THE NEW CLIMATE ECONOMY

The Global Commission on the Economy and Climate

VICTORIA Transport Policy INSTITUTE   **LSECities**

NCE Cities – Sprawl Subsidy Report

ANALYSIS OF PUBLIC POLICIES THAT UNINTENTIONALLY ENCOURAGE AND SUBSIDIZE URBAN SPRAWL

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CONTENTS

The New Climate Economy

The New Climate Economy (NCE) is the flagship project of the Global Commission on the Economy and Climate. It was established by seven countries, Colombia, Ethiopia, Indonesia, Norway, South Korea, Sweden and the United Kingdom, as an independent initiative to examine how countries can achieve economic growth while dealing with the risks posed by climate change. The NCE Cities Research Programme is led by LSE Cities at the London School of Economics. The programme includes a consortium of researchers from the Stockholm Environment Institute, the ESRC Centre for Climate Change Economics and Policy, the World Resources Institute, Victoria Transport Policy Institute, and Oxford Economics. The NCE Cities Research Programme is directed by Graham Floater and Philipp Rode.

SUMMARY

This report investigates evidence that current development policies result in economically excessive sprawl. It defines sprawl and its alternative, "smart growth," describes various costs and benefits of sprawl, and estimates their magnitude. It identifies policy distortions that encourage sprawl. It discusses factors to consider when determining the optimal amount and type of urban expansion for various types of cities. It discusses the implications of this analysis for rapidly urbanizing countries. It identifies potential policy reforms that could result in more efficient and equitable development patterns, and describes examples of their implementation. It also discusses criticisms of sprawl cost studies and smart growth policies.

An abundance of credible research indicates that sprawl significantly increases per capita land development, and by dispersing activities, increases vehicle travel. These physical changes impose various economic costs including reduced agricultural and ecological productivity, increased public infrastructure and service costs, plus increased transport

Internal Review

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costs including consumer costs, traffic congestion, accidents, pollution emissions, reduced accessibility for non-drivers, and reduced public fitness and health. Sprawl provides various benefits, but these are mostly direct benefits to sprawled community residents, while many costs are external, imposed on non-residents. This analysis indicates that sprawl imposes more than $400 billion dollars in external costs and $625 billion in internal costs annually in the U.S., indicating that smart growth policies which encourage more efficient development can provide large economic, social and environmental benefits. Although these costs reflect North American conditions, the results are transferable to developing countries.

EXECUTIVE SUMMARY

The world is experiencing rapid urbanization. How this occurs will have immense economic, social and environmental impacts. To help identify optimal urban development policies, this report investigates the costs of sprawl (dispersed, segregated, automobile-oriented, urban-fringe development) and potential benefits of smart growth (compact, mixed, multi-modal development).

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, increases in total motor vehicle travel. Compared with smart growth development, sprawl typically increases per capita land consumption 60-80% and motor vehicle travel by 20-60%.

Figure ES-1
Sprawl Resource Impacts
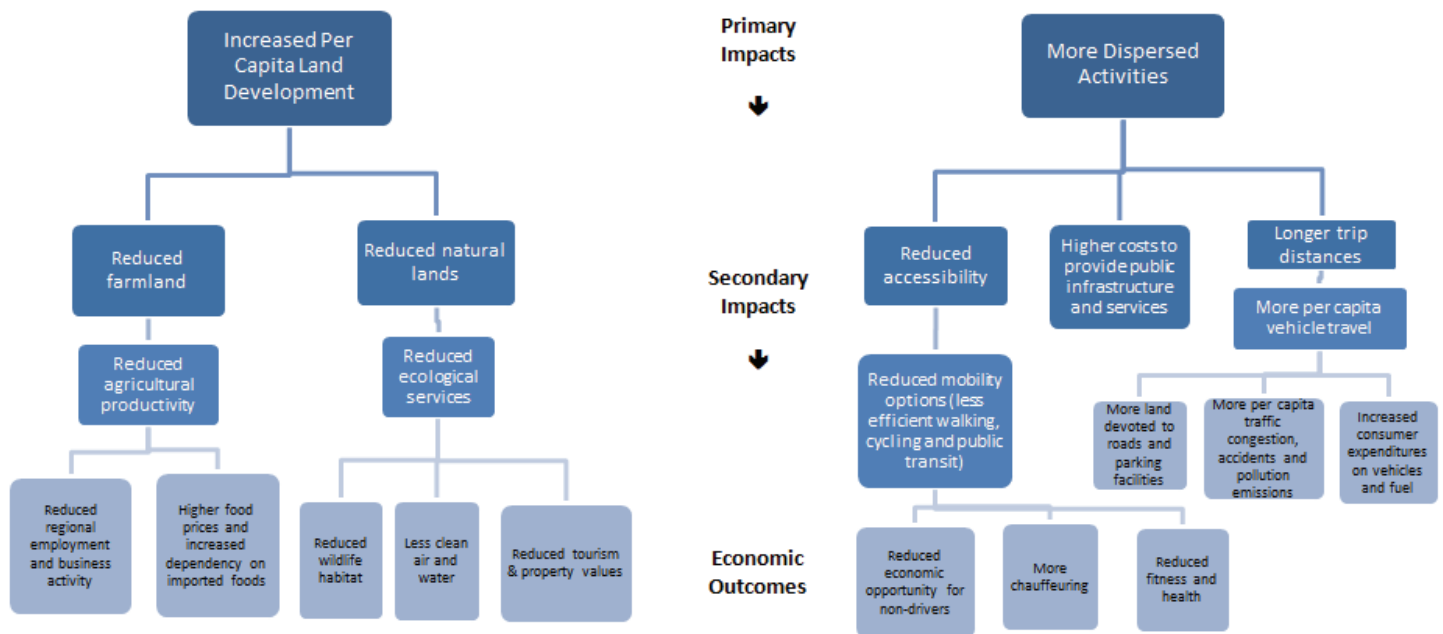
Sprawl has two primary resource impacts: it increases per capita land development, and by dispersing destinations, it increases total vehicle travel. These have various economic costs. This figure illustrates these impacts.

This provides a framework for understanding various economic costs of sprawl, including displacement of agriculturally and ecologically productive lands, increased infrastructure costs, and increased transportation costs including increases in per capita facility costs, consumer expenditures, travel time, congestion delays, traffic accidents and pollution emissions, plus reduced accessibility for non-drivers, and reduced public fitness and health. To the degree that sprawl degrades access by affordable modes (walking, cycling and public transit), these impacts tend to be regressive (they impose particularly large burdens on physically, economically and socially disadvantaged people). To the degree that sprawl concentrates poverty in urban neighborhoods, it tends to exacerbate social problems such as crime and dysfunctional families. To the degree that it reduces agglomeration efficiencies, increases infrastructure costs, and increases expenditures on imported goods (particularly vehicles and fuel), it tends to reduce economic productivity. Sprawl also provides benefits, but these are mostly direct internal benefits to sprawled community residents; there is little reason to expect sprawl to provide significant external benefits to non-residents.

Figure ES-2 indicates the typical costs of automobile travel under urban conditions, including internal-fixed (ownership), internal-variable (operating), and external (imposed on other people) costs. These total thousands of dollars per vehicle-year.

