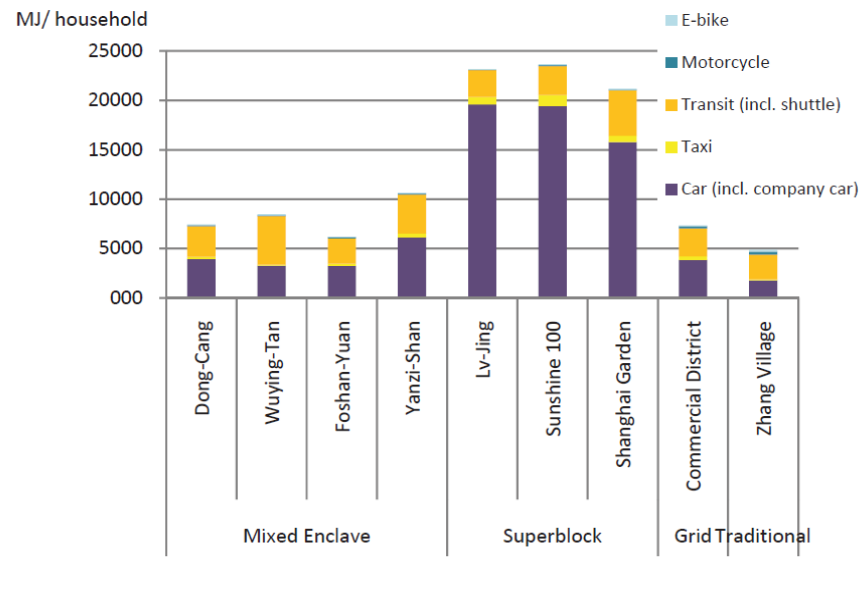
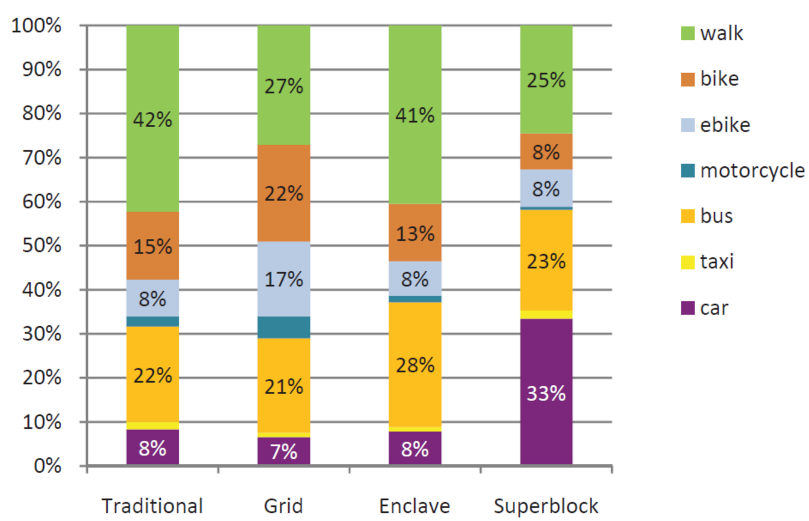
Cycle	China (*Guangzhou*); US (*Washington, D.C.*)	Bike share programs can alleviate congestion: • In Guangzhou, bike-share leads to 14,000 avoided car trips daily (20,000 bike trips daily in all) • In Washington, D.C., bike-share caused 47 percent of transit users concentrated in the congested city center to decrease public transit use	ITDP, 2013; Martin and Shaheen, 2014
	China (*Nanjing*)	Bike park and ride spaces at transit station increase transit use – in a Nanjing study, for each one additional park and ride space, there was an increase of six transit riders (controlling for other factors).	Zhao et al., 2014
	China (*Guangzhou*)	Bike share programs can expand the bicycle user base. A survey of bike share users in Guangzhou found that only 16 percent were previously private bicycle users.	ITDP, 2013
	China	Information about bike-sharing programs in China: • 47 cities have bike-sharing programs with a total of over 250,000 bikes • The largest is in Hangzhou with over 60,000 bikes, followed by Shanghai with 28,000 bikes, and Wuhan with 20,000 bikes • Hangzhou's program has 1.2 million registered users, Shanghai's has 100,000 registered users, and Wuhan's has 560,000 registered users	Chang et al., 2012
	U.S.	Supply of bike lanes increases the number of bikers: • In large U.S. cities, the increase in bikers after protected bike lanes were put into place grew from 54 percent to 266 percent • Buehler and Pucher found that a 10 percent greater supply of bike lanes is associated with a 3.1 percent increase in bike commuters per 10,000 people	Pucher et al., 2013; Buehler and Pucher, 2012
	U.S.	Biking is seven times more space-efficient than car travel.	Kjartan, 2004
	U.S., Norway	The benefits of bike networks are four to five times greater than the cost of implementing them.	Gehl
Transit	China (*Jinan*)	People were more willing to walk further to BRT stations when the walking environment has certain features (median transit-way station location, shaded corridors, busy and interesting sidewalks). • Integrated boulevards, with the positive features described above, increased walking catchment by 158 meters (people are willing to walk that much further) • Terminal stations had walking distance of 400 meters more than transfer stations • Trip-maker (who is taking a trip; their age, income, and other traits) and trip characteristics (where the person is going and why) have a relatively small effect on the decision to choose transit	Jiang et al., 2012
	China (*Guangzhou*), Colombia (*Bogotá*); China (*Beijing*)	Properties next to BRT stations enjoy higher values than those not next to BRT stations: • A 30 percent price premium in Tianhe, Guangzhou • A 13 to 14 percent price premium in Bogota • In Beijing, it was found that the average value of residential properties near BRT increases 2.3 percent faster than properties not close to BRT	ITDP, 2013; Rodriguez and Mojia, 2009; Deng and Nelson, 2010
	U.S. (*Mass.*); China (*Beijing*) US; China (*Shenzhen*)	Properties near rail stations also enjoy a price premium – • In Massachusetts, this premium is 9.6 to 10.1 percent • In Beijing, the price premium is five percent • The effect has also been measured in Shenzhen and all across the U.S	Armstrong and Rodriguez, 2006; Kilpatrick et al., 2007; Wang, 2011; Ma et al, 2013
	Korea (*Seoul*)	BRT improved speeds on all roads where it was put into practice in Seoul. The speed improvement ranged from 32 percent to 85 percent.	Cervero, 2013
	U.S. (*New*	A U.S. study finds that, when the density of bus stops increases by 10 times,	Chatman, 2013

	Jersey)	the likelihood of solo commuting by automobile decreases by 95 percent.	
	U.S. (*Austin, Texas*); US (*Los Angeles, California*)	TOD can decrease congestion significantly: • In Austin, TX, ambitious TOD would decrease VMT by 10 to 12 million daily • In Los Angeles, the benefit of operating the rail system from a congestion standpoint is quantified at $1.2 to 4.1 billion a year	Zhang, 2010; Anderson 2013
	U.S., International	BRT is very cost-effective compared to other public transit options: • BRT capital costs are 1/3 compared to light rail, 1/10 compared to metro rail. BRT operating costs are 1/3 compared to light rail, 1/2 compared to metro rail • ITDP found that BRT costs up to 30 times less to contract and three times less to operate compared to light rail	ITDP; Cervero, 2013
	U.S.	Public transit in general is very cost-effective. In a study of 21 corridors, 14 leveraged greater than $1 of TOD investment per $1 of transit spent. Five of them were BRT, four of them were LRT, two were streetcars, and three were improved bus (non-BRT) corridors.	ITDP, 2013
Shift	China (*Beijing*), China (*Guangzhou*)	Car control and decrease in parking can make more room for green space, which has strong economic benefits: • In Beijing, the economic benefit of green spaces from rainwater runoff was RMB 1.34 billion in 2009 • In Guangzhou, view of green space and proximity to water bodies raised housing prices by 7.1 percent to 13.2 percent, respectively	Zhang et al, 2012; Jim and Chen, 2006
	China (*Chongqing*)	Mode shifting and improved traffic flow can improve traffic speeds by 63 percent. A first phase of the project involving public space improvement led to an increase in the number of people doing stationary activities by 6.42 times.	Energy Foundation
	China (*Beijing*)	Driving restrictions in Beijing are effective in controlling pollution, but there are also economic costs due to decreases in worker output: • Driving restrictions in Beijing lead to 20 percent reduction in air pollution with every-other-day restrictions and nine percent during one-day-per-week restrictions • Economic benefits from reduced morbidity due to driving restrictions are about RMB 1.1 to 1.4 billion, but costs of reduced output are about RMB 0.51 to 0.72 billion annually	Viard and Fu, 2013
	China (*Beijing*)	The lottery system in Beijing is inefficient compared to an auction system, which could lead to a welfare gain of RMB 36 billion ($6 billion USD). A uniform price auction system would raise 21 billion RMB, enough revenue to completely offset public subsidies for transportation in Beijing.	Li, 2014
	Brazil (*Rio and São Paulo*); U.S. (*Utah*); China (*Beijing*)	The cost of congestion is very high: • In Rio and Sao Paulo, it is about 7.8 percent of metropolitan GDP; • In Utah, congestion pricing has been found to lead to about $50 billion of social benefit and 17,000 permanent jobs • The Texas Transportation Institute found that the total cost of congestion for the U.S. in 2011 is $121 billion, taking into account the cost of delay, wasted fuel, CO_2 emissions, and truck congestion costs *(link to graphic)* • In Beijing, passengers don't want to take taxis due to congestion and hence 40 percent of taxis are empty, but still contributing to congestion	Industry Federation of the State of Rio de Janeiro, 2014; Texas Transportation Institute, 2012; Brown, 2014; Fox and Tallon, 2013
	International	Cities can achieve 10 to 15 percent in carbon and energy savings by optimizing the flow of vehicles	LBNL, 2012
	U.S.	The negative health impacts of car use are substantial – Frank 2004 found that each additional hour spent in a car was associated with a six percent increase in obesity likelihood.	Frank, 2004
	US (*New Jersey*)	A household is 57 to 63 percent more likely to be car-free if there is scarce off-street parking.	Chatman, 2013
Walk	China (*Shanghai*),	The health benefits of walking for commutes are widely documented: • In Shanghai, studies found that the odds of developing colon cancer are ½	Lifang et al., 2004; Saelens et al., 2003

	U.S.	as likely to occur for those who engage physical activity as part of their commute • Saelens et al. found that the mean difference between neighborhoods with high and low walkability is 15 to 30 minutes more of exercise per week in the U.S	
	U.S.	Walkable urban areas across the U.S. command higher rents (74 percent higher for office space). *(*link to graphic*)*	GWU and Locus, 2014
	U.S.	Homes in walkable neighborhoods enjoy a price premium of about $4,000 to $34,000 based on a study of 15 U.S. metropolitan areas.	Cortright, 2009
	U.S.	Walking is 10 times more space-efficient than car travel.	Gehl

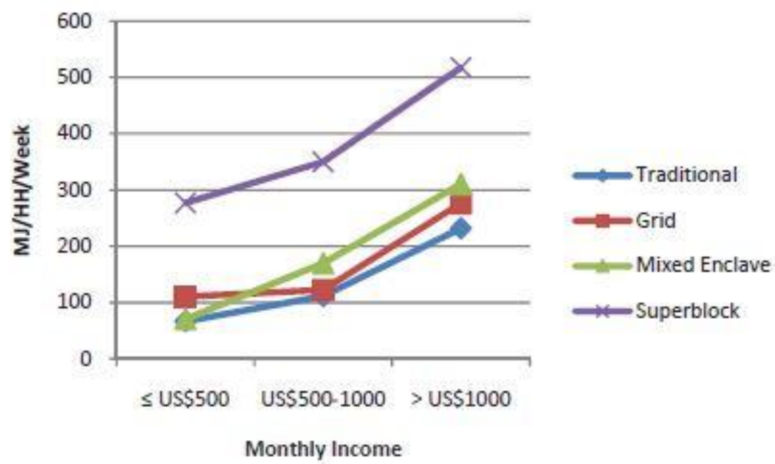
Urban Form

Location	Description	Numerical Result/Graphic	Source
General Urban Form			
CHINA (CHENGGONG)	*Study of benefits expected due to redesign of Chenggong master plan (EF and Calthorpe, 2011)*	• 72 percent reduction in air emissions overall • 59 percent reduction in greenhouse gas emissions • 67 percent reduction vehicle kilometers travelled Improvements in transportation due to more transportation pathways. • Increase in total right of way surface area 3.38 km2 (+56%) • Slight decline in right of way surface area for motorized vehicles 1.05 km^2 (-8%) • I Increase in right of way surface area, portion for NMT 2.33 km^2 (+126%) Though there is more surface area for the transportation network, there is also increased population density and more building floor area constructed. Population density is expected to increase to 18,300/km^2, up 83 percent. For insights into effects on building floor area, look at the specific redesign of Yongxin eco-district. Under this plan, there has been a doubling of building floor space to 842,851 m^2. Other changes in the Yongxin redesign: • The number of blocks increased from four to nine • Parking spaces were cut by 50 percent from 1-1.2 spots/100m^2 of floor area to 0.6 spot/100m^2 of floor area • The first two apartment buildings put on the market were 80 percent sold out after one month.	(EF and Calthorpe and Associates, 2011) China Sustainable Energy Program of the Energy Foundation and Calthorpe Associates, May 2011, *Chengong: Low Carbon City*.
CHINA (JINAN)	*Superblock energy use compared to other neighborhood forms in Jinan (EF, 2011)*	The following tables show: 1) Superblock residents use much more transportation energy than the other forms (mixed enclave and grid traditional); 2) Superblock residents drive more, walk less; 3) This superblock exceptionalism persists after controlling for income.	(EF, 2011) Energy Foundation. 2011. *Design Manual for Low Carbon Development*

