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Determining Optimal Urban Expansion, Population and Vehicle Density, and Housing Types for Rapidly Growing Cities

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Abstract

This study examines the economic, social and environmental impacts of various urban development factors including urban expansion, population and vehicle density, housing type, roadway design and management, and recreation facility availability. The results are used to create guidelines for urban development that optimizes for various planning objectives including openspace (farmland and habitat) preservation, efficient public infrastructure and services, public health and safety, efficient transportation, affordability, economic productivity and opportunity, and urban livability (local environmental quality). This analysis indicates that in geographically unconstrained cities, optimal densities can range from 20-40 residents per hectare, optimal vehicle ownership can range from 300-400 vehicles per 1,000 residents, and a majority of housing can be single-family, but as urban expansion is constrained, optimal densities increase, optimal vehicle ownership rates decline, and a greater share of housing should be multi-family. To be efficient and equitable, cities should provide diverse housing and transport options which respond to consumer demands, particularly affordable housing in accessible, multimodal neighborhoods, and affordable travel modes, with pricing or roadway management that favor resource-efficient modes, plus convenient access to parks and recreational facilities. Various Smart Growth and Transportation Demand Management (TDM) policies can help achieve these targets.

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Keywords: Urban Development; City Planning; Density; Smart Growth; Sprawl

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1. Introduction: responding to rapid urbanization

The world is experiencing rapid urbanization. Between 1950 and 2050 the human population is projected to approximately quadruple and shift from 80% rural to nearly 80% urban (UN 2011). Most of this growth is occurring in developing countries, resulting in approximately 2.2 billion new urban residents in developing countries between 2015 and 2050. How cities accommodate these new residents has huge economic, social and environmental impacts. It is important that urban development policies maximize the benefits and minimize the costs in order to leave a sustainable legacy for future generations.

Nomenclature

A	*Accessibility* – The ability to reach desired services and activities, typically measured by travel time and money costs.
C	*Connectivity* – The density of connections in a sidewalk, path and roadway network
B	*Density* – The number of people, jobs or housing units per land unit (acres, hectares, square kilometers or miles)
D	*Development mix* – The degree that different land uses, building types, and social classes locate close together
E	*Smart Growth* – A set of development policies and practices that create compact, mixed, multimodal communities.
F	*Sprawl* – Lower-density, urban-fringe, automobile-oriented development.

Various studies have investigated the economic, social and environmental impacts (costs and benefits) associated with various land use development patterns (Angel 2011; Burchell and Mukherji 2003; Litman 2014). Early studies considered a relatively narrow set of factors and impacts, such as how development density affects public infrastructure costs or various environmental impacts. Over time the scope of land use factors and impacts has expanded (Ewing and Hamidi 2014). This is often framed as the *costs of sprawl* and the benefits of *Smart Growth* development policies, as summarized in Table 1.

Table 1. Sprawl-inducing versus Smart Growth development policies (SGN 2011).

Sprawl Inducing	Smart Growth
Little coordination between development policies by different jurisdictions and government agencies	Strategic planning which coordinates development (e.g., encourages compact development along frequent transit routes)
Limits on development density and mix	Reduced restrictions on development density and mix
Transport planning and investment practices that favor automobile travel and give little value to other modes	Multimodal transport planning and funding. Transportation demand management programs implemented when cost effective
High minimum parking requirements	Reduced and more flexible parking requirements
Infrastructure (roads, water, sewage, etc.) that favors greenfield development	Infrastructure development that favors infill development
Development fees and taxes that fail to reflect the higher costs of providing public services to more dispersed development	Lower development fees and taxes for infill development, reflecting the lower costs of providing public services in those areas
Housing policies and programs that favor lower-density single-family housing over more compact housing types	Housing policies that favor accessible-affordable housing development (affordable housing built in accessible locations)

This table compares policies and planning practices which encourage sprawl and Smart Growth.

This study uses that research to develop practical guidance for urban development policies that optimize for multiple economic, social and environmental objectives. It evaluates how various factors including urban expansion, population and vehicle density, housing type, roadway design and management, vehicle parking supply and recreation facility availability affect various planning objectives including openspace (farmland and habitat) preservation, consumer demands, efficient public services, public health and safety, efficient transport, affordability, economic productivity and opportunity, energy conservation and emission reductions, and urban livability (local environmental quality). The results should be of interest to anybody involved in strategic urban planning.

2. Data and Measurement Challenges

This type of analysis is challenging due to inconsistent and inadequate data. For example, a key attribute such as urban density can be measured in several different ways:

- *What is measured:* residents, residents plus employees, dwelling units (du) or floor area.
- *Land area units:* acre, hectare, square mile or kilometer.
- *Geographic scale:* parcel (just the land that is developed), neighborhood (including local streets, schools, parks, etc.), or region (including industrial areas and regional open space). Residential parcels typically represent 70-80% of neighborhood and 40-60% of regional land area (Angel 2011).

Table 2 compares how 10 dwelling units per parcel acre would be measured using various units.

Table 2. Comparing different ways to measure 10 dwelling units per residential acre.

	Parcel	**Neighborhood**	**Region**
	Residential land only	*All land in a neighborhood, including streets, schools, local parks, etc.*	*All land in a region including industrial areas and open space*
Residential land/total Land	1.0	0.75	0.5
Dwelling units per acre	10.0	7.5	5.0
Residents per acre	25.0	18.8	12.50
Dwelling units per hectare	24.7	18.5	12.4
Residents per hectare	61.8	46.3	30.9
Residents per square-mile	16,000	12,000	8,000
Residents per square-kilometer	6,178	4,633	3,089

This table shows various equivalencies for 10 dwelling units per residential parcel acre. It is important to use consistent units and measurement methods when comparing densities.

Similarly, transportation data are often inadequate, outdated or unclear. For example, many jurisdictions lack reliable data on how and how much residents travel, vehicle ownership, and traffic volume. Definitions of cars, trucks, buses and motorcycles may vary between jurisdictions. In recent years, some international organizations have started to standardize planning data definitions and collection methods (SLoCaT 2010), but there is still consideration variation, which is important to consider when comparing data from different jurisdictions.

Inadequate data are often a constraint to good planning, evaluation and research. As cities develop and become more affluent it will be important to establish comprehensive data collection programs.