Figure ES-2
Estimated Urban Automobile Costs
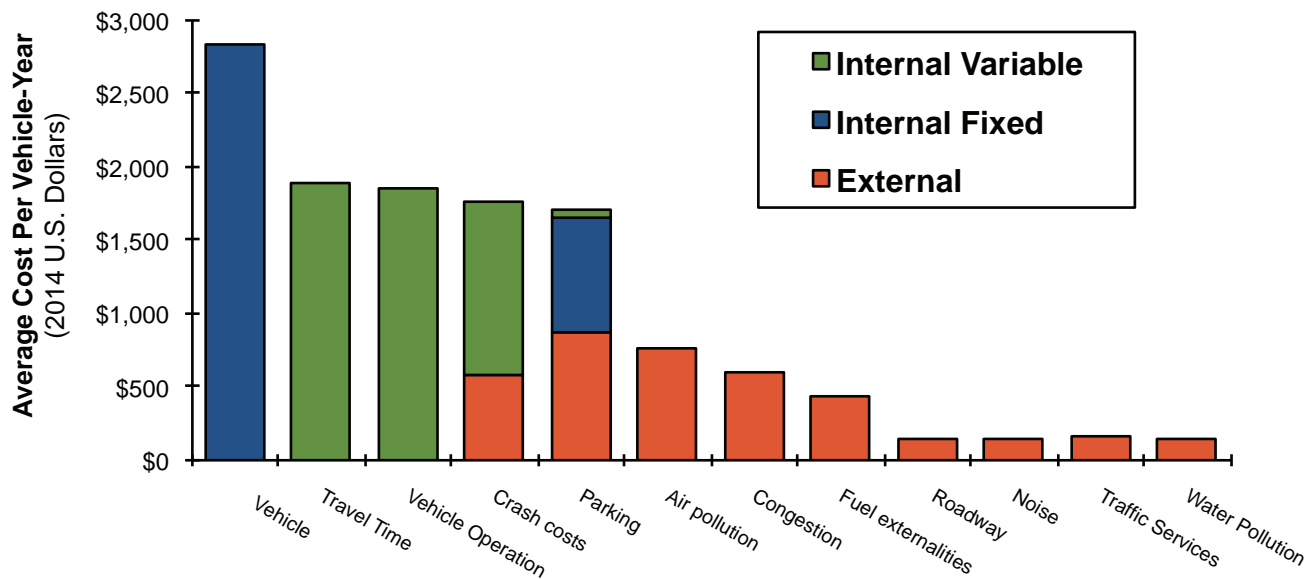
Source: based on Litman 2009
This figure illustrates the estimated costs of motor vehicle ownership and use.

Sprawled urban areas typically have two to five times the traffic fatality rates as in smart growth communities. Very low crash casualty rates (under 5 annual traffic fatalities per 100,000 residents) generally require a combination of smart growth development and transportation demand management strategies, as indicated in Figure ES-3.

Figure ES-3
Traffic Death Rates
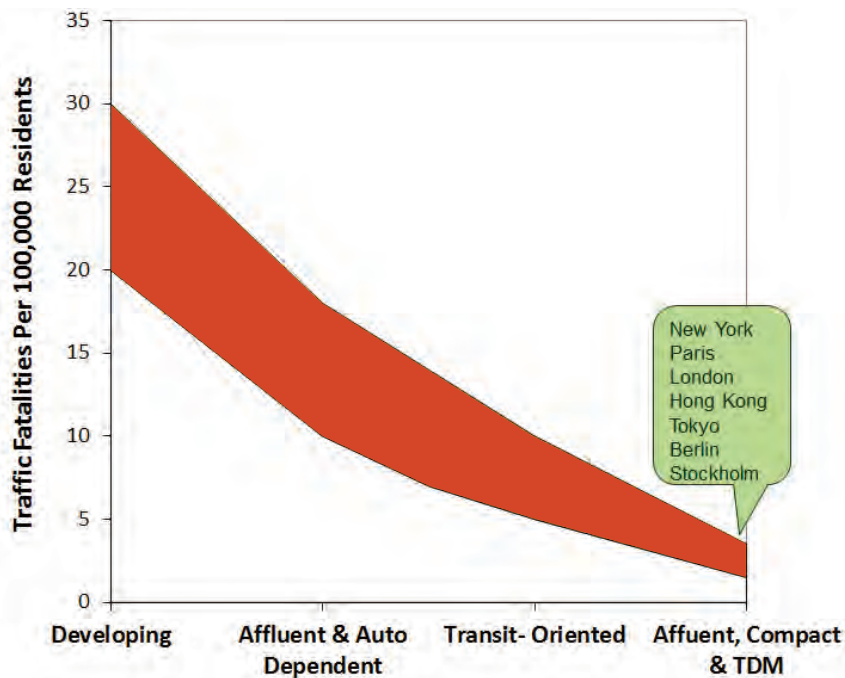
Traffic fatalities per 100,000 residents typically average 20-30 in developing country cities, 10-20 in affluent, automobile-dependent cities, 5-10 in affluent, compact cities, and just 1.5-3 in affluent, compact cities with strong transportation demand management (TDM) programs.

To quantify sprawl costs, this study divided U.S. cities into quintiles (fifths) and estimated the additional land consumption, infrastructure and public service, transport and health costs of more sprawled development. For example, this analysis indicates that sprawl increases annualized infrastructure costs from $502 per capita in the smartest growth quintile cities up to $750 in the most sprawled quintile cities. This analysis indicates that sprawl's incremental costs average approximately $4,556 annual per capita, of which $2,568 is internal (borne directly by sprawl location residents) and $1,988 is external (borne by other people). These external costs probably total more than $400 billion per year in the U.S. Sprawl also provides benefits, including cheaper land, which allows households to afford more private open space (yards and gardens), and it lets affluent households move away from urban social problems such as concentrated poverty and associated crime. However, these are internal benefits and economic transfers (some people benefit but others are worse off), there are seldom significant external benefits since consumers and businesses rationally internalize benefits and externalize costs.

Although many of these costs are lower in absolute value in developing countries, due to lower wages and property values, they are probably similar relative to incomes and regional economies. As a result, smart growth policies that create more compact communities can provide substantial economic, social and environmental benefits in both developed and developing countries.

A key question for this analysis is the degree that sprawl results from policy distortions. It identified various sprawl-inducing planning and market distortions including development practices that favor dispersed development over compact urban infill, underpricing of public infrastructure and services in sprawled locations, underpricing of motor vehicle travel, and transport planning practices that favor mobility over accessibility and automobile travel over more resource-efficient modes. Consumer preference research suggests that more optimal planning and pricing would cause many households to choose more compact communities, drive less, and rely more on alternative modes. Table ES-1 identifies policy reforms that reflect economic principles including consumer sovereignty, efficient pricing and neutral planning. These reforms tend to increase economic efficiency and equity.

Table ES-1
Examples of Efficient Smart Growth Policies

Improved Consumer Options	More Efficient Pricing	More Neutral Planning
• Improved walking, cycling and public transit in response to consumer demands – such as better sidewalks, bike and bus lanes on most urban arterials. • Reduced and more flexible parking requirements and density limits in urban areas. • More diverse and affordable housing options such as secondary suites. • Improved public services (schools, policing, utilities) in smart growth locations.	• Efficient pricing of roads and parking, so motorists pay directly for using these facilities, with higher fees during congested periods. • Distance-based vehicle registration, insurance and emission fees. • Location-based development fees and utility rates so residents pay more for sprawled locations and save with smart growth. • Vehicle registration auctions in large cities where vehicle ownership should be limited.	• More comprehensive evaluation of all impacts and options in the planning process. • Accessibility- rather than mobility-based planning, so accessibility is given equal consideration as mobility when evaluating transport impacts. • *Least-cost transport planning*, which allocates resources to alternative modes and transportation demand management programs when they are effective investments, considering all impacts.

These smart growth policies reflect economic principles. They tend to increase economic efficiency and equity.

This study identified various factors to consider when determining how cities should expand, as summarized in Table ES-2.

ES-2
Optimal Urban Expansion, Density and Development Policies

Factor	Optimal Expansion
Open space (farm and natural lands)	Policies should encourage compact development to minimize farm and ecologically productive land displacement.
Consumer demands	Cities should develop diverse housing options, including affordable housing in accessible, multi-modal areas. In unconstrained cities, the majority of housing may be small-lot single-family. In constrained cities, more housing should be multi-family.
Infrastructure and public services	Policies should encourage moderate- to high-density development along major utility corridors, and discourage leapfrog development distant from existing services.
Transport system efficiency	Policies should encourage densities exceeding 30 residents per hectare along transit lines with frequent service and good walking and cycling conditions.
Economic development	Policies should encourage compact, multi-modal development, favor resource-efficient transport modes, and preserve valuable farmland.
Safety and health	Favor compact development, lower traffic speeds, and transportation demand management to reduce automobile travel and encourage walking and cycling.
Social equity	Provide sufficient space for low-income residents, and encourage development of affordable housing and transport options.
Social problems	Encourage affordable compact development with features that improve at-risk residents' economic opportunities and quality of life.
Optimal roadway supply	Devote 20-25% of land to roads in denser areas, and 10-15% in less dense areas. Design and manage roads to balance various planning objectives. Minimize the amount of land devoted to off-street parking lots through efficient parking management.