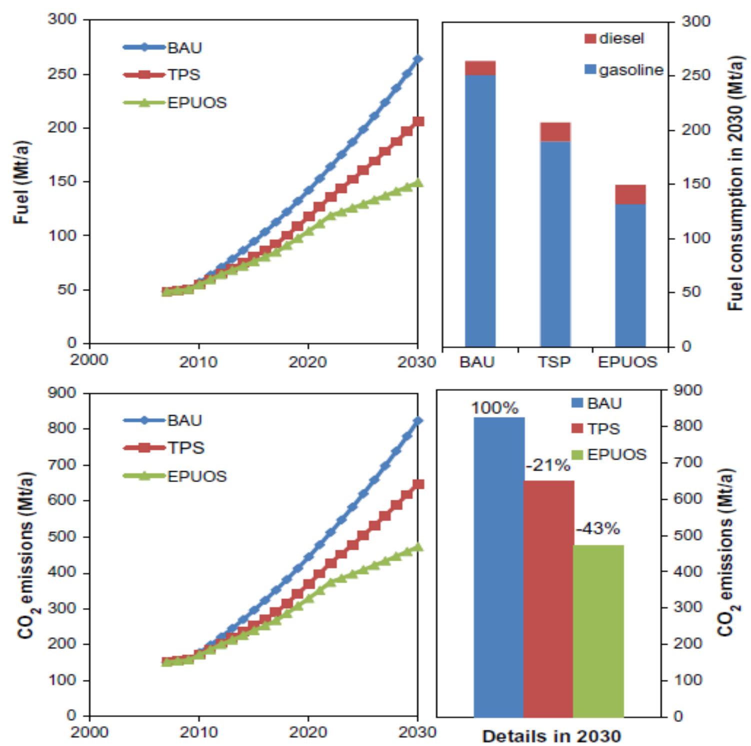
Location	Description	Numerical Result/Graphic	Source
		Figure 1. Transit Use in Superblock/Mixed Enclave/Grid Traditional  *Figure 2. Energy Mix for Traditional/Grid/Enclave/Superblock* 	

Location	Description	Numerical Result/Graphic	Source

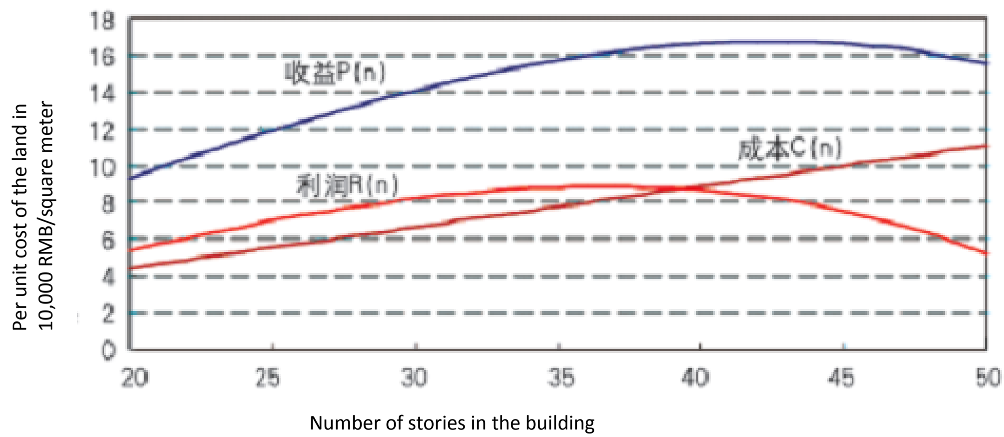
Figure 3. Superblock Exceptionalism Persists When Controlling for Income

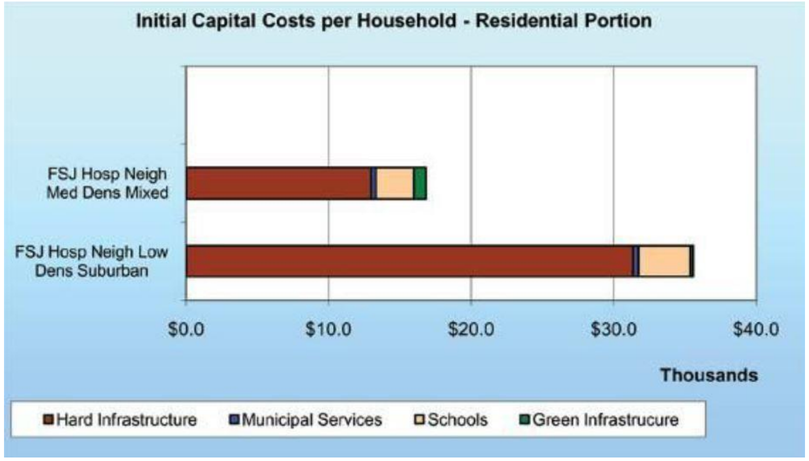
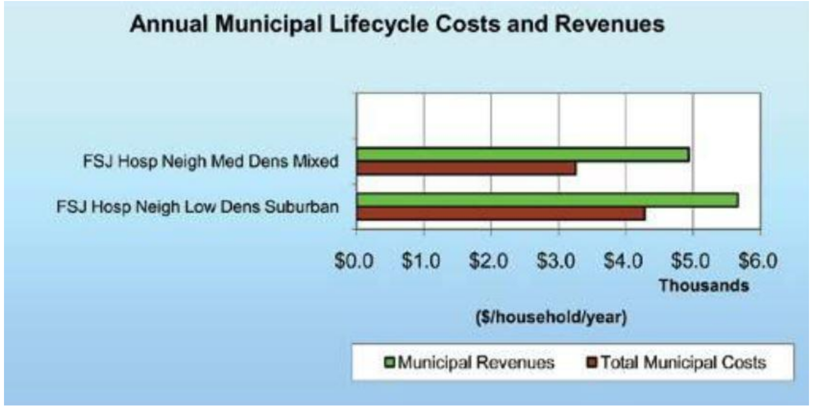


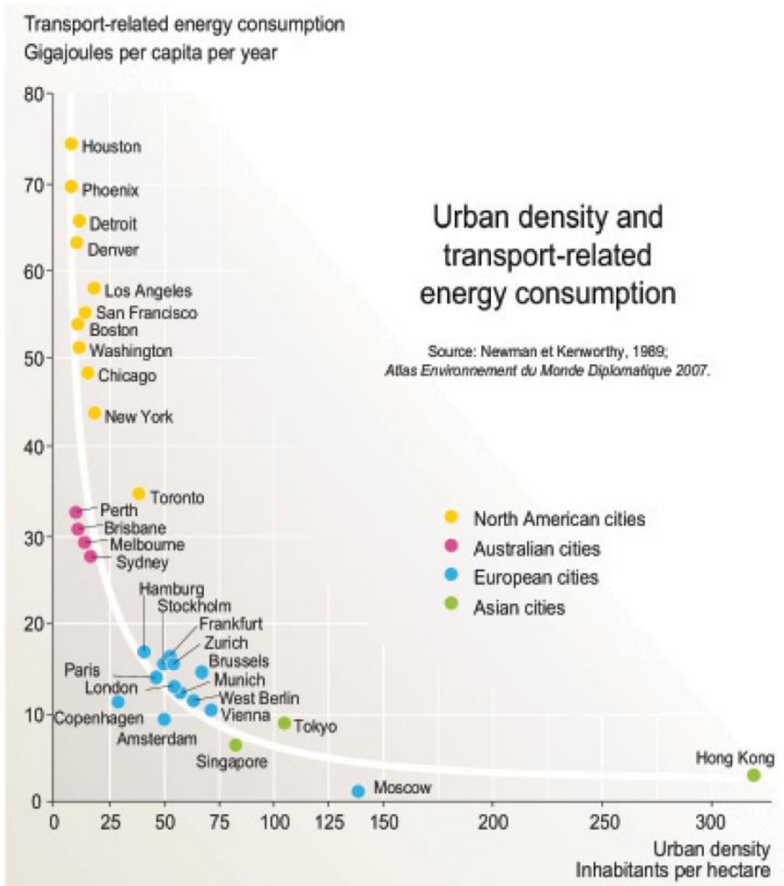
Location	Description	Numerical Result/Graphic	Source
CHINA	*Significant gains when more transformative urban planning is adopted in China (He et al., 2013)*		(He et al., 2013) Dongquan, He; et al., July 2013, “Energy use of, and CO2 emissions from China’s urban passenger transportation sector – Carbon mitigation scenarios upon the transportation mode choices,” Transportation Research Part A, Volume 53, P. 53-67.

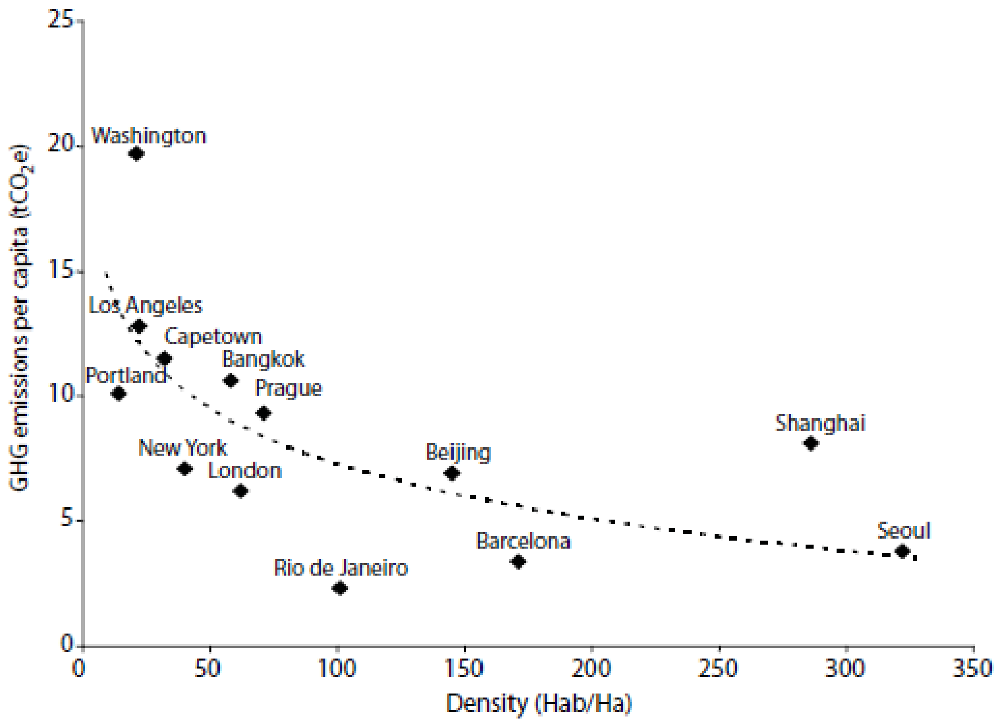
Location	Description	Numerical Result/Graphic	Source
		Figure 4. Decrease in Fuel Consumption due to Mixed Use and Dense Urban Design  The EPUOS policy captures the adoption of "smaller blocks, a higher degree of mixed land use, and a dense road network to accommodate high quality NMT (non-motorized transit)." The TPS policy represents the gains expected from transportation policies in the 12th Five Year Plan. BAU (Business-as-usual) are emissions that would have occurred in the absence of EPUOS or 12th FYP policies.	
CHINA (BEIJING)	*Impacts of congestion, pollution, and climate change on economic output in Beijing (Creutzig and*	The economic output of Beijing is reduced by between 7.5 and 15 percent due to urban congestion, air pollution, and climate change. The wider range is due to uncertainty about climate change damages that are still in the process of occurring.	(Creutzig and He, 2009) Creutzig, F., He, D., 2009. "Climate change mitigation and co-benefits of feasible transport demand policies in Beijing," Transportation