3. Planning Principles

This analysis reflects the following basic planning principles (ADB 2009; Litman 2012).

3.1. Strategic planning

A key planning principle is that individual, short-term decisions should reflect strategic, long-term goals. This is sometimes called *sustainability planning* or simply *comprehensive strategic planning*. Figure 3 summarizes examples of urban planning goals.

Table 3. Typical urban planning strategic planning goals.

Economic	**Social**	**Environmental**
Efficiency and accessibility (minimal money and time costs)	Public health and safety	Openspace (farmland and natural habitat) preservation
Efficient public infrastructure and services	Social equity (the distribution of costs and benefits is considered fair)	Resource (energy) conservation
Supports industry	Economic opportunity for disadvantaged groups	Reduced pollution emissions

Most cities have various economic, social and environmental goals that land use policies should help achieve.

3.2. Consumer sovereignty (responding to consumer demands)

Consumer sovereignty means that markets respond to consumer demands. This has important implications for urban planning: in most cities, it is easy to find expensive housing and lower-priced housing in undesirable locations but often difficult to find *affordable-accessible housing* (lower-price housing in accessible, multimodal neighborhoods). Similarly, in most cities, driving is relatively convenient and comfortable (although congested during peak periods), but other modes are less efficient and uncomfortable to use. Improving affordable housing and travel options tends to increase consumer sovereignty, which increases consumer welfare and is particularly important for physically and economically disadvantaged people who rely on such modes.

For this reason, efficient and equitable cities should provide diverse housing types and prices, including larger units for extended families, and flexible-use lofts for households that need studio or work space, located in accessible, multimodal neighborhoods. Lower-priced housing should be dispersed around the city to avoid concentrating poverty. In some cities, affordable housing policies may include formalizing informal settlements, or making small parcels of serviced land available for owners to build houses. In most cities, most affordable housing consists of low-rise (4-6 story) apartments built by private developers, but in constrained cities governments may need to subsidize high-rise apartments for lower-income households.

Similarly, an efficient and equitable transportation system should be diverse, including good walking and cycling conditions, efficient public transit and taxi services, car- and bike-sharing services, and delivery services, so travelers, including those who are physically or economically disadvantaged, can choose the most efficient mode for each trip. This supports *complete streets* policies, which ensure that roadways accommodate diverse users and uses.

3.3. Cost-based pricing

Economic efficiency requires that prices (what users pay to consume a good) reflect marginal costs (the total incremental costs imposed by that consumption) unless subsidies are specifically justified. Several planning and market distortions tend to underprice automobile travel and sprawl, including road and vehicle parking facilities not financed through user fees, and uncompensated traffic congestion, accident and pollution damages, plus various costs of sprawl. With more efficient pricing, motor vehicle travel would cost more than it does now, resulting in less driving and sprawl, and lower total costs. Public transit subsidies are often justified, in part, as a second-best solution to automobile underpricing (for example, to reduce traffic and parking congestion), but more efficient pricing of automobile travel and sprawl are most efficient overall.

4. Analysis Framework

This analysis starts by identifying basic physical impacts of sprawl, which include increases in the amount of land developed per capita, and by dispersing destinations, it reduces accessibility and increases total motor vehicle travel, as illustrated in Figure 1. Although individual factors often seem to have modest impacts, their effects are cumulative and synergistic (total impacts are often greater than the sum of individual impacts). For example, by itself a 10% increase in density typically only reduces vehicle travel by 0.5-4%. However, an integrated set of Smart Growth policies that include significant increases in development density and mix, path and roadway connectivity, more infill development, reduced parking supply, more efficient road and parking pricing, improved walking and cycling conditions, and improved public transit services can reduce per capita land consumption 60-80% and motor vehicle travel by 20-60% compared with sprawled development (CARB 2010-2015).

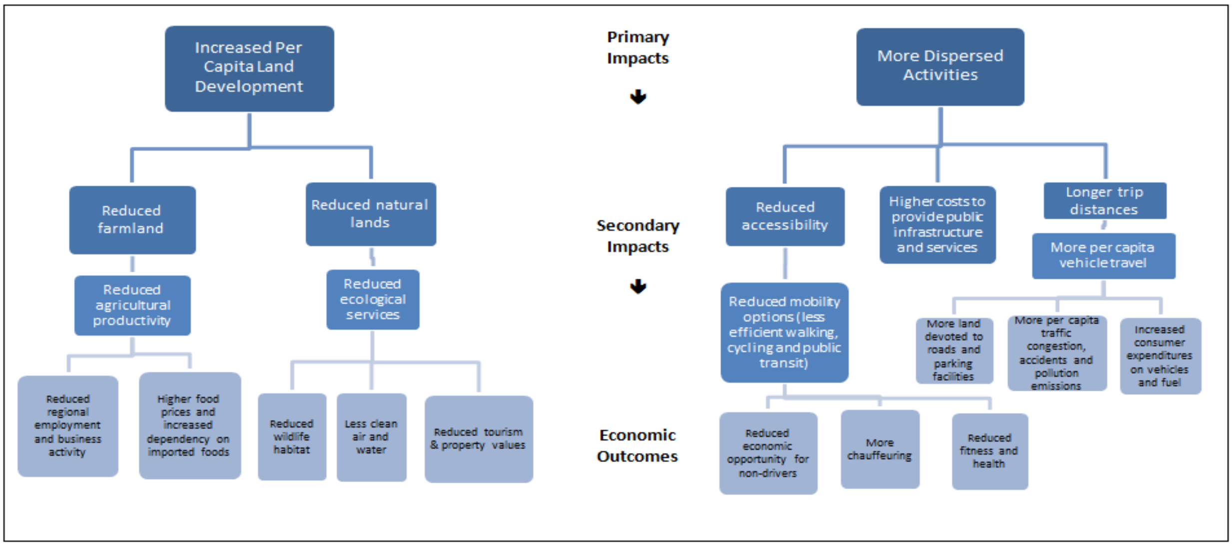

Fig. 1. *Sprawl has two primary resource impacts: it increases per capita land development, and by dispersing destinations, it increases total vehicle travel. These have various economic, social and environmental costs. This figure illustrates these impacts. (Litman 2014)*

These changes in resource consumption have various economic impacts. Tracking these impacts provides a theoretical foundation for understanding outcomes. For example, by displacing farmlands and natural lands sprawl reduces agricultural and ecological production. To the degree that it disperses destinations, it increases the costs of providing public infrastructure and services. By reducing accessibility, it increases various transportation costs including per capita road and parking infrastructure requirements, vehicle costs, total congestion costs, accidents and pollution emissions. To the degree it degrades walking and cycling conditions, and reduces public transit services, it is particularly burdensome to non-drivers. By increasing expenditures on imported goods (particularly vehicles and fuel), it tends to reduce economic productivity. These, in turn, have economic outcomes including reduced employment, productivity, and economic opportunity, plus increased costs to households and businesses.