Various factors should be considered when determining optimal urban expansion and development policies.

To help determine the optimal densities in specific situations, 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 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 their use should be discouraged under urban-peak conditions 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.

Because motor vehicles are very space-intensive – each automobile requires more space for roads and parking than used for a typical urban resident's house – vehicle densities are as important as population densities. As a result, to maximize economic efficiency and livability, cities must efficiently manage roads and parking facilities and limit automobile ownership to what these facilities can accommodate. This requires an integrated program of improvements to space-efficient modes (walking, cycling, ridesharing and public transit), incentives for travelers to use the most efficient mode for each trip, and compact, multi-modal development that maximizes overall accessibility. Since buses are very space-efficient, cities should provide bus lanes on most major urban arterials.

To maximize social welfare it is important that smart growth development respond to consumer demands, for example, by creating communities with diverse housing options, high quality public services (such as policing, schools and local parks), attractive and multi-functional urban streets (including sidewalks, shops, cafes, landscaping and awnings), and programs that encourage positive interactions among residents (local festivals, outdoor markets, recreation and cultural centers, etc.).

Table ES-3 summarizes various factors that should be considered in determining optimal urban expansion, densities and development policies.

Table ES-3
Optimal Urban Expansion, Densities and Development Policies

Factor	Un-Constrained	Semi-Constrained	Constrained
Growth pattern	Expand as needed	Expand less than population growth	Minimal expansion
Optimal regional density (residents / hectare)	20-60	40-100	80 +
Housing types	A majority can be small-lot single-family and adjacent	Approximately equal portions of small-lot single-family, adjacent, and multi-family.	Mostly multi-family
Optimal vehicle ownership (vehicles per 1,000 residents)	300-400	200-300	< 200
Private auto mode share	20-50%	10-20%	Less than 10%
Portion of land devoted to roads and parking	10-15%	15-20%	20-25%
Examples	Most African and American cities.	Most European and Asian cities.	Singapore, Hong Kong, Male, Vatican City.

Different types of cities may have different growth patterns, densities and transport patterns.

Some previous sprawl cost studies have been criticized for various reasons. Critics argue that sprawl cost estimates are exaggerated, that such costs are offset by benefits of equal magnitude, or that more compact, smart growth development patterns impose equal external costs. However, much of this criticism reflects inaccurate assumptions (for example, that smart growth eliminates single-family housing and private automobile ownership) and outdated or inaccurate research (for example, outdated studies which suggested that smart growth provides no energy or infrastructure savings). Although sprawl does provide benefits, these are largely internal benefits to sprawl community residents; there is little evidence of significant external benefits which offset external costs. Probably the most legitimate criticism of smart growth is that it can reduce single-family housing affordability, but many smart growth policies increase overall affordability by allowing more compact housing types and reducing infrastructure and transport costs. This criticism therefore depends on whether single-family housing affordability is more important than more compact housing affordability, and whether house purchase affordability is more important than infrastructure and transport affordability.

Much of the research in this report is based on North American conditions because that is where the best data are available. However, the basic relationships are transferable: more dispersed and automobile-oriented development imposes various costs, including external costs, which can be reduced with smart growth policies which improve transport options, particularly walking, cycling and public transit, and increase housing supply in central cities (Guerra 2015). Smart growth policies can ultimately benefit consumers by improving their housing and transport options and providing new opportunities to save money to households that choose smart growth locations. Smart growth benefits tend to be particularly large:
* In rapidly growing urban areas.
* In urban areas making significant infrastructure investments.
* In cities where urban fringe land has high social or environmental values.
* Where infrastructure and vehicle fuel are costly to produce or import, for example, if a low-income country must import equipment and energy.
* If communities have goals to improve mobility options for disadvantaged populations, improve public fitness and health, or support environmental objectives.

These are complex issues. Urban planning decisions involve numerous trade-offs between various planning objectives, so many different factors must be considered when evaluating policies and projects. There is no single set of development policies that should be imposed everywhere. Every city is unique and must develop in ways that respond to local geographic, demographic and economic factors. The analysis in this report provides ideas and guidance that public officials, practitioners and the general public can use to help identify the truly best way to develop their city, considering all impact and options. More research is needed to better understand the full benefits and costs of specific policy and planning decisions and determine the best policies to implement in a particular situation.

INTRODUCTION

Our world is currently engaged in massive urbanization. Between 1950 and 2050 the human population will approximately quadruple and shift from 80% rural to nearly 80% urban (Figure 1). 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 these cities grow has huge economic, social and environmental impacts. It is important that public policies guide this development to maximize benefits and minimize costs, in order to leave a sustainable legacy for future generations.

Figure 1
World Urbanization
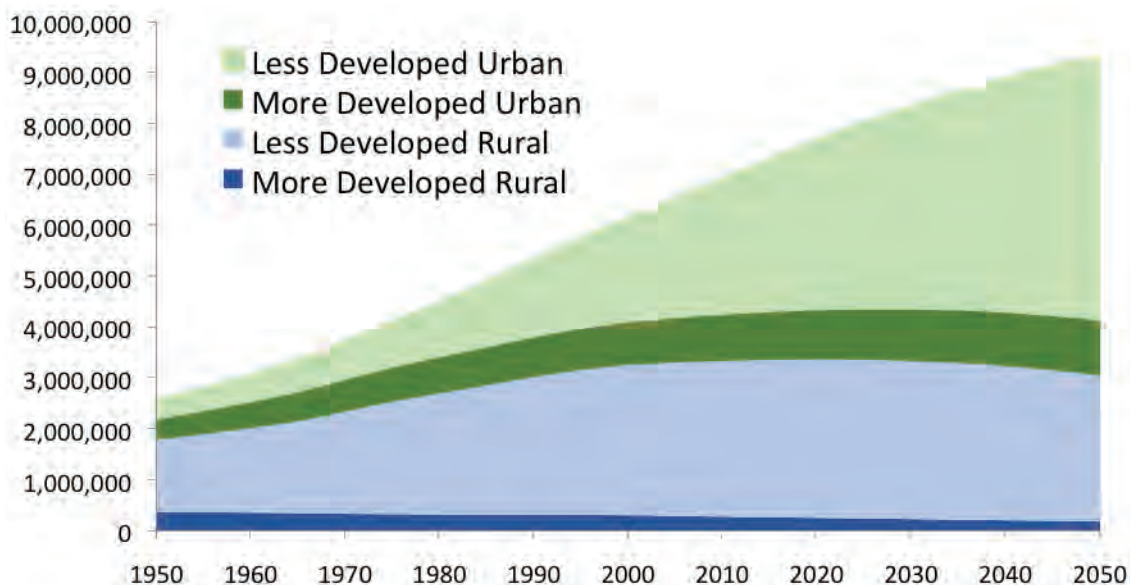
Source: UN 2011
The world is currently experiencing rapid urbanization, particularly in developing countries.

This study investigates an important and timely issue: the degree that current public policies and planning practices unintentionally encourage resource-intensive sprawled development, and therefore the potential economic savings and benefits of "smart growth" policies which create more compact, multi-modal communities. This is not to suggest that there is a single optimal development pattern that should be imposed on all households, rather, it highlights the importance of objective and comprehensive analysis of policies that affect development patterns.

This report examines the following questions:
1. What are sprawl and smart growth?
2. What are the incremental costs and benefits of sprawl?
3. What is the estimated magnitude of sprawl costs?
4. How much urban expansion is optimal?
5. What policy distortions lead to economically excessive sprawl?
6. What are the policy implications of these findings, particularly for rapidly urbanizing countries?