Location	Description	Numerical Result/Graphic	Source
	He, 2009)		Research Part D: Transport and Environment, Volume 14, Issue 2, P. 120–131.
U.S.	*There is a strong association between land-use mix and obesity. (Frank et al., 2004)*	Each quartile increase in land-use mix is associated with a 12.2 percent reduction in the likelihood of obesity across gender and ethnicity.	(Frank et al., 2004) Frank, LD; Andresen, MA, Schmidt, TL, August 2004, "*Obesity relationships with community design, physical activity, and time spent in cars,:* American Journal of Preventative Medicine, Volume 27, Issue 2, P. 87-96.
U.S.	*Lower default risk in neighborhoods that conform to The 8 Principles and in energy efficient homes (Pivo, 2013)*	A study based on a sample of nearly 37,000 loans finds large benefits, in the form of lower loan default rates, due to sustainable development patterns of the recommended type. • Commute time: Every 10-minute decrease in average commute time decreased the risk of default by 45 percent. • Walk commute: Every increase of five percentage points in the portion of residents who walk to work decreased the risk of default by 15 percent. • Freeway presence: Where properties were located within 1,000 feet of a freeway, the risk of default increased by 59 percent. •	(Pivo, 2013) and (University of North Carolina, 2013) Pivo, Gary, October 2013, "The Effect of Sustainability Features on Default Risk. Walk Score and Multifamily D efault: The Significance of 8 and 80:,"
U.S. (CALIFORNIA)	*Predicted impacts of better urban design on California (Vision California, 2011)*	• Land consumed through 2050: (-67%) • Capital infrastructure through: (-19%) • Operation and maintenance costs through: (-18%) • Local revenues through: (+16%) • GHG emissions from transportation per capita in 2050: (-38%) • Local air pollutant emissions in 2050: (-38%) • Health costs in 2035: (-27%)	(Vision California, 2011) Vision California: Statewide Scenarios Report, June 2011.
NORTH AMERICA	*Good urban design attracts venture capital investment.*	North America has seen a shift in venture capital investment to more walkable, transit-connected, central districts. This is reflected in the fact that San Francisco metro area brought in 73 percent more in venture capital investment in 2013 compared to the San Jose metro area, which includes Silicon Valley. The move to more compact urban areas is also seen in data nation-wide, with walkable areas in metros like New York and Boston gaining hefty shares. Statistical evidence is presented, but does not extend beyond correlations. Results are consistent with urban theory going back to Jane Jacobs on why well-designed neighborhoods will spur innovation.	(Florida, 2014) Florida, Richard, March 2014, "*Startup City: The Urban Shift in Venture Capital and High Technology,"* Martin Prosperity Institute, University

Location	Description	Numerical Result/Graphic	Source
			of Toronto.
Density			
CHINA (SHENZHEN)	*Taller buildings command higher economic benefits per meter squared in Shenzhen (Wang et al., 2011)*	*Figure 5. Fitting curves of real estate development cost, revenue and profit for taller buildings*  X-axis: Per unit cost of the land in 10,000 RMB/m^2; Y-axis: Number of stories in the building (Top line is Profit, u-shaped red line is Revenue, and Upward sloping red line is Cost)	(Wang et al., 2011) Wang, Jingyuan; Zheng, Xian; Yikui, Mo, 2011, "Establishment of Density Zoning and Determination of Floor Area Ratio along Rail Transit Line Based on TOD: A Case Study on Rail Transit Line 3 in Shenzhen (in Chinese)," City Planning Review, Vol. 35,
CANADA (FORT ST. JOHN)	*Households and government benefit from denser development in Fort St. John, Canada (The Sheltair Group, 2009)*	Households will save $2,353 per year from lower capital and operating costs. The government will gain $294 per year for each household. The graphs show a comparison of conventional (low density, residential) versus sustainable (medium density, mixed use) development patterns. Values are in 2009 dollars.	(The Sheltair Group, 2009) The Sheltair Group, May 11, 2009, "Sustainable Neighborhood Concept Plan, Fort St. John: Draft for Community Review."

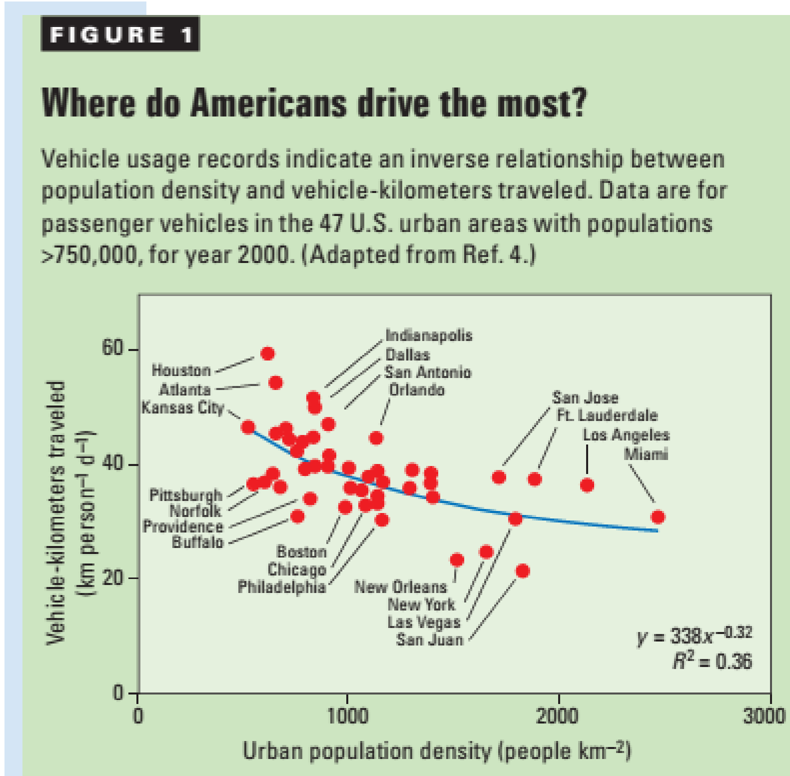
Location	Description	Numerical Result/Graphic	Source
		Figure 6. Initial Costs per Household for Medium and Low Density Neighborhoods  *Figure 7. Annual Municipal Lifecycle Costs and Revenues for Medium and Low Density Neighborhoods* 	
INTERNATIONAL	*Density means lower energy consumption from transportation (World Bank, 2010)*		(World Bank, 2010) Suzuki, Hiroaki; Dastur, Arish; Moffatt, Sebastian; Yabuki, Nanae; Maruyama, Hinako, 2010. "Eco[2] Cities: Ecological Cities as Economic Cities."

Location	Description	Numerical Result/Graphic	Source
		Figure 8. Urban Density and Transport Related Energy Consumption 	
INTERNATIONAL	*GHG emissions tend to decrease as density increases (World Bank, 2012)*		(World Bank, 2012) Baeumler, Axel; Ijjasz-Vasquez, Ede; Mehndiratta, Shomik, 2012. "Sustainable Low-Carbon City Development in China."

Location	Description	Numerical Result/Graphic	Source
		Figure 9. GHG Emissions and Density 	
US	*Inverse relationship between population density and VMT (Marshall, 2008).*		(Marshall, 2008) Marshall, Julian D, May 2008, "[Energy Efficiency Urban Form – Reducing Urban Sprawl Could Play an Important Role in Addressing Climate Change]," Environmental Science and Technology.

<table>
<tr><th>Location</th><th>Description</th><th>Numerical Result/Graphic</th><th>Source</th></tr>
<tr><td></td><td></td><td>

Figure 10. VMT and Urban Population Density



</td><td></td></tr>
<tr><td>U.S. (SAN FRANCISCO, CALIFORNIA)</td><td>Labor productivity and density (Cervero, 2001)</td><td>Employment density has the strongest association with mean productivity per worker – a six percent increase in employment density is associated with a 1 percent increase in mean labor productivity per worker.

(Commute speed and labor marketshed have a positive association with productivity but these coefficients are not significant at even the 90 percent level.)</td><td>(Cervero, 2001)

Cervero, Robert, 2001, Efficient Urbanization – Economic Performance and the Shape of the Metropolis,” Urban Studies, Vol 38, P. 1651-1671.</td></tr>
</table>

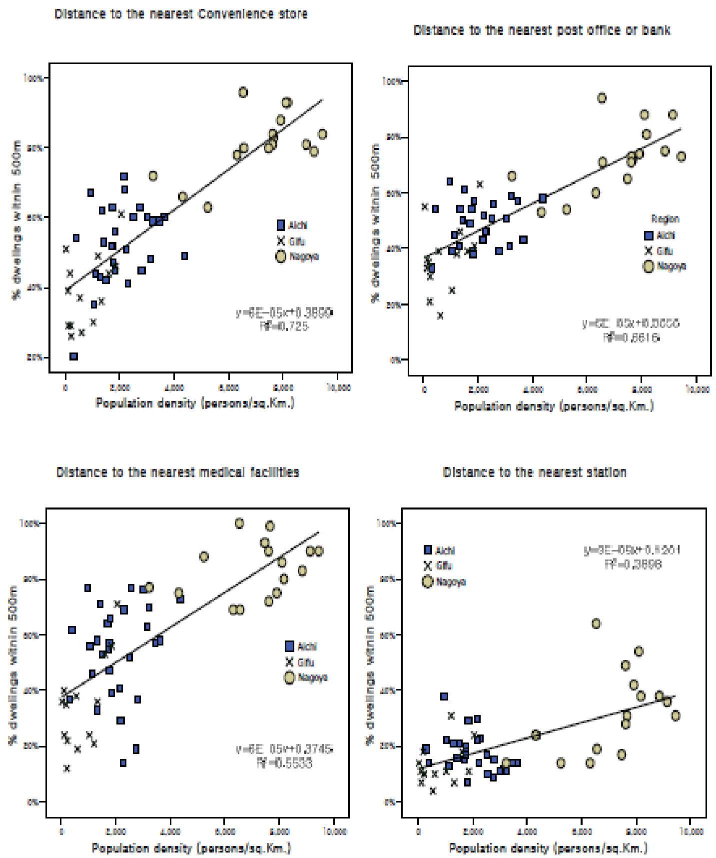
Location	Description	Numerical Result/Graphic	Source

Figure 11. Labor-marketshed model

Table 4. Labour-marketshed model: OLS estimates of worker productivity in the San Francisco Bay Area, exclusive of Santa Clara County super-districts, using three different travel-time sheds (all variables in natural logarithmic form; dependent variable: mean productivity per worker)

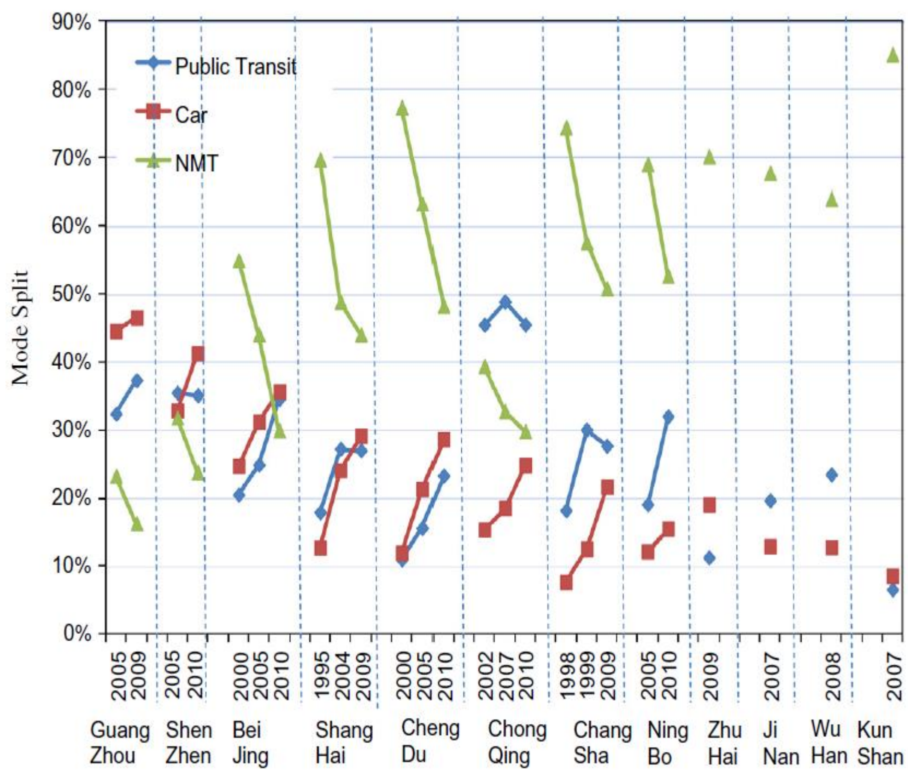
	Travel-time shed					
	30 minutes		45 minutes		60 minutes	
	Coefficient	Probability	Coefficient	Probability	Coefficient	Probability
Labour-marketshed	0.068	0.191	0.078	0.123	0.085	0.096
Average commute speed	0.104	0.220	0.099	0.236	0.110	0.179
Employees per acre	0.057	0.024	0.054	0.033	0.053	0.036
Percentage of workforce white	0.758	0.006	0.767	0.005	0.767	0.004
Constant	−3.052	0.000	−3.186	0.000	−3.308	0.000
R^2	0.484		0.502		0.511	
F statistics	4.781		5.112		5.313	
Probability	0.007		0.005		0.004	
Number of cases	27		27		27	

Location	Description	Numerical Result/Graphic	Source
U.S.	*Labor productivity increases by two to four percent with doubling of population density (Abel et al., 2012)*	Labor productivity increases by two to four percent with each doubling of density, after taking into account self-selection of human capital. (Earlier studies found larger productivity boosts, e.g. in the four to six percent range, but had failed to account for the endogeneity of human capital.)	(Abel et al., 2012) J. R. Abel, I. Dey, T Gabe. 2012, "Productivity and the Density of Human Capital," *Journal of Regional Science*, Volume 52, Issue 4, P. 562-856
U.S.	*Labor productivity and population density (Ciccone and Hall, 1996)*	Average labor productivity increases by six percent when employment density doubles. This was important work on agglomeration effects at the time it was published, but new thinking is that this failed to take into account human capital self-selection effects. Thus, the two to four percent boost should be viewed as the more reliable estimate of the causal effect all other factors equal.	(Ciccone and Hall, 1996) Ciccone and Hall, 1996, "Productivity and the Density of Economic Activity," The American Economic Review, Vol. 86, No. 1.