Sprawl also provides benefits, but these are mostly direct internal benefits to sprawled community residents such as larger gardens with more privacy; there is little reason to expect sprawl to provide significant external benefits, that is, most people who live elsewhere do not benefit if a region has more sprawled rather than Smart Growth development.

5. Impact Categories

5.1. Openspace preservation

Land is a valuable and scarce resource, particularly in urban areas. In addition to its direct benefits to owners, open space provides various external benefits to society (McConnel and Walls 2005). Undeveloped natural lands such as shorelines, forests and deserts tend to provide the greatest ecological benefits, including wildlife habitat, groundwater recharge and aesthetic values. Farms provide agricultural productivity. Gardens and lawns tend to support fewer wildlife species and usually have significant fertilizer and pesticide contamination. Impervious surfaces such as buildings, parking lots and roadways provide the least environmental benefits: they increase stormwater management costs and heat island effects (they absorb sunlight which increases ambient temperatures).

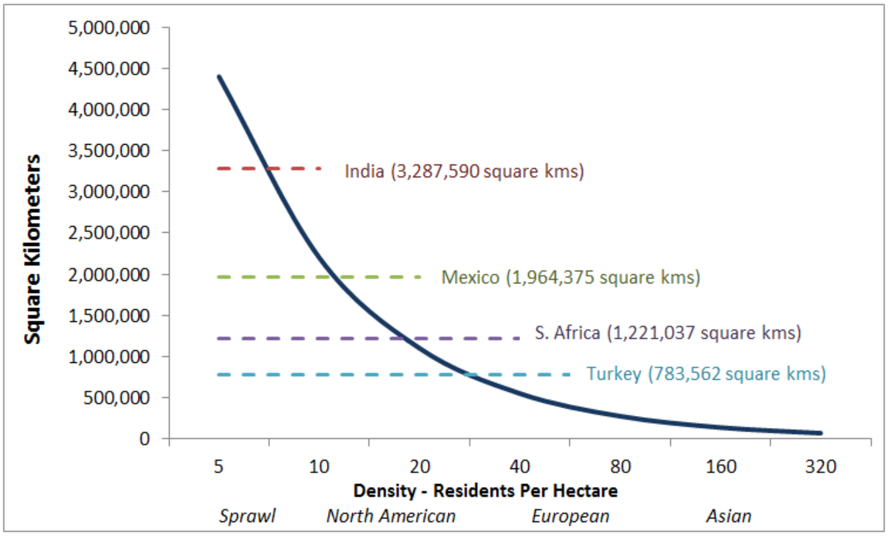

Fig. 2. *At sprawled densities, housing 2.2 billion new urban residents requires more land than the total area of India. Smart Growth policies can reduce development area, leaving more land for farms and other openspace.*

By favoring lower density housing types and increasing per capita motor vehicle ownership and use which increases per capita road and parking facility land requirements, sprawl increases per capita impervious surface areas. Smart growth results in more intense development which reduces land consumption per capita but increases impacts per hectare of urban land developed.

Sprawl significantly increases per capita land consumption. For example, at 5 residents per hectare, which is typical for North American suburbs, each resident uses an order of magnitude more land than in European cities with 50 residents per hectare, and two orders of magnitude more land than residents of high-density Asian cities (Figure 2). Total impacts can be significant. For example, at typical sprawl densities of 5 residents per hectare, the 2.2 billion new urban residents expected in developing countries would require 4,400,000 square kilometers, which is more than the area of India, but at Smart Growth densities of 50 residents per hectare they only require 440,000 sq. kms.

This analysis indicates that very high population densities are not necessary to achieve significant openspace preservation objectives. For example, increasing from 5 to 25 residents per hectare reduces per capita land consumption by 80%, yet still allows all residents to live in single-family homes in quarter-acre lots, and even 50 residents per hectare allows most households to occupy single-family homes, yet reduces land consumption by 90% compared with low-density sprawl.

5.2. Efficient public infrastructure and services

Dispersed development tends to increase the lengths of roads and utility lines (water, power, etc.), and the travel distances needed to provide public services (garbage collection, emergency services, etc.), as illustrated in Figure 3. Rural residents tend to accept lower quality services (unpaved roads, slower emergency response, etc.) and provide many of their own services (well water, septic systems, etc.), but suburban development tends to attract residents who demand urban quality services in dispersed locations, which increases government costs (Stantec 2013).

These relationships are complex. Infill development can increase some costs due to higher design standards and more infrastructure development costs, but are not significantly related to development density: a tall building has similar utility connection and brownfield remediation costs as a smaller building. Credible studies indicate that sprawl typically increases the net costs of providing a given level of infrastructure and public services by 10-40%, and sometimes more (de Duren and Compeán 2015; SGA 2013). This suggests that optimal development policies should encourage moderate-densities (30-80 residents per hectare) along major utility corridors.

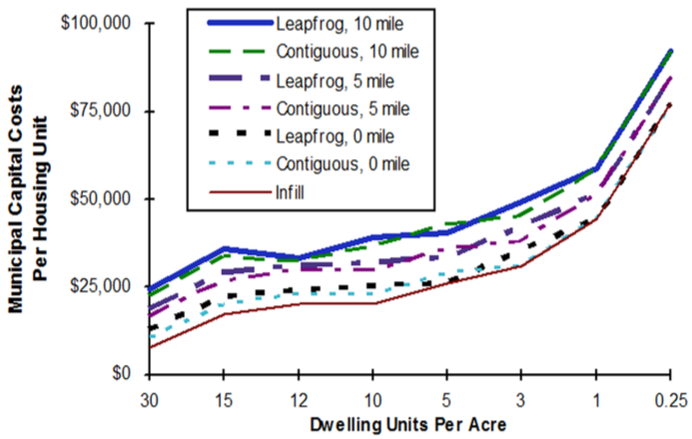

Fig. 3. *The costs of providing public infrastructure, including roads, utilities and schools, tends to be much lower for compact, infill development, providing hundreds of dollars in annual savings per capita compared with sprawl. (Frank 1989)*

5.3. Efficient transportation

How planners define and evaluate transportation efficiency is changing (ADB 2009; Boarnet 2015). The old paradigm evaluated transport system performance based primarily on *mobility*, particularly motor vehicle travel. The new paradigm recognizes that mobility is seldom an end in itself; the ultimate goal of most transport activity is *accessibility*, which refers to people's ability to reach desired services and activities. This expands the range of factors considered in transport planning to include transport network connectivity and land use factors, and recognizes that planning decisions often involve trade-offs between various accessibility factors, for example, roadway expansions improve automobile access but often degrade walking and cycling conditions.