This research is based largely on developed country experience because that is where the urbanization process is most mature and data available, but most results are transferable to rapidly-urbanizing countries. This information can help developing countries balance various economic, social and environmental goals (Adaku 2014; CCICED 2011; Economist 2014; Floater and Rode 2014a).

WHAT ARE SPRAWL AND SMART GROWTH?

This section describes sprawl and smart growth, and how they are commonly measured.

Sprawl refers to dispersed, segregated (single-use), automobile-oriented, urban-fringe development. The alternative, called smart growth in this report, involves more compact, mixed, multi-modal development. Table 1 compares these two development patterns.

Table 1
Sprawl and Smart Growth

	Sprawl	**Smart Growth**
Density	Lower-density, dispersed activities.	Higher-density, clustered activities.
Land use mix	Single use, segregated.	Mixed.
Growth pattern	Urban periphery (greenfield) development.	Infill (brownfield) development.
Scale	Large scale. Larger blocks and wide roads. Less detail, since people experience the landscape at a distance, as motorists.	Human scale. Smaller blocks and roads. Attention to detail, since people experience the landscape up close.
Services (shops, schools, parks, etc.)	Regional, consolidated, larger. Requires automobile access.	Local, distributed, smaller. Accommodates walking access.
Transport	Automobile-oriented. Poorly suited for walking, cycling and transit.	Multi-modal. Supports walking, cycling and public transit.
Connectivity	Hierarchical road network with many unconnected roads and walkways.	Highly connected roads, sidewalks and paths, allowing direct travel.
Street design	Streets designed to maximize motor vehicle traffic volume and speed.	Reflects *complete streets* principles that accommodate diverse modes and activities.
Planning process	Unplanned, with little coordination between jurisdictions and stakeholders.	Planned and coordinated between jurisdictions and stakeholders.
Public space	Emphasis on private realms (yards, shopping malls, gated communities, private clubs).	Emphasis on public realms (shopping streets, parks, and other public facilities).

Source: SGN 2009
This table compares various features of smart growth and sprawl.

Smart growth is a general set of principles that can be applied in many different ways. In rural areas, it creates compact, walkable villages with a mix of single- and multi-family housing organized around a commercial center. In large cities, smart growth creates dense, mixed-use neighborhoods organized around major transit stations. Between these is a wide range of neighborhood types, their common theme is compact and multi-modal development. In mature cities, smart growth consists primarily of incremental infill in existing neighborhoods, but in growing cities it often consists of urban expansion. Smart growth does not necessarily require all residents to live in high-rise apartments and forego automobile travel; excepting cities with severe constraints on expansion, a major portion of households can live in single-family or adjacent housing, and many can own or share cars.

Figure 2 illustrates typical examples of sprawl and smart growth development (Campoli and MacLean 2002; Hartzell 2013).

Figure 2
Sprawl and Smart Growth Illustrated

Sprawl

This U.S. suburb has residential development scattered among farms. Many streets lack sidewalks and there is virtually no transit service. This results in high rates of automobile travel.

Smart Growth

This German town has concentrated and mixed development, with houses close to services and well-defined boundaries. A major portion of travel is by walking, cycling and public transit.

Although sprawl and smart growth differ in many ways, they are often measured based only on density (residents or employees per acre or hectare) or its inverse land consumption (e.g., square meters per resident or employee). Density is a useful indicator because it is widely available and easy to understand, and because it tends to be positively correlated with other smart growth factors including development mix (the proximity of residential, commercial and institutional buildings), transport network connectivity (density of sidewalks, paths and roads), centricity (the degree that employment is concentrated into commercial centers), and transport diversity (quality of walking, cycling and public transport). However, by itself, density is an imperfect indicator since it is possible to have dense sprawl (high-rise buildings in isolated, automobile-dependent areas), and rural smart growth (such as compact, walkable villages linked by high quality public transit). If possible, smart growth should be analyzed using an index which reflects various land use factors including density, mix and connectivity (Ewing and Hamidi 2014). People sometimes confuse density (people per land area) with crowding (people per housing unit, room or square meter of building space) although they are very different. For example, many residents of low-density rural areas live in crowded homes, while many residents of high-density neighborhoods live in spacious apartments.

Density analysis can be confusing because it is measured in many different ways:
- What is measured: residents, residents plus employees, dwelling units (du) and motor vehicles.
- 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).
- Weighting: Population-weighted density, which measures the density that residents actually experience, is a better indicator than simple average densities for evaluating land use economic and livability impacts, but is more difficult to compute (Florida 2012; US Census 2012).

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

Table 2
Comparing Density Units (10 Dwelling Units Per 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 parcel acre. It is important to use consistent units and measurement methods when comparing densities.

Table 3 compares typical densities of various housing types. Developing country cities often have high densities due to larger families which result in more people per housing unit. The amount that densities decline with affluence depends on public policies. Many affluent European and Asian cities are relatively dense due to geographic constraints and policies that encourage compact development, while some low-income cities, particularly in Africa and South America, have relatively low development densities.

Table 3
Typical Densities of Various Housing Types

	Large-lot Single-family	Medium-Lot Single-Family	Small-Lot Single-Family	Attached (Townhouses)	Mid-Rise Multi-Family	High-Rise Multi-Family
Stories	1-3	1-3	2-3	2-3	3-8	Over 8
Units/Hectare	Less than 5	5-10	10-30	20-40	30-60	Over 100
People/Hectare	Less than 10	10-20	20-80	40-100	60-150	Over 200

Densities vary significantly by housing type. Denser cities have a greater portion of compact housing types.

Figure 3 illustrates the land required by 1,000 units for various housing type combinations. Sprawled cities with 80% single-family, 10% attached and 10% multi-family housing (80%-10%-10%), require about twice times as much land as an equal mix of housing types (33%-33%-33%), and more than three times as much land as 10% single-family, 40% adjacent and 50% multi-family.

Figure 3
Land Use Consumption by Housing Type Mix
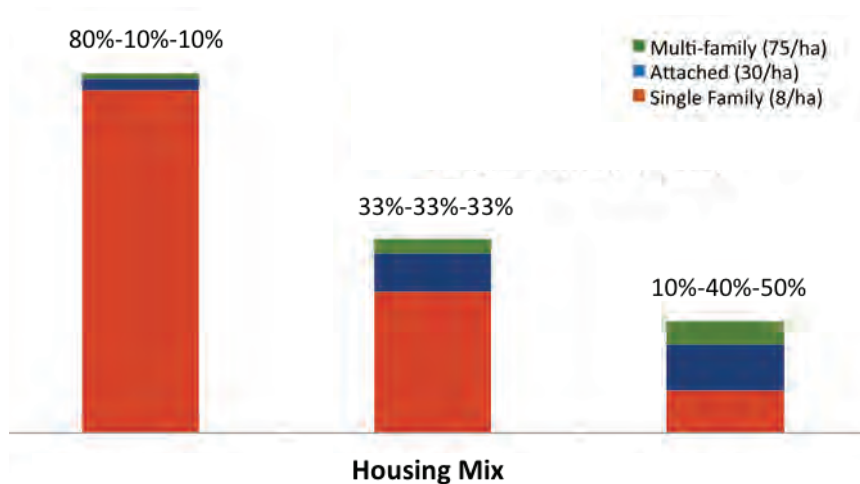
Shifting to more compact housing types significantly reduces residential land consumption. A mix of 80% single-family, 10% attached and 10% multi-family housing requires about twice times as much land as an equal mix of housing types, and more than three times as much land as 10% single-family, 40% adjacent and 50% multi-family.

Transport policies also affect development densities. Because of their size and speed, automobiles require much more space for roads and parking than other modes. In U.S. cities there is approximately 45 square meters (m2) of road space (FHWA 2013, Table HM72), plus two to six off-street parking spaces averaging about 30 square meters, per automobile (Davis, et al. 2010; Litman 2009). This indicates that in order to keep road and parking congestion to the moderate levels that occur in the U.S., each automobile requires 100 to 200 m2 of land for roads and parking facilities, far more than required for other modes, as indicated in Figure 4.