Location	Description	Numerical Result/Graphic	Source
JAPAN	*Higher density means better access to public services in Japan (Kaido and Kwon, 2008)* Higher density areas mean better access to public services.	*Figure 12. Density and Access to Public Services* 	(Kaido and Kwon, 2008) Kaido, K. and J. Kwon, 2008, "Quality of life and spatial urban forms of mega-city regions in Japan", in M. Jenks, D. Kozak and P. Takkanon (eds.), *World cities and urban form: fragmented, polycentric, sustainable?*, Routledge, New York.
Compact			
U.S.	*Compact development can save the US $250 billion in 25 years (Burchell, 2010)*	Burchell (2000) estimated that if one-third of America's future growth was directed towards central cities and inner suburbs and developed with modest changes (slightly higher densities, more mixed uses, traffic calming), the U.S. would save approximately $250 billion in infrastructure and public service outlays over the next 25 years—about $2,500 per household.	(Burchell, 2000) Burchell, R., 2000, "The State of Cities and Sprawl: Bridging the Divide," US Department of Housing and Urban Development.

Location	Description	Numerical Result/Graphic	Source
U.S. (PORTLAND, OREGON)	*Compact urban form reduces household transportation costs by seven percent in Portland (OECD, 2012)*	Average household transportation costs are seven percent lower in Portland (as compared with other urban households in the West).	(OECD, 2011) OECD, 2011, "Compact City Policies: A Comparative Assessment – Final Report."
U.S.	*Impact of sprawl on costs in the US is $12.6 billion (Transportation Research Board, 2000)*	According to the calculation, it is possible to have $12.6 billion by containing sprawl. Similar calculations for road infrastructure show that cost savings of $110 billion could be achieved. For the cost of public service provision, the study shows that under a controlled-growth scenario, local public-service costs would be reduced by $4 billion.	(Transportation Research Board, 2000) Transportation Research Board of the National Academies, 2000, *"Costs of Sprawl."*
U.S.	*More compact urban design would lead to an average of eight percent fewer miles driven (Ewing et al., 2007)*	A literature review of compact urban design found that compact design would lead to eight percent less driving on average, with 31.7 percent being the maximum of driving reduced. The travel mode analysis in these studies almost certainly underestimates the impact because these crude models since most do not account walking or biking trips that might replace driving. A study of three proposed infill developments in Atlanta found they would reduce driving by 35 percent on average.	(Ewing et al., 2007) Reid Ewing, Keith Bartholomew, Steve Winkelman, Jerry Walters, Don Chen. Growing Cooler: The Evidence on Urban Development and Climate Change, 2007. Link to shortened version:
U.S. (UTAH)	*Compact development reduces the costs of infrastructure in Utah. (Ewing et al., 2007)*	The Envision Utah scenario saves the region about $4.5 billion in infrastructure spending over a scenario that continues with sprawling development.	(Ewing et al., 2007) Reid Ewing, Keith Bartholomew, Steve Winkelman, Jerry Walters, Don Chen, 2007, "Growing Cooler: The Evidence on Urban Development and Climate Change."

Transportation

Location	Description	Numerical Result/Graphic	Source
Walk			
CHINA	*Sharp declines of NMT (non-motorized transit) in China since 2000 (He et al., 2013).*	This graph pertains to both walking and biking, referred to collectively as non-motorized transit (NMT). It illustrates the problem of sharp declines in travel by NMT and increase in car travel since 2000. *Figure 13. NMT versus MT - Time Trends for Cities in China* 	(He et al., 2013) Dongquan, He; et al., July 2013, "Energy use of, and CO2 emissions from China's urban passenger transportation sector – Carbon mitigation scenarios upon the transportation mode choices," Transportation Research Part A, Volume 53, P. 53-67.
CHINA (CHONGQING)	*Chongqing public space project results (EF)*	• Based on simulation results, due to mode-shifting and improved traffic flow, the project is expected to improve traffic speed on major arterials from 11.36 km per hour on average to 18.56 km per hour, a 63 percent improvement • After the first phase of the project, which involved pedestrian path upgrades, the number of people doing stationary activities has increased 6.42 times over earlier levels of use. 97.6 percent of residents report satisfaction with the project	Proprietary analysis from EF

Location	Description	Numerical Result/Graphic	Source
CHINA (SHANGHAI)	*Colon cancer risks reduced through physical activity from commuting (Lifang et al., 2004)*	For both men and women with high commuting physical activity, their odds of developing colon cancer was about ½ of those who did not have high commuting physical activity.	(Lifang et al., 2004) Lifang Hou, Bu-Tian Ji, et al., 2004, "Commuting Physical Activity and Risk of Colon Cancer in Shanghai, China,"American Journal of Epidemiology, Vol. 160, No. 9.
U.S.	*Walkable urban areas command higher rents (GWU and LOCUS, 2014)*	• Walkable urban office space in the 30 largest U.S. metro areas commands a 74 percent rent-per-square-foot premium over rents in drivable suburban areas • Businesses in suburban areas of Boston have to pay $25,000 more for an equivalent employee than center city businesses due to workers preferences for where they want to live	(GWU and LOCUS, 2014) Center for Real Estate and Urban Analysis at George Washington University School of Busines, 2004, "Foot Traffic Ahead: Ranking Walkable Urbanism in America's Largest Metros."
U.S.	*Walking boosts creativity by 60 percent (Oppenzo and Schwartz, 2014) .*	Stanford researchers found that walking boosts creative inspiration. They examined creativity levels of people while they walked versus while they sat. Results showed that walking increased a person's creative by an average of 60 percent.	(Oppenzzo and Schwartz, 2014) Oppezzo, Marilyn; Schwartz, Daniel L, 2014. "Give Your Ideas Some Legs: The Positive Effect of Walking on Creative Thinking," *Journal of Experimental Psychology: Learning, Memory, and Cognition*, Vol. 40, No. 4, 1142–1152
International	*Public health benefits from more NMT (Saelens et al., 2003)*	Moderate-intensity physical activity acquired through more non-motorized transit would have a significant public health impact. The mean difference between high- and low-walkable neighborhoods translates into about 15 to 20 minutes more of physical exercise per week for each resident of high-walkable neighborhoods. This means that for one year, a 150 lb. person, this translates into energy expenditure of about 0.85 to 1.75 lb (or 0.39 to 0.79 kg).	(Saelens et al., 2003) Walking; Saelens, BE; Sallis, JF; Frank, LD., Spring 2003, "Environmental Correlates of Walking and Cycling: Findings from the Transportation, Urban Design, and Planning Literatures," Annual Behavior Medicine, Vol. 25, Issue 2.

Location	Description	Numerical Result/Graphic	Source
			Annual Behavior Medicine
U.S.	*Housing premium in walkable neighborhoods (Cortright, 2009)*	Homes in more walkable neighborhoods enjoy a price premium of $4,000 to $34,000, according to a study of 15 U.S. metropolitan areas.	(Cortright, 2009) Cortright, Joe, 2009, "Walking the Walk: How Walking Raises Home Values in US Cities" CEO's for Cities.
U.S.	*Space efficiency of walking (Gehl)*	Walking is 10 times more space efficient than car travel. In many places, cars are privileged to benefit from most surface space use, but represent a small fraction of users of public transportation corridors. For example, on Shanghai's East Nanjing Road, pedestrians are 97 percent of the users of the surface space (meaning roadway plus sidewalks) but enjoy only 17 percent of the surface space.	Energy Foundation and Gehl Architects. A Livability and Green Mobility Strategy for Huangpu, Shanghai
Cycle			
CHINA (BEIJING)	*Travel by bicycle increases when local street crossings increase (Zhao, 2014)*	The odds of travel by bicycle will increase three times when the number of local street crossings increases by one unit, holding other variables constant.	(Zhao, 2014) Zhao, Pengjun, 2014, "The Impact of Built Environment on Bicycle Commuting: Evidence from Beijing," Urban Studies, Vol. 51, No. 5.
CHINA (GUANGZHOU)	*Bike share programs expand the user base in Guangzhou (ITDP, 2013)*	Bike share programs can expand the bicycle user base. A survey of bike share users in Guangzhou found that only 16 percent were previously private bicycle users.	(ITDP, 2013) ITDP, 2013, "The Bike Share Planning Guide."
CHINA (NANJING)	*Bike parking at transit stations contributes significantly to metro ridership in Nanjing (Zhao et al., 2014)*	This study found that providing each additional bike P&R space (P&R stands for park and ride space; these are dedicated bike parking at transit stations) lead to an increase of six transit riders (p. 145).	(Zhao et al., 2014) Zhao, Jinbao, Deng, Wei; Song, Yan; Zun, Yueran, 2014, "Analysis of Metro ridership at station level and station to station level in Nanjing: An Approach Based on Direct Demand Models," Transportation, Vol. 31, Issue 1, P. 133-155.
CHINA (GUANGZHOU)	*Bike share leads to avoided car trips in Guangzhou (ITDP, 2013)*	14,000 motorized trips avoided car trips daily due to Guangzhou bike share. Guangzhou's bike share program includes 113 stations, 5,000 bikes, 20,000 trips daily.	(ITDP, 2013) ITDP, 2013, "*Better Streets, Better Cities* (China version)."

Location	Description	Numerical Result/Graphic	Source
CHINA	*China has over 47 bike share programs with over a quarter of million bikes (Chang et al., 2012)*	Information about bike-sharing programs in China: • 47 cities have bike-sharing programs with a total of over 250,000 bikes • The largest is in Hangzhou with over 60,000 bikes, then Shanghai with 28,000 bikes, and Wuhan with 20,000 bikes • Hangzhou's program has 1.2 million registered users, Shanghai's has 100,000 registered users, and Wuhan's has 560,000 registered users	(Chang et al., 2012) Chang, HW; Hsieh, HN; Feng, CM. 2012. "Public Bike System and Marketing: Bike Sharing System in Asian Cities," Presented at the Velo-City Global Conference in Vancouver Canada.
NEW ZEALAND (AUCKLAND)	*Investments in bike paths produce large net benefits (A. Macmillian et al. 2014)*	Investment in improving infrastructure for bikes yields benefits that are 10 to 25 times greater than the cost.	(A. Macmillian et al. 2014) A. Macmillian et al., 2012, "The Societal Costs and Benefits of Commuter Bicycling: Simulating the Effects of Specific Policies Using System Dynamics Modeling,"*Environmental Health Perspectives,* Vol. 122, Issue 4, P. 335-344.
U.S.	*US spends $81 billion on biking annually, generating 770,000 jobs (Outdoor Industry Association, 2012)*	Americans spend about $10 billion on gear, accessories, and vehicles, and about $70 billion in expenditures during bicycling trips. In comparison, Americans spend about $51 billion on airplane tickets. The direct economic impact is about 772,000 jobs. The Outdoor Industry Association estimates that the "ripple effect" of all this activity from biking is over $198 billion and supports about 1.5 million jobs.	(Outdoor Industry Association, 2012) The Outdoor Recreation Economy, Outdoor Industry Association, 2012. Link: http://outdoorindustry.org/pdf/OIA_OutdoorRecEconomyReport2012.pdf
U.S.	*Biking is seven times more space efficient than car travel (EF and Gehl)*	Biking is seven times more space efficient than car travel.	(EF and Gehl) Energy Foundation and Gehl Architects, A Livability and Green Mobility Strategy for Huangpu, Shanghai.
NORWAY	*Benefits of cycle networks compared to costs in Norway*	The benefits of cycle networks are to be at least four to five times the cost of implementing them from evidence from three cities in Norway.	(Kjartan, 2004) Saelensminde, Kjartan, 2004,