Table 4. Factors affecting accessibility

Mobility	Transport Network Connectivity	Land Use
Automobile travel speeds and affordability Transit service coverage, quality and affordability Walking and cycling conditions	Path and road connectivity (intersection density) Quality of connections between modes, such as walking and cycling access to transit stations	Development density and mix Centricity (degree that activities are located close to an urban center) Vehicle parking supply and price

Various factors affect accessibility, including transport, transport network connectivity and land use patterns.

The old paradigm assumed that the primary transport planning goal is to maximize motor vehicle travel speeds, and so evaluated urban transport system performance using indicators such as average traffic speeds and roadway level-of-service. From this perspective, congestion is the primary urban transport problem and roadway expansion is the preferred solution. The new paradigm expands the scope of modes, objectives and impacts considered in transport planning. This tends to justify policies and planning practices that favor walking, cycling and public transit over automobile travel, particularly in urban areas, because they are more resource-efficient – they cost less to use, require less space, and impose less risk and pollution costs on other, so use of these modes increases transport system efficiency compared with driving. Where such policies are implemented, residents can meet their accessibility needs with 20-60% fewer annual kilometers than in sprawled, automobile-dependent areas (CARB 2012-2015; Ewing and Cervero 2010; JICA 2011).

This indicates that efficiency and equity require a diverse transport system, and incentives that encourage travelers to use resource-efficient modes, with good walking and cycling conditions; bike- and car-sharing services; complete streets policies; efficient road and parking pricing; commute trip reduction and mobility management marketing programs; plus HOV, bus and freight lanes. More diverse and efficient transportation systems can provide many savings and benefits, including congestion reductions, facility cost savings, consumer savings and affordability, increased safety, pollution reductions, improved mobility for non-drivers (and therefore reduced chauffeuring burdens), plus improved public fitness and health. Most alternative modes experience economies of scale (more users reduce costs per passenger-trip and justify more service), so policies that encourage their use increase their operating efficiency. Smart Growth tends to have mixed congestion impacts: it tends to increase congestion *intensity* (the reduction in traffic speeds experienced by motorists during peak periods), but by reducing auto mode share and trip lengths, it tends to reduce per capita congestion costs (Kuzmyak 2012). Policies and planning practices intended to increase transport system efficiency are called *Transportation Demand Management* (TDM), as summarized in Table 5.

Table 5. Transportation demand management strategies (VTPI 2015)

Improve Transport Options	**Efficient Option incentives**	**Land Use Policies**	**Programs**
Walking and cycling improvements	Efficient road and parking pricing	Smart Growth policies	Commute trip reduction
Public transit improvements	Roadway management that favors resource-efficient modes	Transit-oriented development	School transport management
Car- and bike-sharing	Mobility management marketing	Efficient parking management and pricing	Transportation management associations

Transportation demand management includes various strategies that increase transport system efficiency.

Many of these strategies have synergistic effects; they are most efficient if implemented together. For example, public transit improvements tend to be most effective if implemented with transit-oriented development policies which result in compact development (typically at least 30 residents or employees per hectare) near high quality transit stops and stations, plus good walking and cycling conditions, and mixed development so most common services (shops, restaurants, parks, schools, etc.) are located within convenient walking distance, creating a multimodal *urban villages* that provide a high level of accessibility, particularly for non-drivers.

Because urban automobile travel has many indirect and external costs, efficient transport system management can provide large total benefits. For example, more efficient road and parking pricing not only reduce traffic and parking congestion problems, they also tend to reduce traffic accidents and pollution emissions. Similarly, improving walking, cycling and public transit can provide a variety of benefits (traffic and parking congestion reductions, infrastructure cost savings, consumer savings and affordability, improved mobility for non-drivers, increased safety and health, energy conservation and emission reductions), all of which should be considered when evaluating transport system efficiency. Conventional planning tends to consider a limited set of these impacts, typically focusing on traffic congestion as well as vehicle operating and accident costs, but ignoring parking costs, vehicle ownership costs, the mobility needs of non-drivers, and public health impacts. As a result, conventional planning often results in economically excessive road and parking supply, underinvestment in alternative modes, underpricing, and excessive sprawl.

5.4. Efficient roads and parking facilities

Cities should expand systematically along major roads and transit corridors (Angel 2011; UN-Habitat 2013). Cities need sufficient road and parking supply, which typically requires a network of major arterial roadways spaced 500 to 1,000 meters apart, and 10-25% of urban land dedicated to road rights-of-way. Roads should be designed and managed using *complete streets* principles, which ensure that roadways accommodate diverse uses and users, including walking, cycling, automobile and public transit travel, plus, areas where commercial activities occur such as roadside shops. This requires limiting traffic speeds to what is safe for all road users.

An important factor in urban transportation efficiency is the degree of network connectivity. More connected paths and roads, with higher intersection density (more than 60 per square kilometer), shorter blocks (less than 200 meters), and fewer dead-end links (less than 20% of total road links), provides more direct connections between activities, and so reduces travel distances (Handy, Paterson and Butler 2004).

Roads should be managed to favor higher value trips and more space-efficient modes through congestion pricing (road tolls and parking fees that are higher under congested conditions) or special lanes for high occupancy and freight vehicles. Dedicated bus lanes are particularly effective if implemented in conjunction with other pro-transit policies which maximize ridership and, therefore, total benefits.