Figure 4
Space Required By Travel Mode[1]
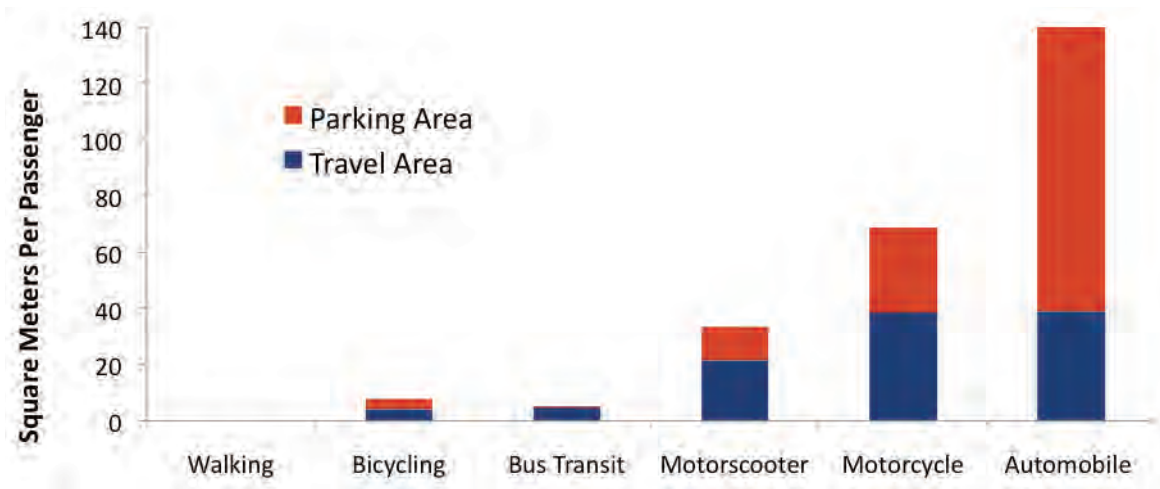
Automobiles require far more road and parking space than other modes due to their size and speed.

As a result, high vehicle ownership rates can limit urban population densities. For example, a one-hectare parcel might accommodate 50 townhouses if there are only 10 on-site parking spaces, but if each unit has two surface parking spaces, as many zoning codes require, the number of potential units declines to 30. Similarly, wider roads reduce the amount of land available for housing and greenspace.

Figure 5 shows the densities of urban regions around the world. Typical urban densities range from 5-20 residents per hectare in North America, 20-100 residents per hectare in Europe, and more than 100 residents per hectare in many Asian cities. Similar variations exist within urban regions, for example, between central city and urban fringe neighborhoods.

Smart growth generally requires at least 30 residents per neighborhood hectare in order to provide sufficient demand for local services such as stores, schools and public transit within walking distance of homes (Pushkarev and Zupan 1977). Not every house needs to reflect that threshold, smart growth communities can include some lower density development provided they are offset by a similar amount of higher-density development. Smart growth densities can generally be achieved with 30-50% single-family, 25-35% adjacent (townhouse), and 25-35% multi-family housing, resulting in 40-80 residents per regional hectare, although higher densities are needed in cities where expansion is constrained.

1 Transport Land Requirements Spreadsheet (www.vtpi.org/Transport_Land.xls). Assumes 45 m2 of road space and four 30 m2 parking spaces per automobile, with the following passenger car equivalent (PCE) values for other modes: walk 0.01; bicycle 0.1; bus 3.0 divided by 25 average peak-period passengers; motorcycle 0.5.

Figure 5
## People Per Hectare In Various World Cities
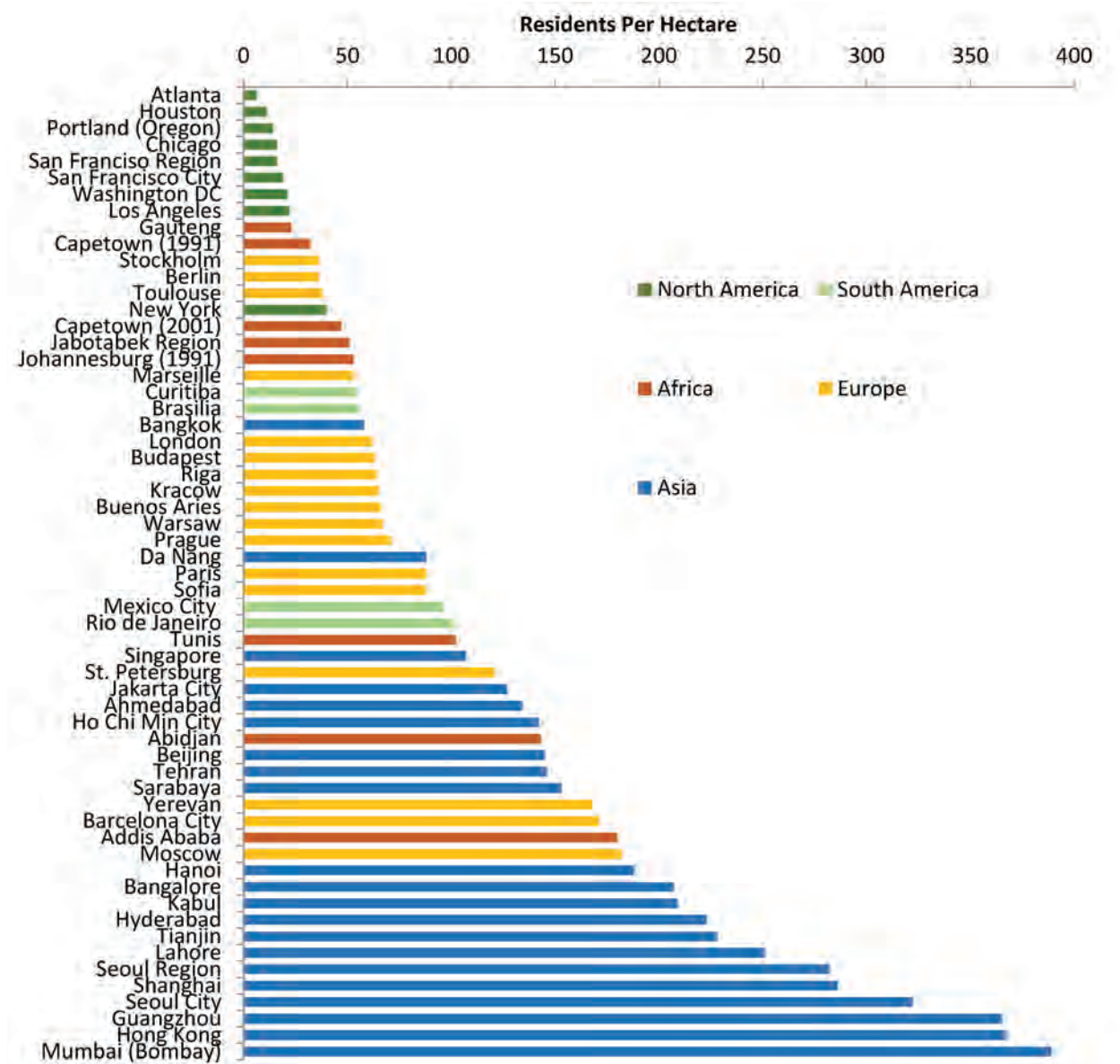
Source: (Bertaud 2012)
Urban population densities vary significantly from under 10 to more than 300 residents per hectare.

Smart growth represents a major policy shift. During the last century, many development policies encouraged sprawl and automobile dependency. These included planning practices that favored urban expansion over infill development, restrictions on building density and height, minimum parking and setback requirements, transport planning that favored automobile travel over other modes, plus utility pricing and tax rates that fails to reflect the higher costs of providing public services in sprawled locations. Although individually these pro-sprawl policies may seem modest and justified, they contribute to a self-reinforcing cycle of sprawl and automobile dependency (Figure 6). These polices reduce housing and transport options, and increase economic and environmental costs (Garceau, et al. 2013; ITDP 2012). In response, many governments and professional organizations now support smart growth policies (ADB 2009; ICMA 2014; ITE 2010; UN 2014).