Location	Description	Numerical Result/Graphic	Source
	(Kjartan, 2004)	Study finds that a change from motorized to non-motorized transport reduces air pollution, noise, and parking costs. Moreover, "barrier costs" from motorized transport preventing non-motorized transport from being used are just as high as the air pollution and double the noise costs. These "barrier costs" are often not taken into considering when doing cost-benefit analysis in favor of bike lanes.	"Cost-benefit analyses of walking and cycling track networks taking in account insecurity, health effects, and external costs of motorized traffic," Transportation Research Part A: Policy and Practice, Vol. 38, Issue 8.
U.S.	*Protected bike lanes and ability to increase bike traffic (Pucher et al., 2013)*	• 266 percent increase in biking on buffered bike lanes in Spruce and Pine streets in Philadelphia • 55 percent increase in biking in protected bike lane on Kinzie St. in Chicoag • 56 percent increase in biking in protected bike lane on Columbus Avenue in NYC • 54 percent increase in biking in protected bike lane on protected bike lane in Vancouver, Canada • 200 percent increase in biking on median bike lanes in Washington DC on Pennsylvania Ave • 190 percent increase in biking on protected bike lane in Prospect Park West in NYC • 115 percent increase in biking on protected bike lane on Market St. in San Francisco	(Pucher et al., 2013) Pucher, John; Dill, Jennifer; Handy, Susan; Buehler, Ralph, August 2013, "Protected Bike Lanes Mean Business: How to Increase Cycling for Daily Travel: Lessons from Cities from Across the Globe," Data presented at a joint webinar on the Institute of Transportation Engineers and the Active Living Research Program of the Robert Wood Johnson Foundation.
US (WASHINGTON, D.C.)	*Bike-share can help alleviate public transit congestion in Washington, D.C. (Martin and Shaheen, 2014)*	In Washington, D.C., a survey of more than 4,800 members found that 47 percent decreased their rail transit use after the introduction the city's bike-share program, which is concentrated primarily in the city center. This suggests that bike-share can act as a substitute for short rail trips. In dense areas where subway congestion is a problem, bike-share is a substitute that helps reduce crowding. In less dense, outlying areas, bike-share serves as an extension of the public transit system, helping people get to and from motorized transit stations. In these areas, bike-share complements and increases use of motorized public transit. The Minneapolis bike-share system is an example of this effect. The introduction of that bike-share system has led to a 12 percent net increase in transit. (14 percent of bike-share users increased their use of rail transit, and two percent decreased it.)	(Martin and Shaheen, 2014) Martin, Elliott W., Shaheen, Susan A., July 2014, "Evaluating public transit modal shift dynamics in response to bikesharing: a Tale of two U.S. cities," (Elliot W. Martin, Susan A Shaheen) Journal of Transport Geography.

<table>
<tr><th>Location</th><th>Description</th><th>Numerical Result/Graphic</th><th>Source</th></tr>
<tr><td>U.S.</td><td>Cities with a greater supply of bike paths have higher bike commute rates (Buehler and Pucher, 2012)</td><td>Even when controlling for land use, climate, socioeconomic factors, gasoline prices, public transport supply, and cycling safety, cities with a greater supply of bike paths have higher commutes by bike – suggesting a more causal relationship of bike paths amount and level of actual biking. A 10 percent greater supply of bike lanes is associated with a 3.1 percent greater number of bike commuters per 10,000 population. A 10 percent greater supply of bike paths is associated with a 2.5 percent higher level of bike commuting.

Cycling safety is also statistically significant – a 10 percent higher cyclist fatality rate per 10,000 commuter cyclists is associated with 3.7 percent fewer bike commuters per 10,000 population. A 10 percent higher share of students in the population is associated with 8.6 percent more bike commuting.</td><td>(Buehler and Pucher, 2012)

Buehler, Ralph; Pucher, John, 2012, "Cycling to work in 90 large American Cities: New Evidence on the Role of Bike Paths and Lanes," Transportation, Vol. 39, P. 409-432.</td></tr>
<tr><td colspan="4">Transit</td></tr>
<tr><td>CHINA (SHANGHAI)</td><td>Increase in commercial activity from metro in Shanghai (Pan and Zhang)</td><td>Metro increased the amount of times that residents travelled to downtown commercial area – true for both 2002 and 2003.

Figure 14. Metro Installation and Trips Taken Downtown

<table>
<tr><th></th><th>Daily</th><th>Every 2-3 Days</th><th>Once a Week</th><th>2-3 Times per Week</th><th>Once a Month</th><th>Sometimes</th><th>Rarely</th><th></th></tr>
<tr><td>Year 2002</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Before</td><td>10.00%</td><td>9.70%</td><td>13.90%</td><td>15.10%</td><td>17.40%</td><td>27.00%</td><td>6.90%</td><td>100.00%</td></tr>
<tr><td>After</td><td>15.60%</td><td>13.20%</td><td>15.60%</td><td>16.10%</td><td>15.80%</td><td>16.70%</td><td>7.00%</td><td>100.00%</td></tr>
<tr><td>Year 2003</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Before</td><td>8.95%</td><td>13.23%</td><td>12.45%</td><td>10.12%</td><td>15.17%</td><td>31.91%</td><td>8.17%</td><td>100.00%</td></tr>
<tr><td>After</td><td>12.18%</td><td>16.67%</td><td>14.74%</td><td>19.55%</td><td>16.67%</td><td>14.10%</td><td>6.09%</td><td>100.00%</td></tr>
</table>
</td><td>(Pan and Zhang)

Pan, Haixiao; Zhang, Ming. Rail Transit Impacts on Trip Making and Land Development in Shanghai, China. Study sponsored by the Natural Science Foundation of China and the University of Texas at Austin.</td></tr>
<tr><td>CHINA (SHANGHAI)</td><td>Metro decreased long trips and increased 15- to 30-minute trips in Shanghai (Pan and Zhang)</td><td></td><td>(Pan and Zhang)

Pan, Haixiao; Zhang, Ming. Rail Transit Impacts on Trip Making and Land Development in Shanghai, China. Study sponsored by the Natural Science</td></tr>
</table>

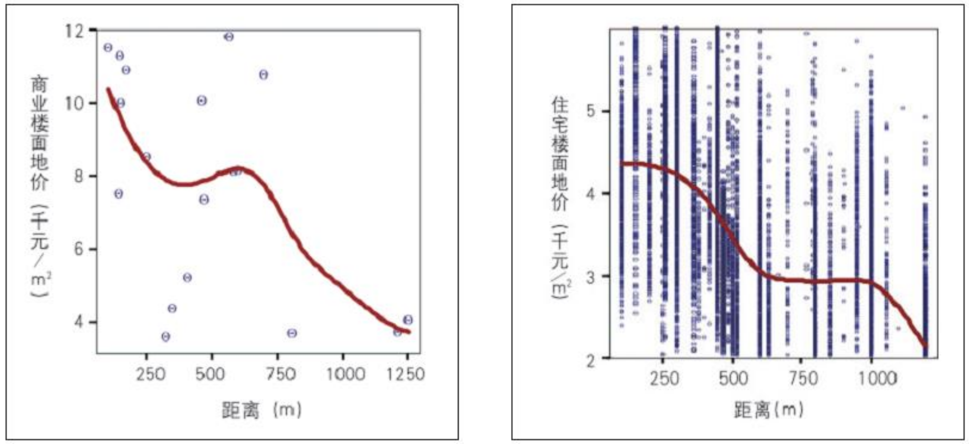
Location	Description	Numerical Result/Graphic	Source
		Figure 15. Trip Duration Before and After Metro Installation	Foundation of China and the University of Texas at Austin.

2002 Interview						
Trip Time (min.)	<=5	6~15	16~30	31~60	61~120	> 120
Before Rail	4.60%	11.90%	20.10%	33.30%	20.10%	10.00%
Now	8.30%	29.20%	37.10%	19.20%	5.10%	1.10%
2003 Interview						
	≤5	6~15	16~30	31~60	61~120	>120
Before Rail	5.65%	16.96%	18.70%	38.26%	18.26%	2.17%
Now	4.94%	23.77%	40.12%	24.38%	4.32%	2.47%

Location	Description	Numerical Result/Graphic	Source
CHINA (SHANGHAI)	*Metro caused huge shift from bus trips to metro trips in Shanghai; car trips went down too (Pan and Zhang)*	*Figure 16. Mode Shifting Due to Metro in Shanghai*	Pan and Zhang. Pan, Haixiao; Zhang, Ming. Rail Transit Impacts on Trip Making and Land Development in Shanghai, China. Study sponsored by the Natural Science Foundation of China and the University of Texas at Austin.

	Walk	Bicycle	Powered Bicycle	Motorcycle	Bus	Car	Metro	Other
Before Metro Opening	11.45%	14.48%	4.04%	1.68%	63.30%	2.36%	0	2.70%
Current	9.42%	14.86%	3.26%	0.36%	17.39%	1.45%	52.90%	0.36%

Location	Description	Numerical Result/Graphic	Source
CHINA (SHENZHEN)	*Proximity to transit stations increases property prices in Shenzhen (Wang, 2011)*		(Wang 2011) Wang, Jingyuan; Zheng, Xian; Yikui, Mo, 2011, "Establishment of Density Zoning and Determination of Floor Area Ratio along Rail Transit Line Based on TOD: A Case Study on Rail Transit Line 3 in Shenzhen (in Chinese)," City Planning Review, Vol. 35.

Location	Description	Numerical Result/Graphic	Source
		Figure 17. Property Value and Relationship to Distance from Public Transit  图1 商业地价局部线性回归局部放大 Fig.1 An enlarged part of local linear regression of commercial land price 图2 住宅地价局部线性回归局部放大 Fig.2 An enlarged part of local linear regression of residential land price X axis = Property value (in Thousands of RMB/sq. meter) – first for commercial and then for residential)	
CHINA (BEIJING)	*Homes near BRT stations in Beijing are worth more than other comparable homes (Deng and Nelson, 2010)*	The average values of residential properties near BRT stations increased 2.3 percent faster annually than properties that were not served by a BRT station. This is based on evidence from interviews with key stakeholder groups and longitudinal analysis of changes of property prices. BRT Line 1 in Beijing has had positive development effects with higher property value and faster land development. The study used geographic location, types of units, and building age as the chief control variables with judgment from local estate agents as well. It also selected control areas to be as similar to the catchment areas and exhibit similar characteristics (including metro and bus access), which are referred to as “significant external effects.”	(Deng and Nelson, 2010) Deng, Taotao; Nelson, John D., 2010, “The Impact of Bus Rapid Transit on Land Development: A Case Study of Beijing, China, 2010, World Academy of Science, Engineering, and Technology, Vol. 4.

Location	Description	Numerical Result/Graphic	Source
		Figure 18. Catchment Areas and Control Areas for Beijing BRT Impact on Land Study  Fig. 2 Locations of catchment areas and control areas, *Source*: based on the map from http://map.sogou.com/	
CHINA (BEIJING)	*Price premium for properties near rail stations in Beijing (Ma et al., 2013)*	There was a price premium of about five percent for properties near rail stations, and this increases to up to 10 percent for stations in suburban and low-income areas. This means that the price premium of rail transit increases in neighborhoods where car ownership is less likely.	(Ma et al., 2013) Ma, L; Ye, R; Titheridge, H, 2013, "Capitalization effects of rail transit and BRT on residential property values in a booming economy: evidence from Beijing." Presented at: Transportation Research Board 92nd Annual Meeting, Washington DC, US.
CHINA (GUANGZHOU)	*Evaluation of the impact of comprehensive urban form upgrades (ITDP, 2013)*	ITDP observes: "[The introduction of ground floor commercial use] had already multiplied [real estate] values several times before the renovation program [public space improvements carried out in preparation for the 2009 Asian Games]. The approximately 900 area shops experienced a general increase in value of 30 percent following the re-opening."	(ITDP, 2013) ITDP, 2013, "*Better Streets, Better Cities* (China version)."
CHINA (JINAN)	*Walking environment can influence how far*	People were more willing to walk further to BRT stations when the walking environment has certain features (median transit-way station location, shaded corridors, busy and interesting	(Jiang et al., 2012)

Location	Description	Numerical Result/Graphic	Source
	people walk to BRT stations (Jiang et al., 2012)	sidewalks). • Integrated boulevards, with the positive features described above, increased walking catchment by 158 meters (people are willing to walk that much further) • Terminal stations had walking distance of 400 meters more than transfer stations • Trip-maker (who is taking a trip; their age, income, and other traits) and trip characteristics (where the person is going and why) have a relatively small effect on the decision to choose transit	Jiang, Yang; Zegras, Christopher P.; Mehndiratta, Shomik, 2012, "Walk the Line: Station context, corridor type and bus rapid transit walk access in Jinan, China," Journal of Transport Geography, Vol. 20.