Cities also need a sufficient vehicle parking supply. Both on- and off-street parking should be efficiently priced, with higher rates during congested periods. Some cities require motorists to have an off-street parking space in order to register a vehicle to prevent them from parking overnight on public streets and limit automobile ownership.

5.5. Public safety, health and security

Although traffic casualty (injury and death) rates tend to decline as cities develop and improve their roads, vehicles and safety programs, among affluent cities various studies using a variety of analysis methods and data sets indicate that those that are sprawled have far higher rates than those that are compact and multimodal (Dumbaugh and Rae 2009; Ewing and Hamidi 2014). This probably results from more per capita vehicle travel, higher traffic speeds and more high risk (youth, senior and impaired) driving due to inadequate alternatives. Very low crash traffic casualty rates (under 5 annual fatalities per 100,000 residents) generally require a combination of smart growth and transportation demand management, as indicated in Figure 4.

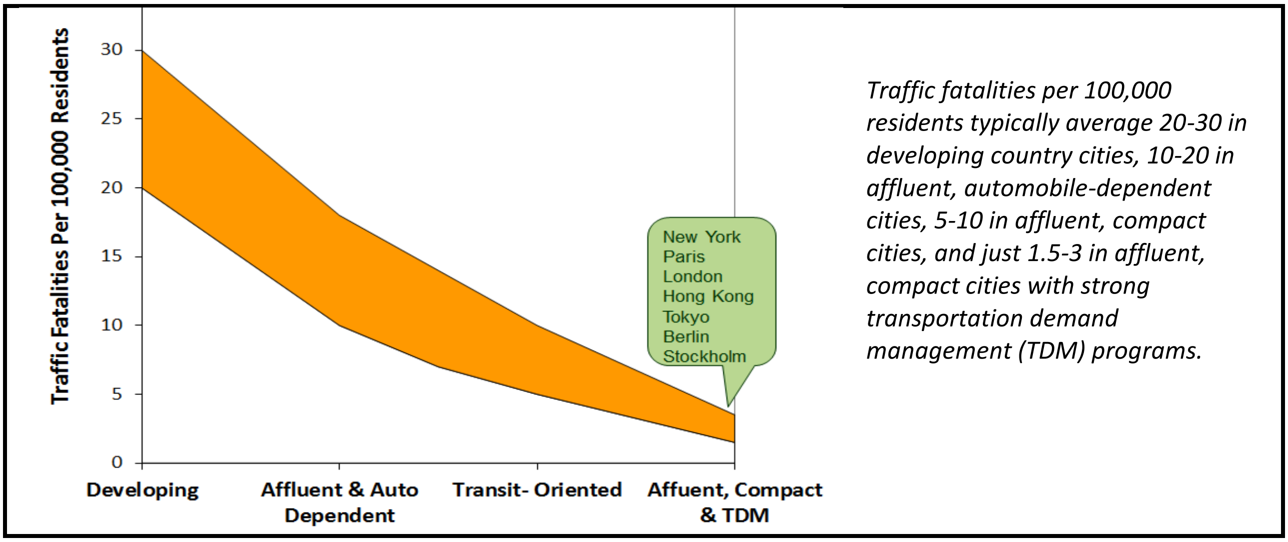

Fig. 4. *Although traffic fatality rates tend to decline as cities develop and improve their roads, vehicles and traffic safety programs, affluent, Sprawled cities have far higher fatality rates than compact cities that implement transportation demand management policies. (Litman 2014)*

Public health experts are increasingly concerned about the health risks associated with sedentary (i.e., lack of physical activity) lifestyles (WHO 2013). Although there are many possible ways to exercise, one of the most effective ways to increase physical fitness by at-risk people (people who are sedentary and overweight) is to improve active transport (walking and cycling) conditions. A ten-year study found that the overall health of residents improved when they moved to more compact, walkable urban neighborhoods (Giles-Corti, et al. 2013). Ewing and Hamidi (2014) found a significant, positive correlation between smart growth and longevity: each 10% increase in their compactness index is associated with a 0.4% increase in lifespans. However, increased urban densities can increase some health risks such as exposure to noise and local air pollutants.

People sometimes assume that denser urban neighborhoods have higher crime rates (less security), but this reflects the confounding effects of concentrated poverty in urban areas, and the relative affluence of suburban communities. This does not mean that compact urban development *causes* higher crime or that sprawl reduces it; on the contrary, all else being equal, per capita crime rates tend to decline with urban density and mix. For example, after adjusting for socioeconomic factors such as age, employment status and income, Browning, et al. (2010) found that per capita violent crime rates decline with density in Columbus, Ohio urban neighborhoods, particularly in the most economically disadvantaged area. Similarly, after adjusting for socioeconomic factors, Christens and Speer (2005) found a significant negative relationship between census block population density and per capita violent crime rates in Nashville, Tennessee and nearby suburban communities. Hillier and Sahbaz (2006) found that, all else being equal, crime rates were inversely related to the number and density of dwellings on a street. For example, grid street segments with more than 50 dwellings had a burglary rate of 0.142, but those with 100 dwellings have a much lower rate of 0.086. The researchers conclude that crime risk tends to decline on streets that have more through traffic, and more commercial and residential buildings located close together.

This suggests that smart growth strategies that create communities where residents drive less and rely more on active modes, plus targeted strategies to reduce noise and air pollution tend to increase safety, health and security.

5.6. Affordability

Affordability refers to households' ability to afford essential goods including food, housing and transport. Affordability is often defined as households spending less than 30% of income on housing, or less than 45% of income on housing and transport combined (CNT 2013). Smart Growth can increase affordability in some ways and reduce it in others (Table 6). It tends to increase land prices per hectare, but reduces land required per housing unit, and it can reduce transport and public service costs. Mid-rise (two to six story) wood frame housing in accessible, multi-modal neighborhoods tends to be most affordable overall by minimizing land, construction and transport costs, and avoiding the need for elevators (http://missingmiddlehousing.com). High-rise, concrete buildings cost more to construct and operate, but require less land per unit and so become cost-effective in high land price areas.

Table 6. Smart Growth household affordability impacts.

Reduces affordability	**Increases Affordability**
• Increases land unit costs (per square meter). • Increases some infrastructure requirements (curbs, sidewalks, sound barriers, etc.).	• Reduces land use per housing unit • More compact and affordable housing types • Reduces parking requirements and costs. • Reduces transport costs • Reduces infrastructure and utility costs.