Figure 6
Cycle of Sprawl and Automobile Dependency
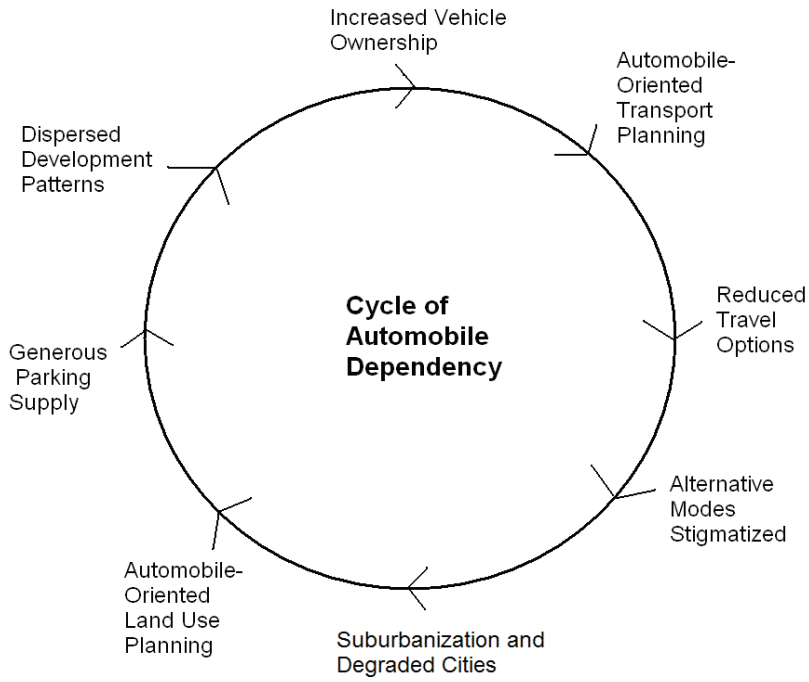
This figure illustrates the self-reinforcing cycle of increased automobile dependency and sprawl.

THE DEMAND FOR SPRAWL

This section examines the "demand for sprawl," which refers to the amount that people and businesses will choose sprawl over smart growth locations, and factors that influence these decisions.

The "demand for sprawl" refers to the degree that consumers prefer to live in dispersed, automobile-dependent locations, the amount they would be willing to pay to do so, and the factors that affect those decisions. Understanding these factors can help evaluate potential land use policies, such as the number and type of households that would choose compact neighborhoods, and how to successfully attract households to such neighborhoods.

As households become wealthier they tend to demand larger houses and gardens, but responding to this demand does not necessarily require sprawl (Cheshire 2009). As discussed previously, in most urban regions (depending on a city's ability to expand), smart growth can accommodate 35-70% single-family or adjacent (townhouse) housing. Advocates of low-density development policies claim that nearly all households prefer sprawl neighborhoods (Bruegmann 2005: Kotkin 2013), citing consumer surveys which indicate that most households aspire to own a single-family home in a quiet neighborhood. However, more detailed analysis indicates that households also want smart growth attributes and will often choose more compact neighborhoods if they have suitable features (Levine, et al. 2002).

For example, the U.S. National Association of Realtors Community Preference Survey (NAR 2013) found that although most Americans prefer single-family homes and place a high value on privacy, they also desire the convenience of walkable, mixed-use communities with shorter commutes and convenient access to public services. When faced with trade-offs between specific attributes, a majority of respondents choose smaller-lot homes that provide shorter commutes and short walks to schools, stores and restaurants over large-lot houses in more automobile-dependent neighborhoods. Another survey found that households would prefer an urban townhouse over a suburban single-family home if they saved on average CA$130 per month in housing costs (Hunt 2001). This price incentive is comparable in magnitude to the public services savings provided by more compact development, as described later in this report, indicating that many households would choose smart growth locations in response to more efficient development and utility pricing.

Much of the preference for sprawl reflects economic and social factors, such as the perceived safety, affordability, public school quality, prestige and financial security of suburban neighborhoods, rather than physical features of sprawl, as summarized in Table 4. As a result, many households will choose smart growth neighborhoods if they are considered safe, convenient, attractive, and prestigious (Pembina 2014). Policies that make compact neighborhoods more attractive responds to these consumer demands, which benefit residents directly, in addition to the external benefits from reduced economic, social and environmental costs described later in this report.

Table 4
Attractions of Sprawl

Physical Features	Economic and Social Features
• Lower land prices, allowing households to afford larger lawns and gardens • More privacy (more distance between homes) • More and cheaper parking	• Perceived safety • Less concentrated poverty and associated social problems • Better public services (e.g., schools) • More prestige

Many of the attractions of sprawl are economic and social factors that can be replicated in compact communities.

Single-family housing tends to be valued most by households with younger children that want outdoor play areas, or that have space-intensive hobbies such as gardening, large pets or vehicle repair. These demands can be served in smart growth communities with suitable features. For example, smart growth neighborhoods can include small-lot single-family and townhouses with yards, apartments with shared play areas and rooftop gardens, public parks and allotment gardens, plus studios, workshops and garages included in residential buildings or available for rent nearby.

Many policy and planning decisions can affect household location decisions. As residents become more affluent they demand higher quality housing. As a result, to be successful in economically developing cities smart growth must place more emphasis on housing quality and neighborhood livability, with high quality amenities such as parks and plazas, attractive sidewalks and streetscaping, high quality transit services, and incentives to encourage residents to choose resource efficient transport modes when possible. Pricing reforms, such as development charges and utility fees that reflect the costs of providing public infrastructure and services in specific locations, resulting in lower fees in compact neighborhoods, can attract more households to smart growth areas. Similarly, transport pricing reforms, such as efficient road and parking pricing, and employer-subsidized transit fares, can encourage residents to drive less and rely more on other transport modes.

Figure 7
Smart Growth Requires Suitable Quality and Incentives
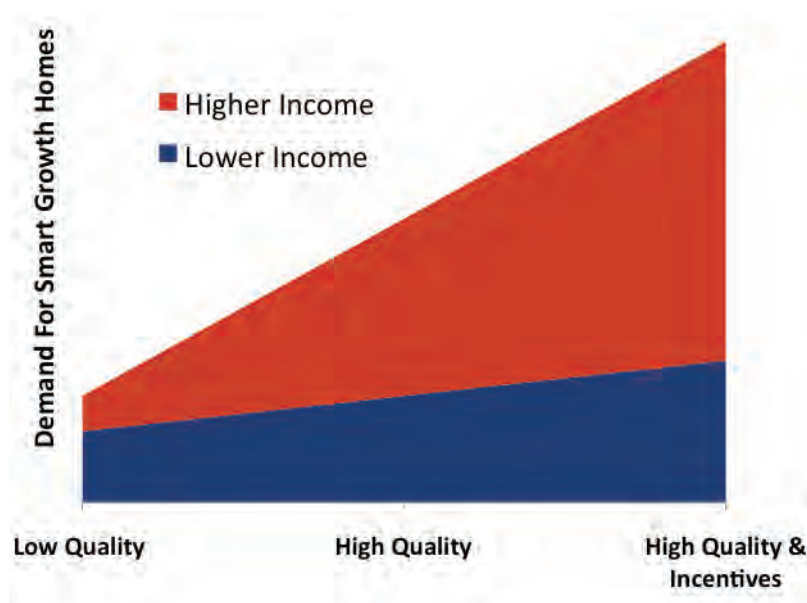
Lower income households often choose compact housing out of necessity. Higher income households have the option of choosing sprawled location homes, so to be successful, smart growth must offer appropriate high quality compact housing and incentives that attract affluent households.