Figure 19. OLS Regression Models Predicting BRT Walk Distance

Variable	Control model		Full model	
	Coefficient	*t*-Test	Coefficient	*t*-Test
BRT trip maker and trip characteristics				
Income <2000 RMB	120.371*	1.69	165.651**	2.60
Income 2000–10,000 RMB	Ref		Ref	
Income >10,000 RMB	−133.728	−1.08	−54.418	−0.49
Occupation: Professional	24.397	0.58	−9.133	−0.24
Occupation: Blue collar	105.998	1.40	−43.635	−0.64
Occupation: Service/self-employed	15.386	0.28	−48.788	−1.00
Gender: Female	−29.701	−0.99	2.330	0.08
Age <20	2.552	0.04	−72.527	−1.14
Age 20–40	Ref		Ref	
Age 40–60	−36.600	−0.79	−73.832*	−1.75
Age >60	200.407**	2.20	26.446	0.32
BRT-dominant user	19.723	0.63	42.035	1.47
Car ownership	−26.006	−0.62	6.414	0.17
Trip purpose: Commuting/schooling	Ref		Ref	
Trip purpose: Shopping	−68.515	−1.37	−46.560	−1.04
Trip purpose: Recreation/social	53.361	1.21	22.799	0.58
Trip purpose: Personal business/ other	−59.678	−1.55	−21.551	−0.62
No alternative mode available	470.689**	2.55	415.598**	2.53
Trip time: Weekend	−7.556	−0.22	−26.062	−0.85
In group	13.516	0.39	28.053	0.90
BRT corridor type				
Integrated-boulevard (Lishan Rd.)			158.810**	2.60
Below-expressway (Beiyuan Rd.)			−20.432	−0.32
Arterial-edge (Jingshi Rd.)			Ref	
BRT station context				
Terminal station			372.886**	3.52
Transfer station			−126.453**	−2.34
Typical station			Ref	
Density gradient: Hill			−156.771**	−4.15
Density gradient: Flat			Ref	
Density gradient: Valley			153.714**	3.52
Number of feeder bus routes			0.583	0.18
Distance to city center (km)			75.926**	2.40
Feeder road length in 600 m catchment area			−11.127	−1.16
(Constant)	640.032**	12.27	597.833**	3.06
No. Observations	1233		1233	
(d.f.)	(18,1214)		(27,1205)	
F	1.882*		14.576**	
Adjusted R^2	0.012		0.223	

* $p < .10$.
** $p < .05$.

Location	Description	Numerical Result/Graphic	Source
U.S. (LOS ANGELES, CALIFORNIA)	*Economic impacts of public transit on LA are between $1.2 to $4.1 billion per year (Anderson, 2013)*	Average highway delay increases 47 percent when transit service ceases. The congestion relief benefit of operating the Los Angeles transit system is between $1.2 billion to $4.1 billion per year, or $1.20 to $4.10 per peak-hour transit passenger mile. This is not the total value, just the value of reduced congestion at peak times.	Anderson, Micheal, 2013, *Subways, Strikes, and Slowdowns: The Impacts of Public Transit on Traffic Congestion.* UC Berkeley working paper. (Accepted to American Economic Review.)
COLOMBIA (BOGOTA)	*BRT can increase property values in Bogota (Rodriguez and Mojica, 2009)*	Properties offered the year the extension of BRT was offered and in subsequent years have property prices that are 13 to 14 percent higher than prices for properties in the control area, and this is after controlling for structural, neighborhood, and regional accessibility characteristics of each property. There is also a premium of 6.8 to 9.3 percent for every 5 minutes walking time closer to the BRT station. *Figure 20. Estimated Yearly Difference in Prices for Properties in Areas With and Without Transit*	(Rodriguez and Mojica, 2009) Rodriguez, Daniel; Mojica, Carlos H., 2009, "Capitalization of BRT Network Effects into Land Prices," Meeting submitted for presentation only at the Transportation Research Board's Annual Meeting.

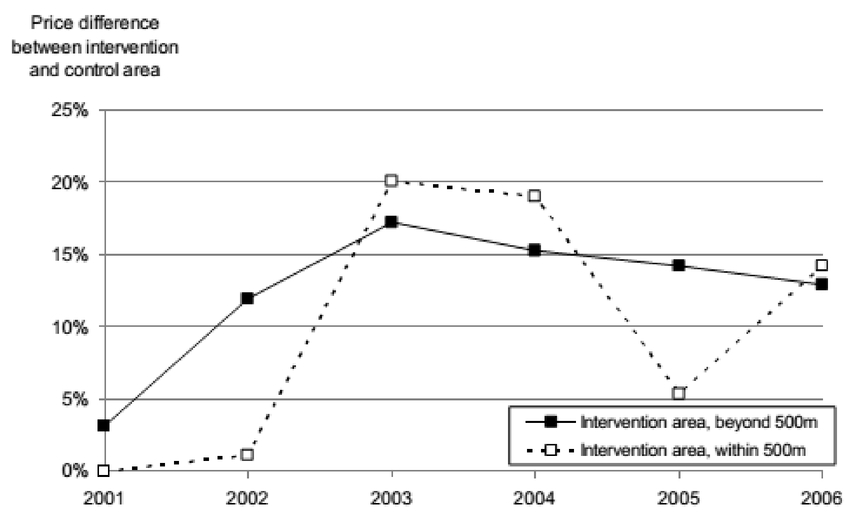


Figure 4. Estimated yearly difference in prices (%) for properties in intervention and control areas

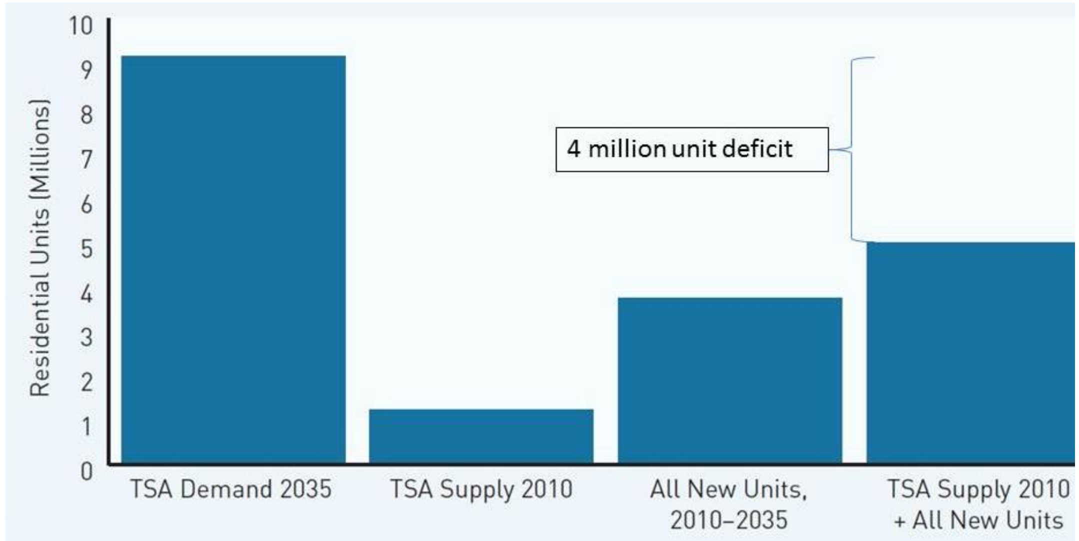
<table>
<tr><th>Location</th><th>Description</th><th>Numerical Result/Graphic</th><th>Source</th></tr>
<tr><td>JAPAN</td><td>Transit improves buyer-seller relations and leads to better economic performance (Bernard, Moxnes, Saito, 2014)</td><td>More network links increase probability of buyer-seller relations between pairs of firms. Geography, density, quality of network connections are strongly correlated with downstream customer firm performance.</td><td>(Bernard, Moxnes, and Yukiko, 2014)

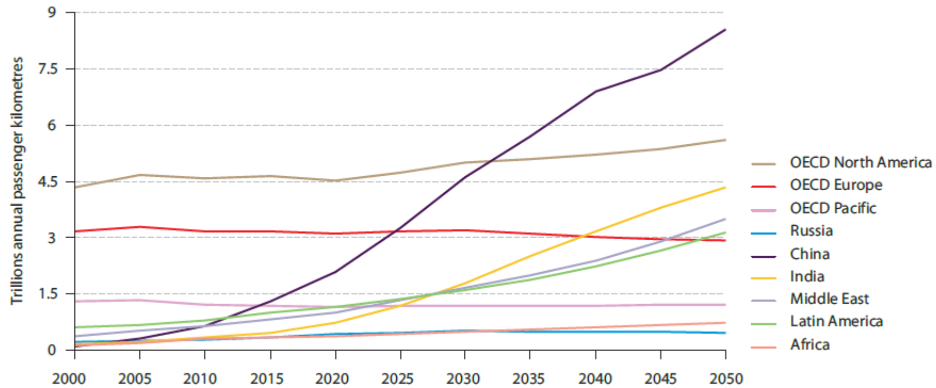
Bernard, Andrew B.; Moxnes, Andreas; Yukiko, Saito U., June 2014, "Geography and Firm Performance in Japanese Production Network," RIETI Discussion Paper</td></tr>
<tr><td>U.S.</td><td>Comparison of operating costs and other characteristics of light rail and metro rail in U.S. (Cervero, 2013)</td><td>Figure 21. Comparison of BRT and Urban Rail Transit Systems

Table 3 Comparisons of BRT and Urban Rail Transit systems
SOURCE Levinson et al., (2003); Vuchic (2005); Hensher and Golob (2008); Zhang (2009); Deng and Nelson (2011)
<table>
<tr><th></th><th></th><th>URBAN RAIL TRANSIT</th><th></th></tr>
<tr><th></th><th>BRT</th><th>LIGHT RAIL</th><th>METRORAIL</th></tr>
<tr><td>RIGHTS-OF-WAY</td><td>Mixed: shared (at-grade); dedicated and exclusive lanes</td><td>Exclusive (elevated or barriers) or shared (at-grade)</td><td>Exclusive, grade-separated</td></tr>
<tr><td>RUNNING WAYS</td><td>Pavement; roadways</td><td>Steel track</td><td>Steel track</td></tr>
<tr><td>VEHICLE PROPULSION</td><td>Internal combustion engine</td><td>Electric (overhead wires)</td><td>Electric (high-voltage third rail)</td></tr>
<tr><td>VEHICLE CONTROL</td><td>Operator/visual</td><td>Automated/sign control</td><td>Automated/sign control</td></tr>
<tr><td>CONSTRUCTION TIME</td><td>1-2 years</td><td>2-3 years</td><td>4-10 years</td></tr>
<tr><td>MAXIMUM CAPACITY (passengers/vehicle unit)</td><td>160-270</td><td>170-280</td><td>240-320</td></tr>
<tr><td>MAXIMUM CAPACITY (passengers/coupled unit)</td><td>160-270</td><td>500-900</td><td>1000-2400</td></tr>
<tr><td>MINIMUM HEADWAY (seconds)</td><td>12-30</td><td>75-150</td><td>120-150</td></tr>
<tr><td>LINE CAPACITY (passengers/direction/hour)</td><td>5000 - 45000</td><td>12000 – 27000</td><td>40000 - 72000</td></tr>
<tr><td>MAXIMUM SPEED (kph)</td><td>60-70</td><td>60-80</td><td>70-100</td></tr>
<tr><td>AVERAGE CAPITAL COSTS [1] (2000 US$/km)</td><td>8.4</td><td>21.5</td><td>104.5</td></tr>
<tr><td>AVERAGE OPERATING COST [1] (2000 US$ per vehicle revenue km)</td><td>2.94</td><td>7.58</td><td>5.30</td></tr>
</table>
1. Costs figures are for US case studies. Costs adjusted to $2000, calculated using Consumer Price Index average.</td><td>(Cervero, 2013)

Cervero, Robert, December 213, "Bus Rapid Transit: An Efficient and Competitive Mode of Transportation," 20th ACEA Scientific Advisory Group Report.</td></tr>
<tr><td>U.S. (CALIFORNIA)</td><td>Market preferences are shifting to transit station accessible housing (Nelson, 2014)</td><td>Increasing preference for transit-oriented housing in California, but supply side is not not responding quickly enough. Four million unit deficit in transit-oriented housing predicted for 2035 based on current trends.</td><td>(Nelson, 2014)

Nelson, Arthur C., 2014, "The New California Dream: How Demographic and Economic Trends May Shape the Housing Market." The Urban Land Institute.</td></tr>
</table>

Location	Description	Numerical Result/Graphic	Source
		Figure 22. Supply and Demand for Transit Accessible Housing  	
INTERNATIONAL	*BRT is much cheaper to construct and operate compared to light rail (ITDP)*	BRT costs up to 30 times less to construct and three times less to operate compared to light rail.	ITDP Web Page (hyperlinked here), accessed August 11, 2014
NORTH AMERICA	*Study of transit dollars from BRT vs. other technologies (ITDP, 2013)*	Both BRT and LRT can leverage many times more TOD investment than they cost. However, per dollar of transit investment, and under similar conditions, Bus Rapid Transit leverages more transit-oriented development investment than Light Rail Transit or streetcars. Cleveland's HealthLine BRT and Portland's MAX Blue Line LRT leveraged the most overall TOD investment of all the corridors we studied—$5.8 billion and $6.6 billion, respectively. Yet, because the HealthLine BRT cost significantly less to build than the MAX Blue Line LRT, Cleveland's HealthLine BRT leveraged approximately 31 times more TOD investment per dollar spent on transit than Portland's MAX Blue Line LRT. Of the 21 corridors we studied, 14 leveraged greater than $1 of TOD investment per $1 of transit spent. Five of them were BRT, four of them were LRT, two were streetcars, and three were improved bus (non-BRT) corridors.	Hook, Walter; Lotshaw, Stephanie; Weinstock, Annie, ITDP, "*More Development for Your Dollar: An Analysis of 21 N. American Transit Corridors*."
INTERNATIONAL	*Passenger vehicle travel is increasing at an unsustainable rate (IEA, 2013)*	*Figure 23. Trillions Annual Passenger Kilometers*	(IEA, 2013) International Energy Agency, 2013, "A Tale of Renewed Cities."