Some Smart Growth policies reduce affordability, others increase it, so overall impacts depend on the combination of policies implemented.

Some recent studies have investigated how sprawl affects household affordability in developing countries (Adaku 2014; Aribigbola 2011; JICA 2011). Isalou, Litman and Shahmoradi (2014) found that in Qom City, Iran, suburban-area households spend more than 57% of their monthly income on housing and transport, significantly more than the 45% spent by households in the central district, and more than is considered affordable.

5.7. Social equity objectives

Social equity refers to the distribution of impacts (benefits and costs), and the degree that this is considered fair and appropriate. Development patterns can have various social equity impacts:

- To the degree that motor vehicle travel and sprawled development are underpriced (for example, motorists are not charged marginal costs of road and parking facilities, congestion, accident risk and pollution costs their vehicles impose on others, or central neighborhood residents cross-subsidize the costs of providing public services to urban fringe locations), more compact, multimodal development tends to increase horizontal equity.
- Improving affordable travel options (walking, cycling, public transit and ridesharing), *universal design* (transport systems designed to accommodate all users, including people with mobility impairments) and more affordable-accessible housing tend to benefit disadvantaged people, which increases vertically equity.
- Smart Growth policies can have mixed affordability impacts. As previously described, they tend to increase compact housing options (such as townhouses and apartments with unbundled parking) and reduce household transport costs, but increase the costs of large-lot single-family housing; overall, this benefits some households (those that prefer affordable-accessible housing) but can harm others (those that prefer larger-lot housing and automobile travel).

For social equity sake, cities should encourage development of diverse affordable housing and transport options, and apply universal design practices to ensure that buildings and transport systems accommodate all potential users.

5.8. Energy conservation and emission reductions

Energy conservation and emission reductions provide both direct benefits (financial savings and health benefits to residents) and indirect benefits (less money leaving the local economy to import fuel, and reduced climate change.

There are many ways that cities can reduce energy consumption and pollution emissions, including policies that encourage or require more efficient buildings and vehicles, and by reducing motor vehicle travel.

More compact development tends to support these goals by reducing travel distances, supporting efficient modes (walking, cycling and public transit), reducing building heating (due to more multi-story buildings) and infrastructure energy requirements (e.g., shorter utility lines reduce embodied energy, water and sewage pumping loads, street lighting, etc.) (Ewing and Rong 2008; LSE Cities 2014). The largest impacts are caused by shifts from low to moderate densities (from under 20 to over 40 residents per hectare), and from high to moderate vehicle ownership rates (over 500 to under 300 vehicles per 1,000 residents) as indicated in Figure 5.

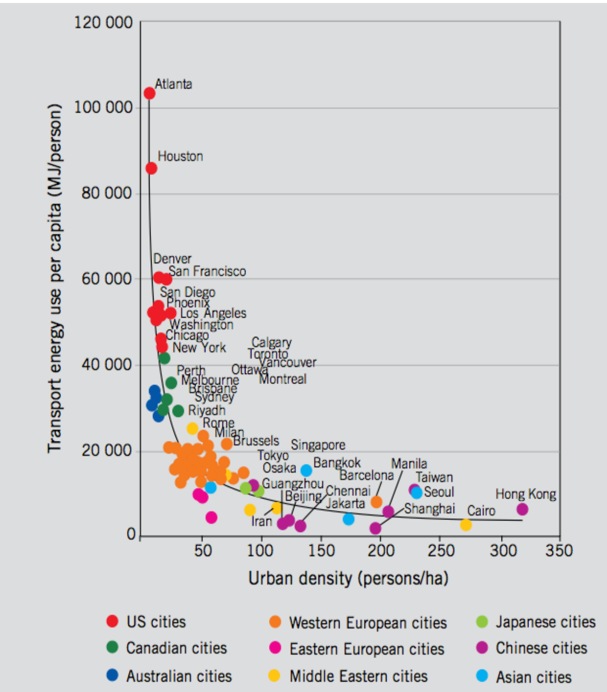

Fig. 5. *Per capita transportation energy consumption tends to decline with increased urban density. Shifts from low to moderate densities (from under 20 to over 40 residents per hectare) tend to provide large energy savings and carbon emission reductions. (Newman and Kenworthy 1999)*

5.9. Urban livability

Livability refers to local environmental quality as experienced by people who live, work or visit an area. This typically includes impacts such as exposure to noise and local air pollution; perceived safety and security; the convenience and comfort of walking and sitting; affordability; aesthetic; recreation opportunities; plus *community cohesion* (the quality of social interactions among neighbors) (FHWA 2011).

Certain urban development features can support livability. City streets can be designed to be convenient and safe for walking, cycling and sidewalk activities, with reduced traffic volumes and speeds to reduce traffic risk, noise and dust. Neighborhoods can be designed as *urban villages*, which are compact, mixed, walkable districts where most common services and activities (shops, schools, parks, etc.) are located within convenient walking distances of most houses, with the public realm (public spaces where people naturally interact, including sidewalks, parks and public institutions such as schools) designed to be attractive and encourage recreation and social interactions.

It is important for cities to have sufficient and suitable public recreation spaces, including neighborhood and regional parks, sports fields, trails and recreation centers that reflect local need and preferences. For example, some cultures prefer formal plazas and gardens, others want trails or sports fields, some (particularly cities with harsh climates or poor air quality) need indoor recreation facilities, and some prefer parks with natural landscapes, such as forests and shorelines. Most homes, particularly those with children, should have playgrounds and sports fields within a safe, ten-minute walk, plus at least 10% of the regional land area devoted to larger parks.

5.10. Variations within cities

Many optimal urban design features should vary between different districts within cities, with higher densities and transit mode share, and lower automobile ownership, mode share and parking supply in central locations than in outlying areas, as indicated in Figure 6.