Table 5 lists various factors that affect the demand for sprawl, and ways that smart growth policies can respond to them. For example, many families choose sprawled housing so their children can attend better-ranking suburban schools. This creates a self-fulfilling prophecy by concentrating poverty and academically disadvantaged students in urban schools which further degrade their ranking. Smart growth policies can address this obstacle by improving urban school quality, for example, with targeted improvement programs and specialized "magnet" courses and curricula that attract highly-qualified students. Urban school improvement programs are justified for many reasons. Not only do they help achieve social equity objectives and reduce crime, by attracting more middle-class households to compact, multi-modal neighborhoods, they can also help reduce sprawl and its associated costs

Table 5
Factors That Affect The Demand For Sprawl

Factor	Smart Growth Policies
Demographics. Families with young children want larger houses with secure play areas.	Develop suitable housing options, including townhouses and apartments with numerous bedrooms and children's play areas.
Special space needs. Some households enjoy gardening or have hobbies or businesses that require extra space.	Design housing that incorporates or is located close to gardens (rooftop and allotment gardens), lofts, studios, workshops and garages.
Affordability. Housing tends to be cheaper in suburbs than urban neighborhoods.	Include affordable housing in smart growth neighborhoods. Reduce development fees, utility charges and taxes for smart growth locations, reflecting the lower costs of providing public services. Provide information on smart growth consumer savings.
Perception that public services (policing and schools) are better in suburban areas.	Improve public services, such as policing and schools, in urban neighborhoods.
Perceived safety of suburban locations.	Improve urban neighborhood safety and security. Reduce concentrated urban poverty. Provide information on smart growth safety and security benefits.
Relative accessibility.	Improve walking, cycling, public transit and carsharing. Reduce automobile travel subsidies, such as road, parking and vehicle fuel underpricing. Apply complete streets policies (design streets to accommodate all users) in urban neighborhoods.
Prestige of suburban locations and automobile travel.	Promote smart growth neighborhoods as safe, healthy, attractive places suitable for successful and happy households.

Many factors affect the demand for sprawl. Smart growth strategies can respond to those demands.

Box 1
Smart Growth Helps Generate Household Wealth

Real estate tends to appreciate in value. Vehicles tend to depreciate, and expenditures on vehicle operation (fuel, tire replacement, tolls, etc.) provide no durable assets. In addition, real estate in more accessible neighborhoods tends to retain its value better than in sprawled areas during real estate market declines, reflecting the value of urban accessibility (USEPA 2014). As a result, households tend to gain more long-term wealth by choosing smart growth over sprawl housing options. For example, in the short-term a smart growth house with a $20,000 annual mortgage and $5,000 annual transport expenses appears to have the same total costs as a sprawl location house with $15,000 annual mortgage and $10,000 transport expenses; both have $25,000 total annual expenses. However, after a decade the smart growth option, with higher housing and lower transport expenditures, typically generates $50,000 to $150,000 in additional household equity (wealth) compared with the sprawled location where $5,000 more is spent each year on vehicles and fuel rather than invested in real estate.

*Source: USEPA (2014), Smart Growth And Economic Success: Investing In Infill Development, U.S. Environmental Protection Agency (www.epa.gov); at www.epa.gov/smartgrowth/pdf/economicsuccess/Developer-Infill-Paper-508b.pdf.*

WHAT ARE THE INCREMENTAL COSTS AND BENEFITS OF SPRAWL?

This section describes various costs and benefits of sprawl, and factors that affect them.

Sprawl can have various economic, social and environmental impacts (benefits and costs). These result from two primary impacts: sprawl increases per capita land development, which reduces the amount of land available for openspace (farming and ecologically productive lands, and it disperses activities (homes, businesses, services, jobs, etc.), which increases infrastructure requirements (e.g., meters of roads and utility lines per capita) and the travel distances required to reach destinations, which, in turn, increases per capita motor vehicle travel. These have various economic outcomes such as reduced agricultural productivity, increased infrastructure and transport costs, and an increased need to import vehicles and fuel. Figure 8 illustrates these relationships.

Figure 8
Sprawl Resource Impacts
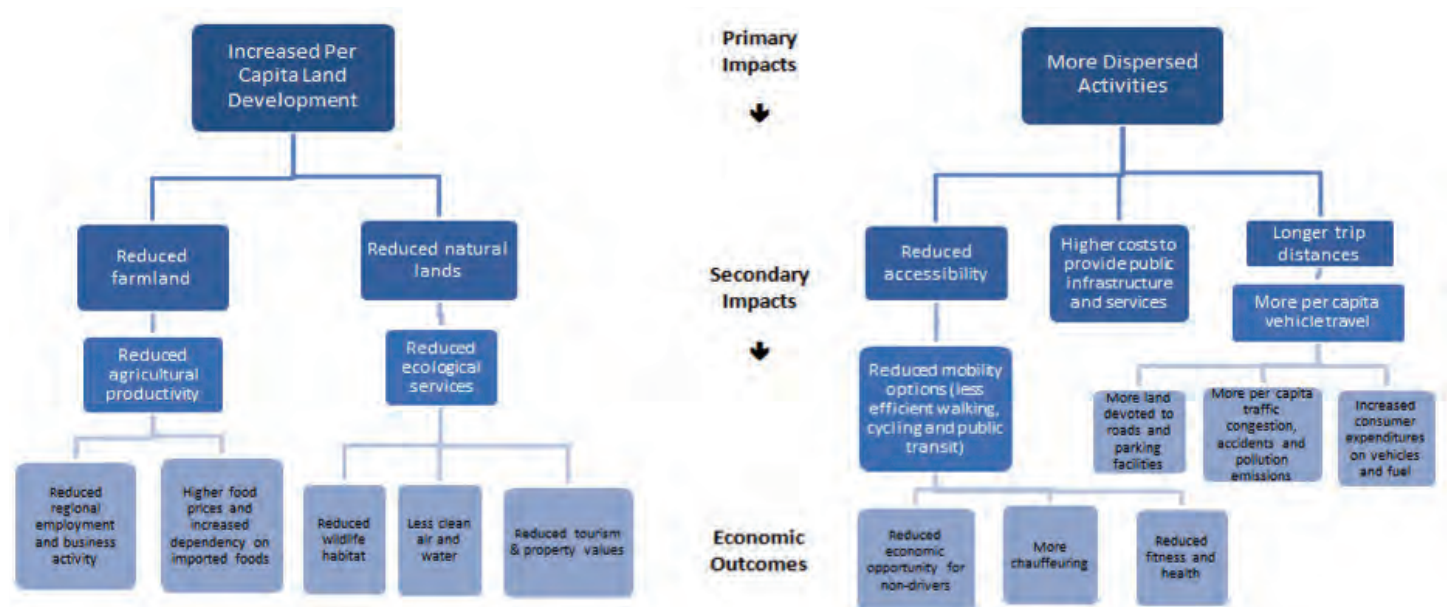
Sprawl has two primary resource impacts: it increases per capita land development, and it increased the distances between destinations, which increases per capita vehicle travel. These have various economic costs. This figure illustrates the relationships between these impacts.

Various studies have quantified and monetized (measured in monetary units) many of these impacts (Bartholomew, et al. 2009; Bhatta 2010; Burchell and Mukherji 2003; Ewing and Hamidi 2014; NHOEP 2012). Such studies vary in scope and methods. Some only consider infrastructure (road, utility, school, etc.) costs, while others also consider public service costs (emergency response, garbage collection, school busing, etc.). Some include transport costs (vehicle costs, accidents, fuel consumption and pollution emissions). Some include other economic, social and environmental impacts.

These studies also vary in geographic scale (neighborhood, city, region and country) and how sprawl is measured. Most studies have been performed in North America, since that is where debates about sprawl are most intense and suitable data most available. However, most of these economic impacts occur throughout the world so most of analysis results are transferable to developing countries, provided that they are scaled to reflect each city's demographic and geographic conditions.

The following section summarizes comprehensive sprawl cost studies and examines specific impacts in more detail.

Comprehensive Impact Studies

- A major study for the Transportation Research Board (a division of the U.S. National Academy of Sciences) titled, *The Costs of Sprawl – 2000* (Burchell, et al. 2002; Burchell and Mukherji 2003), identified various sprawl impacts, including:
  - Land conversion from farm and wild lands to housing and commercial development.
  - Water and sewage infrastructure.
  - Local roads.
  - Local public services.
  - Real estate development costs.
  - Increased vehicle travel and associated costs.
  - Residents' quality of life.
  - Urban decline (negative impacts on urban residents).