<table>
<tr><th>Location</th><th>Description</th><th>Numerical Result/Graphic</th><th>Source</th></tr>
<tr><td></td><td></td><td>
</td><td></td></tr>
<tr><td>U.S. (NEW JERSEY)</td><td>Increase in bus-stop density decreases the chance of commuting solo by automobile (Chatman, 2013)</td><td>A 10-times increase in the density of bus stops decreases by 95 percent the chance of solo commuting by automobile.</td><td>(Chatman, 2013)

Chatman, Daniel G, 2013, “Does TOD Need the T?,” Journal of the American Planning Association, Vol. 79, Issue 1, P. 17-31.</td></tr>
<tr><td>KOREAN (SEOUL)</td><td>BRT improved speeds on roads in Seoul (Cervero, 2013)</td><td>Figure 24. Changes in Operating Speeds (km/h) of Cars and Buses Along Road Segments Before and After BRT

Table 2 Comparison of changes in operating speeds (km/h) of cars and buses along three road segments with exclusive median bus lanes, before and after BRT
SOURCE Seoul Development Institute, 2005
<table>
<tr><th></th><th>DESCRIPTION</th><th>BEFORE (JUNE 2004)</th><th>AFTER (AUGUST 2004)</th><th>PERCENTAGE CHANGE</th></tr>
<tr><td>ROAD A</td><td>Bus (exclusive lane)</td><td>11</td><td>20.3</td><td>85.0%</td></tr>
<tr><td></td><td>Car (other lane)</td><td>18.5</td><td>19.9</td><td>7.6%</td></tr>
<tr><td>ROAD B</td><td>Bus (exclusive lane)</td><td>13.1</td><td>22.5</td><td>70.0%</td></tr>
<tr><td></td><td>Car (other lane)</td><td>20.3</td><td>21</td><td>3.4%</td></tr>
<tr><td>ROAD C</td><td>Bus (exclusive lane)</td><td>13</td><td>17.2</td><td>32.0%</td></tr>
<tr><td></td><td>Car (other lane)</td><td>18</td><td>19.1</td><td>6.1%</td></tr>
</table></td><td>(Cervero, 2013)

Cervero, Robert, 2013, “Bus Rapid Transit: An Efficient and Competitive Mode of Transportation,” 20th ACEA Scientific Advisory Group Report.</td></tr>
<tr><td>ECUADOR (QUITO)</td><td>Cost savings of BRT in the U.S. and an</td><td>Figure 25. Comparison of Cost Savings of BRT, LRT, and Bus on HOV Lane</td><td>(Cervero, 2013)</td></tr>
</table>

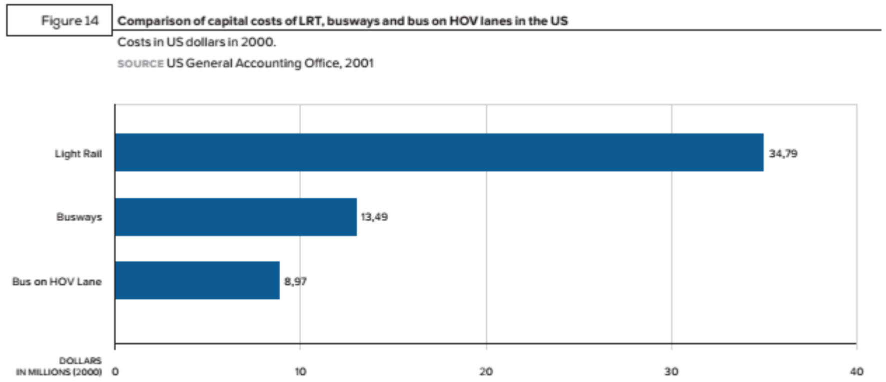
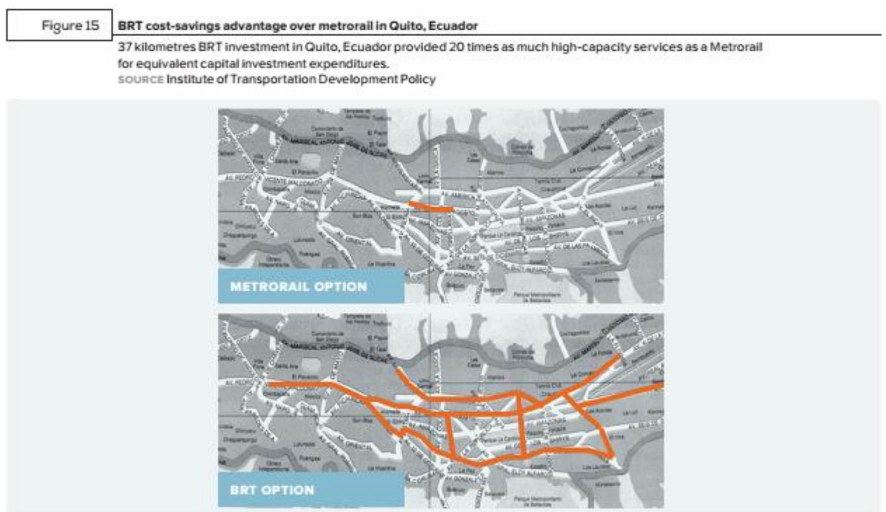
<table>
<tr><th>Location</th><th>Description</th><th>Numerical Result/Graphic</th><th>Source</th></tr>
<tr><td></td><td>example in Quito, Ecuador (Cervero, 2013)</td><td>


Figure 26. BRT Cost-Savings Advantage over Metro Rail in Quito



</td><td>Cervero, Robert, 2013, “Bus Rapid Transit: An Efficient and Competitive Mode of Transportation,” 20th ACEA Scientific Advisory Group Report.</td></tr>
<tr><td>U.S. (MASSACHUSETTS)</td><td>Commuter rail stations increase land prices (Armstrong and Rodriguez, 2006)</td><td>The properties in the areas with commuter rail stations have values that are from 9.6 to 10.1 percent higher than properties in municipalities without a commuter rail station.</td><td>(Armstrong and Rodriguez, 2006)

Armstrong, Robert J.; Rodriguez, Daniel A., 2006, “An evaluation of the accessibility benefits of</td></tr>
</table>

Location	Description	Numerical Result/Graphic	Source
			commuter rail in East Massachusetts using spatial hedonic price functions," Transportation, Vol. 33, P. 12-43.
U.S.	*Proximity to transit increases property values – evidence from across the U.S. (Kilpatrick et al., 2007)*	• Workman and Brod (1997) examines individual San Francisco neighborhoods and finds a decline in home prices of $1,578 to $2,300 for every 100 feet from a BART station • Sedway Group (1999) reports a decline in housing price of $74 per foot from a BART station within the first quarter of a mile and $30 per foot for those greater than a quarter of a mile away • Baum-Snow and Kahn (2001), a multi-city study analysis, finds that moving from three miles to one mile away from a transit station creates a rent increase of $19 per month and a housing premium of $4,972 • Garrett (2004), a study on the Metrolink in St. Louis, shows an increase of $140 in home price per 10 feet closer to a station	(Kilpatrick et al., 2007) Kilpatrick, John A.; Throupe, Ronald L.; Carruthers, John I.; Krause, Andrew, 2007, "The Impact of Transit Corridors on Residential Property Values," JRER, Vol. 29, No. 3.
U.S. (AUSTIN, TX)	*Congestion can decrease with TOD in Austin, TX (Zhang, 2010)*	Aggressive TOD would have great mobility benefits for Austin, TX; would reduce congested roadway by nearly 770 lane miles. Daily vehicle miles traveled would be reduced by 10 to 12 million in the region, or by 3.5 to 4.5 person miles traveled per person. The range is due to a comparison of two scenarios – a rail-only TOD development path (10 transit oriented districts around the proposed rail stations) and a "all systems go TOD" (bus-based TOD corridors that are combined with all of the rail-based TOD's). The results are based on a four-step modeling process that is commonly used by urban planners, where a key limitation is the assumption of the exogeneity of land use.	(Zhang, 2010) Zhang, Ming, 2010, "Can Transit-Oriented Development Reduce Peak-Hour Congestion?, Transportation Research Record: Journal of the Transportation Research Board, Volum 2174, P. 148-155.
Shift			
CHINA (DAOLI, HARBIN)	*Study found off-street parking is prevalent and that most cars park for free in Daoli, Harbin (ITDP, 2008)*	In summary, the study found: 41 percent = the percentage of cars parked illegally on the sidewalk 78 percent = the percentage of parked cars not being charged (parking for free) 2000 = excess spots at peak time not being 60 percent = percentage of cars parked for at least four hours (not rapid turnover to support commerce) Demand exceeds formal supply but there is ample parking. Informal and walkway parking is prevalent. The government could earn an additional RMB 29.3 million in revenue each year under introduction of metered spaces. Here are the details of the survey of parking uses:	(ITDP, 2008) ITDP, 2008, Harbin Daoli Parking Analysis.

Location	Description	Numerical Result/Graphic	Source
		Figure 27. Parking Patterns in Daoli, Harbin	

FIGURE 4. SUMMARY OF FINDINGS

	TOTAL	SUBAREAS 1	2	3	4	5	
Parked cars (12-2PM)	**8,072**	2,680	2,652	680	653	819	5
Marked spaces	**6,295**	2,387	2,150	275	287	392	8
Empty marked spaces	**2,108**	916	385	80	75	148	5
% parked informally	**47%**	44%	31%	71%	68%	70%	50
% parked on sidewalk	**41%**	19%	68%	35%	52%	37%	26
% parked for free	**> 78%**	60%	91%	85%	96%	86%	59
% parked more than 4 hours	**60%**			N/A			

Location	Description	Numerical Result/Graphic	Source
CHINA (BEIJING)	*Economic benefits of green space in Beijing (Zhang et al., 2012)*	This study analyzed the economic benefits of urban green spaces, which often can be created by reducing parking space or increasing car control. The total economic benefit was RMB 1.34 billion in 2009, which is equivalent to three-quarters of the maintenance cost of Beijing's green spaces; the value of rainwater-runoff reduction was RMB 21,770 per hectare	(Zhang et al., 2012) Zhang, Biao; Xie, Gaodi; Zhang, Canqiang; Zhang, Jing, June 2012, "The Economic Benefits of Rainwater Runoff Reduction by Urban Green Spaces in Beijing, China," Journal of Environmental Management, Vol. 100.
CHINA (GUANGZHOU)	*View of green space and proximity to water bodies raised housing prices by 7.1 percent and 13.2 percent (Jim and Chen, 2006)*	This article looks at the amenity value of urban green spaces and urges developers and the government to integrate these factors into property pricing and associated decisions. View of green space and proximity to water bodies raised housing prices by 7.1 percent and 13.2 percent respectively.	(Jim and Chen, 2006) Jim, C.Y.; Chen, Wendy Y., , November 2006, "Impacts of Urban Environmental Elements on Residential Housing Prices in Guangzhou," Landscape and Urban Planning, Volume 78, Issue 4.
CHINA (BEIJING)	*Lottery system in Beijing for license plates is inefficient compared to auction system (Li, 2014)*	This analysis shows that the lottery system offers a large advantage over the auction system in reducing automobile externalities within a quota system. Nevertheless, this advantage is offset by its allocative cost due to misallocation. The estimated welfare loss from the lottery system in Beijing is RMB 36 billion (or $6 billion) in 2012. The lottery is more effective in reducing driving-related externalities because it does not allow richer households to use their income advantage to secure a larger share of vehicle registrations. This reduces externalities somewhat because	(Li, 2014) Li, Shanjun. 2014, "Better Lucky Than Rich? Welfare Analysis of Automobile License