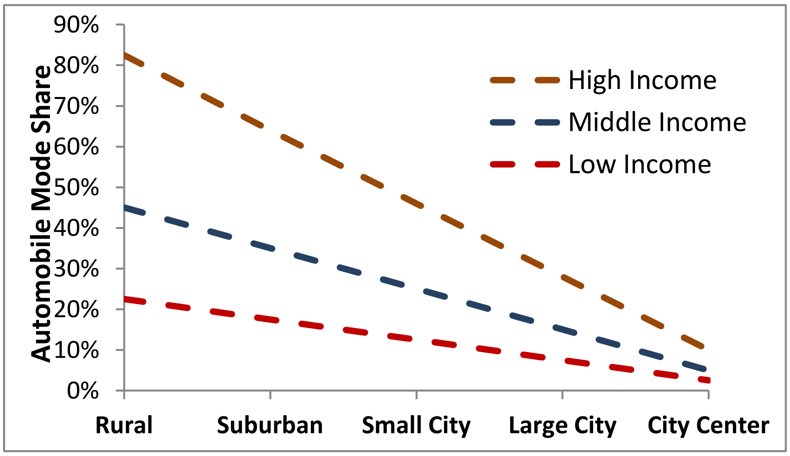

Fig. 6. *Optimal urban design features should vary between different locations, with higher densities and transit mode share, and lower automobile ownership and mode share in central locations than in suburbs.*

These features provide a basic foundation, but there is more to optimal urban design (Alexander, et al. 1977). Good urban planning strives to create complete, mixed-use neighborhoods (also called *urban villages*) in which common services and activities (healthcare services, shops, restaurants, schools, parks and recreation, etc.) demanded by residents and employees are available within convenient walking distances of most residents and worksites. Isolated and closed (gated) neighborhoods should be avoided. The public realm, including roadways and public parks, should be designed to be attractive and vibrant places, in addition to being functional. This is often described as *transit-oriented development*, with transit stations providing a catalyst for higher density, mixed use development with good walking and cycling conditions and attention to the public realm (Suzuki, Cervero and Iuchi 2013).

5.11. Summary

Cities are complex systems, so urban planning must balance various economic, social and environmental objectives. Table 7 summarizes key factors to consider when optimizing urban development policies. Because it is more resource efficient (it requires less land, infrastructure and motor vehicle travel), more accessible (travel distances are shorter) and more multimodal (it supports walking, cycling and public transit, as well as automobile travel), Smart Growth urban development tends to help achieve multiple objectives.

Table 7. Factors to consider when optimizing urban development policies.

Objective	**Optimal development policies**
Open space preservation	Encourage compact development to preserve farms and ecologically productive lands.
Efficient public infrastructure and services	Encourage moderate- to high-density development along major utility corridors.
Transport system efficiency	Encourage transit-oriented development with at least 30 residents per hectare along major transit routes.
Efficient roads	Provide a sufficient supply of well-connected paths and roads that are managed efficiently.
Safety and health	Favor compact, multimodal development with lower traffic speeds. Encourage active transport. Discourage automobile travel.
Affordability	Ensure an adequate supply of affordable transport and housing options.
Social equity	Improve affordable housing and transport options. Minimize subsidies for automobile travel.
Energy conservation and emission reductions	Encourage fuel efficient buildings and transportation.
Urban livability	Create walkable urban villages. Provide parks and recreation. Control urban vehicle traffic.

By creating more resource-efficient, accessible and multimodal communities, Smart Growth policies help achieve multiple planning objectives.

Applying these guidelines provides a foundation for creating efficient and equitable cities that protect openspace, minimize public infrastructure and service costs, provide a high level of accessibility to all residents (including those who are physically, economically and socially disadvantaged), and minimize automobile costs. Of course, good urban planning requires much more than just these features, it also requires good design, attractive public realm and effective social services that respond to community needs. Housing mix and design, the types of parks and recreation facilities provided, and roadway design and management should all reflect local demographic, economic and geographic conditions. Successful urban planning therefore requires effective public engagement which allows all community members to understand and contribute to development policies and planning decisions.

6. Criticisms

Research concerning optimal urban development policies has stimulated considerable debate. Critics argue that most households rationally prefer lower-density, single-family housing and automobile travel over alternatives, so sprawl reflects consumer sovereignty and is efficient (Cox 2015). Smart Growth advocates argue that sprawl results in part from various market and planning distortions which favor lower-density development and automobile travel, and so market-based reforms can create more economically efficient and equitable cities (Blais 2010; Lewyn and Jackson 2014), as summarized in Table 8.

Table 8. Sprawl-encouraging market distortions and Smart Growth reforms.

Distortion	Impacts	Smart Growth Market Reforms
Restrictions on density, mix, and multi-family housing	Reduces development densities and increases housing costs	Allow and encourage more compact, mixed development
High minimum parking requirements	Reduces density and increases automobile ownership and use	Eliminate minimum parking requirements. Require or encourage parking unbundling
Underpriced public services to sprawled locations	Encourages sprawl. Increases government costs	Development and utility fees that reflect the higher costs of serving sprawled locations
Tax policies that support home purchases	Encourages the purchase of larger, suburban homes	Eliminate or make neutral housing tax policies
Automobile-oriented transport planning	Favors automobile travel over other modes. Degrades walking and cycling	More neutral transport planning and funding
Transport underpricing (roads, parking, fuel, insurance, etc.)	Encourages vehicle ownership and use	More efficient pricing
Tax policies that favor automobile commuting	Encourages automobile travel over other modes	Eliminate parking tax benefits or provide equal benefits for all modes

Sprawl results, in part, from market distortions which favor lower-density development and automobile travel, so market-based Smart Growth reforms can create more economically efficient and equitable cities.

Although many of these distortions may seem to have modest impacts and are justified from some perspectives, their impacts are cumulative and synergistic (their impacts are greater when implemented together). Together, they tend to significantly increase automobile travel and land consumption beyond what households would choose if they had better housing and transport options (for example, more affordable housing in accessible, multimodal neighborhoods with good walking and cycling conditions, and convenient and comfortable public transit services). For example, charging marginal prices for using roads and parking facilities typically reduces automobile travel by 20-40%, and even more if implemented with pro-transit policies such as bus-lanes; reforms that are justified on economic efficiency and social equity principles. If all economically-justified Smart Growth reforms were implemented to the degree justified by market principles, per capita urban land use consumption and motor vehicle travel are predicted to decline by 25-50% (Litman 2014b).

7. Conclusions

The world is experiencing rapid urbanization. How this occurs will have immense and durable economic, social and environmental impacts. Cities can become more efficient, equitable and sustainable as they grow by establishing appropriate land use and transportation system development policies and targets. To provide guidance on optimal urban development policies, this study investigated various economic, social and environmental impacts of land use and transportation factors such as development densities, housing type, vehicle ownership rates, road and parking supply, and transportation system management.

Cities are, by definition, places where many people and activities occur close together, so urban space is always scarce and valuable. Because motor vehicles are space-intensive – automobile travel requires orders of magnitude more space than most other travel modes, and each automobile typically requires more space for roads and parking than the land used for a typical urban resident's house – vehicle densities are as important as human population densities. In addition, motor vehicle travel imposes significant external costs, including congestion, accident risk, noise and air pollution, which degrades urban environments. As a result, efficient and livable urban development requires limiting automobile ownership and use to available roads and parking facility capacity. This requires an integrated program of improvements to space-efficient modes (walking, cycling, ridesharing and public transit), incentives (efficient road and parking pricing, and appropriate roadway management) for travelers to use the most efficient mode for each trip, plus compact, mixed development which minimizes the need to drive.

This study identifies basic physical impacts of sprawl and the benefits of Smart Growth. This analysis indicates that compared with conventional sprawled development (typically less than 6 residents per hectare) Smart Growth (typically more than 30 residents per regional hectare) reduces per capita land consumption by 60-80%, motor vehicle travel and associated costs by 20-60%, public infrastructure and service costs by 10-40%, and tends to benefits physically and economically disadvantaged people by increasing their housing and mobility options. This analysis identifies the combination of policies and planning practices that can achieve these benefits.

For this analysis cities are divided into three categories:

1. *Unconstrained cities* are surrounded by an abundant supply of lower-value lands. They can expand significantly. This should occur on major corridors and maintain at least 30 residents per hectare densities. A significant portion of new housing may consist of small-lot single-family housing, plus some larger-lot parcels to accommodate residents who have space-intensive hobbies such as large-scale gardening or owning large pets. Such cities should maintain strong downtowns surrounded by higher-density neighborhoods with diverse, affordable housing options. In such cities, private automobile ownership may be common but under urban-peak conditions their use should be discouraged by applying complete streets policies (all streets should include adequate sidewalks, crosswalks, bike lanes and bus stops), transit priority features on major arterials, efficient parking management, and transport pricing reforms which discourage urban-peak automobile travel.

2. *Semi-constrained cities* have a limited ability to expand. Their development policies should include a combination of infill development and modest expansion on major corridors. A significant portion of new housing may consist of attached housing (townhouses) and mid-rise multi-family. Such cities should maintain strong downtowns surrounded by higher-density neighborhoods. In such cities, private automobile ownership should be discouraged with policies such as requiring vehicle owners to demonstrate that they have an off-street parking space to store their car, pricing of on-street parking with strong enforcement, roadway design that favors walking, cycling and public transit, and road pricing that limits vehicle travel to what their road system can accommodate.

3. *Constrained cities* cannot significantly expand, so population and economic growth requires increased densities. In such cities, most new housing will be high-rise and few households will own private cars. Such cities require strong policies that maximize livability in dense neighborhoods, including well-designed streets that accommodate diverse activities; adequate public greenspace (parks and trails); building designs that maximize fresh air, privacy and private outdoor space; transport policies that favor space-efficient modes (walking, cycling and public transit); and restrictions on motor vehicle ownership and use, particularly internal combustion vehicles.

Table 9 summarizes what this analysis indicates to be suitable land use and transport planning targets to achieve various economic, social and environmental goals, suitable for various types of cities. These densities tend to be somewhat higher and vehicle ownership rates lower than most North American cities, comparable to most European cities, and these recommended densities are lower than many Asian cities. These moderate densities and vehicle ownership rates are consistent with what consumers tend to choose if urban development and transport systems reflect market principles of consumer sovereignty and efficient pricing, that is, if public policies ensure that sufficient compact but affordable housing is located in accessible, multimodal neighborhoods; urban roads are designed and managed to accommodate all modes and favor space-efficient modes under congested conditions; and road and parking pricing is efficient (road tolls and parking fees reflect marginal costs). Where it is politically infeasible to fully implement these market-based policies, blunter strategies, such as large public transit subsidies, and motor vehicle travel restrictions, may be justified on second-best grounds.

Table 9. Optimal Urban Expansion, Densities and Development Policies

Factor	Unconstrained	Semi-constrained	Constrained
Growth pattern	Expand as needed	Expand less than population growth	Minimal expansion
Regional density (residents / ha)	20-60	40-80	80 +
Housing types	A majority can be small-lot single-family or adjacent	Approximately equal portions of small-lot single-family, adjacent, and multi-family	Mostly multi-family
Vehicle ownership (per 1,000 pop.)	300-400	200-300	< 200
Private auto mode share	20-50%	10-20%	Less than 10%
Intersection density per sq. km.	40+	60+	80+
Portion of land in road ROW	10-15%	15-20%	20-25%
Recreational facilities	Most households are located within a ten-minute walk of local parks, trails or other recreational facilities, and at least 10% of urban land is devoted to larger regional parks		
Examples	Most African and American cities	Most European and Asian cities	Singapore, Hong Kong, Male

This table summarizes the optimal development parameters recommended by this analysis for the three types of cities.

These features provide a basic foundation, but there is more to optimal urban design. Good urban planning strives to create complete, mixed-use neighborhoods in which common services and activities demanded by residents and employees are available within convenient walking distances of most residents and worksites. The public realm, including roadways and public parks, should be designed to be attractive and vibrant places, in addition to being functional.

This analysis can respond to criticisms that Smart Growth development policies will deprive future urban residents of their preferred housing and transportation options; in most situations, efficient and equitable development does *not* require most households to live in high-rise housing and be car-free. On the contrary, excepting highly constrained cities, the planning objectives considered in this analysis can be achieved with moderate population densities (20-80 residents per regional hectare), which allows most residents to live in single-family or adjacent (townhouse) homes, and moderate motor vehicle ownership rates (200-400 vehicles per 1,000 residents), which allows automobiles to serve a major share of total trips. These rates are typical of affluent cities in Europe and transit-oriented neighborhoods in North America, which many people consider to be very convenient and desirable places to live. Higher densities and lower vehicle ownership rates provide modest additional benefits and are generally only required in geographically constrained cities, although all cities should include high density districts around major business districts and transit stations, and cities such as Singapore and Seoul demonstrate that with good planning, such neighborhoods can provide high quality livability.

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