Location	Description	Numerical Result/Graphic	Source
		that are more likely to drive more and drive larger, less efficient vehicles	Allocations in Beijing and Shanghai," Cornell University, School of Applied Economics and Management Working Paper Series.
CHINA (BEIJING)	*Driving restrictions in Beijing reduce pollution and yield net economic benefits (Viard and FU, 2013)*	Driving restrictions in Beijing are effective to control pollution but there are also economic costs from decrease in worker output: • Driving restrictions in Beijing lead to 20 percent reduction in air pollution with every-other-day restrictions and nine percent during one-day-per-week restrictions • Economic benefits from reduced morbidity from driving restrictions are about RMB 1.1 to 1.4 billion, but costs of reduced output are about RMB 0.51 to 0.72 billion annually	(Viard and Fu, 2013) Viard, Brian V.; Fu, Shihe. Draft: The Effect of Beijing's Driving Restrictions on Pollution and Economic Activity.
CHINA (BEIJING)	*Inefficiencies of taxi use due to congestion in Beijing (Fox and Tallon, 2013)*	Even though there are 67,000 taxis that are operational in Beijing, potential passengers are reluctant to use them due to congestion. This means that about 40 percent are empty and still contributing to congestion problems.	(Fox and Tallon, 2013) Fox, Martin. Tallon, Andrew, Spring 2013, "Traffic congestion in Beijing: Issues and Policies, Geography, Vol. 98, P. 43-49.
BRAZIL (RIO DE JANEIRO AND SAO PAULO)	*Congestion costs 7.8 percent of GDP for Rio and Sao Paulo. (Industry Federation of the State of Rio de Janeiro, 2014)*	The cost of congestion in the cities of Rio and Sao Paul is equivalent to 7.8 percent of the economic output of these metros areas, or $43 billion total. The study only took into account the economic cost of lost work hours and wasted fuel. Costs would be higher if public health, vehicle maintenance, road infrastructure, and other more difficult to quantify impacts were considered.	(Industry Federation of the State of Rio de Janeiro, 2014) Industry Federation of the State of Rio de Janeiro, 2014, "Study: Rio de Janeiro and Sao Paulo lost USD 43 billion from Traffic Congestion in 2013."
U.S.	*Car use increases likelihood of obesity (Frank et al., 2004)*	Each additional hour spent in a car per day was associated with a six percent increase in the likelihood of obesity.	(Frank et al., 2004) Frank, LD; Andresen, MA, Schmidt, TL, August 2004, "*Obesity relationships with community design, physical activity, and time spent in cars,"* American Journal of Preventative Medicine, Volume 27, Issue 2, P. 87-96.
U.S. (NEW JERSEY)	*Off-street parking and relationship to*	The chance that a household will be "car free" increases by 57 to 63 percent if off-street parking is scarce.	(Chatman, 2013)

Location	Description	Numerical Result/Graphic	Source
	car ownership (Chatman, 2013)		Chatman, Daniel G, 2013, "Does TOD Need the T?," Journal of the American Planning Association, Vol. 79, Issue 1, P. 17-31.
U.S. (New York City)	*Developers do not really want parking minimums (NYU)*	Sixty-eight percent of developers took a waiver on parking minimums when offered in a study of over 1,000 New York City residential building projects. Of these developers choosing to build less parking, 83 percent chose to build no parking at all.	(NYU, 2012) New York University. 2012. Searching for the Right Spot: Minimum Parking Requirements and Housing Affordability in New York City. Fuhrman Center for Real Estate and Urban Policy, NYU. (March)
BRAZIL (SAO PAULO)	*The first city to completely do away with minimum parking is Sao Paulo (ITDP, 2014)*	There are zero new developments in Sao Paulo that will have a minimum parking requirement.	(ITDP, 2014) New Sao Paulo Master Plan Promotes Sustainable Growth, Eliminates Parking Minimums Citywide, ITDP Transport Matters Blog, Link: https://go.itdp.org/pages/viewpage.action?pageId=60294380
INTERNATIONAL	*Cities can achieve 10-15percent in carbon and energy savings by optimizing the flow of vehicle traffic (LBNL, 2012)*	Cities can achieve 10 to 15 percent savings in energy and CO_2 emissions by optimizing the flow of vehicle traffic. Controlling the number of automobile licenses could achieve even greater savings.	(LBNL, 2012) Zhou, Nan; Price, Lynn; Fridley, David; Ohshita, Stephanie; Khanna, Nina. LBNL, November 2012, "Strategies for Local Low-Carbon Development."
U.S. (SALT LAKE CITY, UTAH)	*Economic benefits of congestion pricing in Salt Lake City (Brown, 2014)*	Using TREDIS economic impact software, Brown's firm tested what congestion pricing could do for Utah's Wasatch Front in 2040 compared to the region's 2040 plan. The accumulated result over 25 years (2015-2040) was approximately $50 billion worth of societal benefit, $12 billion in higher Gross Regional Product and 17,000 permanent jobs.	(Brown, 2014) Brown, Michael, 2014, "Who Wants to Be a Billionaire? Embrace Congestion Pricing."

Location	Description	Numerical Result/Graphic	Source
US (NEW YORK CITY, NEW YORK)	*Quality of life, economic, and safety benefits due to New York City public space improvements (Gehl ND)*	• 29 percent raise in land value while the rest of NY dropped by 6.5 to 35 percent • 11 percent increase in pedestrian numbers • 63 percent decrease in injuries • 35 percent decrease in pedestrian injuries • 74 percent say Times Square has improved dramatically • 17 percent improvements in travel time	(Gehl Architects, ND) Gehl Architects, "Learning from New York Pilot Projects."
U.S.	*Congestion costs of the U.S. in 2012 (Schrank et al., 2013)*	*Figure 28. Costs of Congestion for the United States in 2012* (table below)	(Schrank et al., 2012) Schrank, David; Eisele, Bill, Lomax, Tim, December 2012, "[Texas Transportation Institute's 2012 Urban Mobility Report: Powered by INRIX Traffic Data]()."

Figure 28. Costs of Congestion for the United States in 2012

Measures of…	1982	2000	2005	2010	2011
… Individual Congestion					
Yearly delay per auto commuter (hours)	16	39	43	38	38
Travel Time Index	1.07	1.19	1.23	1.18	1.18
Planning Time Index (Freeway only)	--	--	--	--	3.09
"Wasted" fuel per auto commuter (gallons)	8	19	23	19	19
CO_2 per auto commuter during congestion (lbs)	160	388	451	376	380
Congestion cost per auto commuter (2011 dollars)	$342	$795	$924	$810	$818
… The Nation's Congestion Problem					
Travel delay (billion hours)	1.1	4.5	5.9	5.5	5.5
"Wasted" fuel (billion gallons)	0.5	2.4	3.2	2.9	2.9
CO_2 produced during congestion (billions of lbs)	10	47	62	56	56
Truck congestion cost (billions of 2011 dollars)	--	--	--	$27	$27
Congestion cost (billions of 2011 dollars)	$24	$94	$128	$120	$121
… The Effect of Some Solutions					
Yearly travel delay saved by:					
Operational treatments (million hours)	9	215	368	370	374
Public transportation (million hours)	409	774	869	856	865
Yearly congestion costs saved by:					
Operational treatments (billions of 2011$)	$0.2	$3.6	$7.3	$8.3	$8.5
Public transportation (billions of 2011$)	$8.0	$14.0	$18.5	$20.2	$20.8

Yearly delay per auto commuter – The extra time spent traveling at congested speeds rather than free-flow speeds by private vehicle drivers and passengers who typically travel in the peak periods.
Travel Time Index (TTI) – The ratio of travel time in the peak period to travel time at free-flow conditions. A Travel Time Index of 1.30 indicates a 20-minute free-flow trip takes 26 minutes in the peak period.
Commuter Stress Index – The ratio of travel time for the peak direction to travel time at free-flow conditions. A TTI calculation for only the most congested direction in both peak periods.
Planning Time Index (PTI) – The ratio of travel time on the worst day of the month to travel time at free-flow conditions. A Planning Time Index of 1.80 indicates a traveler should plan for 36 minutes for a trip that takes 20 minutes in free-flow conditions (20 minutes x 1.80 = 36 minutes). The Planning Time Index is only computed for freeways only; it does not include arterials.
Wasted fuel – Extra fuel consumed during congested travel.
CO_2 per auto commuter during congestion –The extra CO_2 emitted at congested speeds rather than free-flow speed by private vehicle drivers and passenger who typically travel in the peak periods.
Congestion cost – The yearly value of delay time and wasted fuel.

Appendix 1. Better urban form offers economic, energy and environmental benefits (Calthorpe, 2011)

Figure 29. Housing, Transportation and Other Costs Based on Location

Neighborhood	Units	Russian Hill	Rockridge	San Ramon
Annual carbon (transportation + heat)	Mt of CO_2	6	10	21
Land	Acres per 100 units housing	2	7	30
Household vehicle miles traveled	Miles/year	7,300	12,200	30,000
Walk score	Index from 0-100	98	74	46
Property Value	$/SQ FT	550	420	320
Transportation Costs**	$/Day/Household	$20.6	$35.2	$42
Housing Cost as Percentage of Income*	%	27%	25%	41%
Transportation Cost as Percentage of Income*	%	12%	16%	203%
Housing + Transportation Cost	%	39	41	61

*Housing and transportation cost as percentage of income estimates for Russian Hill are based on an average for San Francisco and the estimates for Rockridge are based on an average of Oakland. The percentages were obtained from: http://htaindex.cnt.org/map/

**Transportation costs are based on the Transportation tool created by Abogo. The tool can be found at http://abogo.cnt.org

Data other than housing and transportation from: Peter Calthorpe. 2011. Urbanism in the Age of Climate Change (Plate 10.)

Appendix 2: A typology of the benefits and costs of compact development (OECD, 2011)

The OECD's Working Party on Territorial Policy in Urban Areas released an excellent review and synthesis of the science on compact cities in 2011. It included the following typologies of the positive and negative impacts due to a more compact – denser, less sprawling – urban development pattern. Some costs are avoidable. For example, done badly, compact and dense development can lead to congestion. This happens if the vast majority of people are forced into their cars to carry out their daily activities. It is also true that density helps make larger infrastructure investments more effective by increasing the intensity of their use.

The Benefits of Compact

Figure 30. The Contribution of the Compact City to Urban Sustainability

Sub-characteristics of the Compact City	Contribution to Urban Sustainability		
	Environmental Benefits	**Social Benefits**	**Economic Benefits**
Shorter intra-urban travel distances	• Fewer CO_2 emissions • Less pollution from automobiles	• Greater accessibility due to lower cost	• Higher productivity due to shorter travel time for workers
Less automobile dependency	• Fewer CO_2 emissions • Less pollution from automobiles	• Lower transport costs • Higher mobility for people without access to a car • Improved human health due to more cycling and walking	• Development of green jobs and technologies
More district-wide energy utilization and local energy generation	• Less energy consumption per capita, fewer CO_2 emissions		• Development of green jobs/technologies • More energy independence
Optimum use of land resources and more opportunity for urban-rural linkage	• Conservation of farmlands and natural biodiversity • Fewer CO_2 emissions due to shorter food travel mileage	• Higher quality of life due to more recreational activities	• Rural economic development (urban agricultural, renewable energy, etc.)
More efficient public service delivery		• Public service level for social welfare maintained by	• Lower infrastructure investments and cost of maintenance

		improved efficiency	
Better access to diverse local services and jobs		• Higher quality of life due to access to local services (shops, hospitals, etc.)	• Skilled labor force attracted by high quality of life • Greater productivity due to more diversity, vitality, innovation, and creativity

Potential Costs of Compact Cities

Figure 31. Potential Adverse Effects of Compact Cities

Environmental	Social	Economic
• High air pollution levels caused by traffic congestion; • High energy demands in densely built-up areas; • Increase in energy consumption caused by urban heat island effects; • Vulnerability to natural disasters.	• Housing affordability; • Loss of open and recreational spaces; • Reduced sense of privacy and personal security due to high density; • Anxiety and social withdrawal due to high density.	• Economic cost and loss of productivity due to traffic congestion; • Reduced business opportunities and competitiveness due to constraints on land use and high land prices.

Source: Adapted from Churchman, A. (1999)