  The study monetized some of these impacts and estimated the net savings if growth management were applied in the U.S. between 2000 and 2025. Under a managed growth scenario a major portion of potential rural county development is shifted to urbanized counties, densities increase 20%, and the portion of households in attached (townhouse) and multi-family (apartment) housing increases by a quarter. The analysis indicates that managed growth reduces land consumption by 21% (2.4 million acres), reduces local road lane-miles 10%, reduces annual public service costs about 10% and housing costs about 8%, saving on average $13,000 per dwelling unit, or 7.8% of total development costs. This analysis only considers relatively modest smart growth policies (most new housing continues to be single-family) and so represents a lower-bound estimate of potential savings.

- The report, *The High Costs of Sprawl: Why Building More Sustainable Communities Will Save Us Time and Money*, (Environmental Defense 2013) identified various external costs of sprawl including higher infrastructure costs, loss of open space and farmland, increased driving and related health problems, increased air pollution emissions, and reduced community cohesion (positive interactions among neighbors). It calculates the costs of sprawled development and compares this with current development cost charges in various jurisdictions; it concludes that these fees fail to reflect the full incremental costs of sprawl, resulting in taxpayers in existing communities paying the additional costs of new sprawled development. It emphasizes the unfairness that results from these cross subsidies and external costs.

- The Utah's Governor's Office used an integrated transportation and land use impact model to predict regional, subregional and on-site infrastructure costs of various development scenarios in the Salt Lake City region. The results indicate that more compact and multi-modal development options, typically reduce total per capita land consumption 39%, water consumption 25%, infrastructure by 39%, and air pollution by 6%, as well as improving mobility options for non-drivers. *Utah's Governor's Office (2003), Municipal Infrastructure Planning and Cost Model User's Manual*, Utah Governor's Office of Planning and Budget (www.governor.state.ut.us); at www.governor.state.ut.us/planning/mipcom.htm. Also see www.fhwa.dot.gov/planning/toolbox/utah_methodology_infrastructure.htm.

- The report, *Suburban Sprawl: Exposing Hidden Costs, Identifying Innovations* (SP 2013), identified various government costs that tend to increase with sprawl (construction and maintenance of roads, sewers, water, community centres and libraries, plus fire protection, policing, and school busing) and compared the incremental costs with the incremental tax revenues. It concluded that incremental revenues from suburban developers and households rarely cover the full incremental costs of the new infrastructure. It also discussed various economic benefits of more compact development, including cost savings, agglomeration efficiencies, and support for social equity objectives.

- The report, *Measuring Sprawl*, calculated a Sprawl Index (although, since ratings increase with more compact development, it would be more accurate to call it a Smart Growth Index) score for 221 U.S. metropolitan areas and 994 counties based on four factors: density (people and jobs per square mile), mix (combination of homes, jobs and services), roadway connectivity (density of road network connections) and centricity (the portion of jobs in major centers). The index averages 100, so scores below 100 indicate sprawl and above 100 indicate smart growth. The table below summarizes the study's key results.

Table 6
Summary of Smart Growth Outcomes

Outcome	Relationship to Compactness	Impact of 10% Score Increase
Average household vehicle ownership	Negative and significant	0.6% decline
Vehicle miles traveled	Negative	7.8% to 9.5% decline
Walking commute mode share	Positive and significant	3.9% increase
Public transit commute mode share	Positive and significant	11.5% increase
Average journey-to-work drive time	Negative and significant	0.5% decline
Traffic crashes per 100,000 population	Positive and significant	0.4% increase
Injury crash rate per 100,000 population	Positive and significant	0.6% increase
Fatal crash rate per 100,000 population	Negative and significant	13.8% decline
Body mass index	Negative and significant	0.4% decline
Obesity	Negative and significant	3.6% decline
Any physical activity	Not significant	0.2% increase
Diagnosed high blood pressure	Negative and significant	1.7% decline
Diagnosed heart disease	Negative and significant	3.2% decline
Diagnosed diabetes	Negative and significant	1.7% decline
Average life expectancy	Positive and significant	0.4% increase
Upward mobility (probability a child born in the lowest income quintile reaches the top quintile by age 30)	Positive and significant	4.1% increase
Transportation affordability	Positive and significant	3.5% decrease in transport costs relative to income
Housing affordability	Negative and significant	1.1% increase in housing costs relative to income.

Source: Ewing and Hamidi 2014
**This table summarizes various economic, health and environmental impacts from more compact development.**

• A detailed study for Halifax, Nova Scotia (Stantec 2013) found that the most compact development scenario, which increased the portion of new housing located in existing urban centers from 25% to 50%, with reductions in suburban and rural development, reduced infrastructure and transportation costs by about 10%, and helped achieve other social and environmental objectives including improved public fitness and health, and reduced pollution emissions.

The following sections discuss specific categories of impacts.

Land Development

Land is a valuable and scarce resource. Sprawl increases the amount of land developed per capita. For example, at 5 residents per hectare, which is typical for North American suburbs, each resident uses about ten times as much land as in European cities with 50 residents per hectare, and 100 times as much land as residents of high-density Asian cities. These 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 (3,287,590 square kilometers), but at smart growth densities of 50 residents per hectare they require a much smaller 440,000 sq. kms, as illustrated in Figure 9.

Figure 9
Land Needed to Accommodate 2.2 Billion People At Various Densities
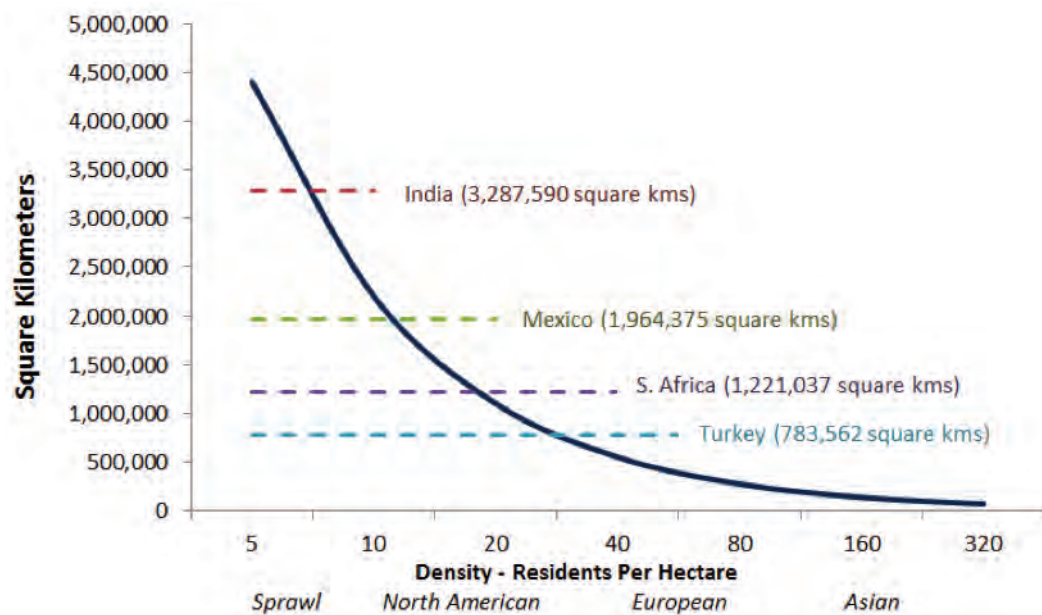
At sprawled densities, housing 2.2 billion new urban residents requires more land than the total area of India. Smart growth policies can reduce development area, leaving more land for farms and other openspace.

We sometimes say that sprawl consumes land but this is not really accurate since the land still exists after development occurs, but it is changed in ways that reduce some important benefits. Development displaces open space such as farmland, wetlands, parks and forests, and sometimes culturally significant sites. In addition to direct impacts, development can reduce the productivity of nearby lands, for example, by disrupting farming activities, disturbing wildlife, contaminating groundwater, and driving up land prices beyond what local residents can afford. This tends to reduce agricultural productivity and ecological services such as groundwater recharge, wildlife habitat, recreation and aesthetic values, which in turn, can require more expensive potable water sources or reduce economic activities such as tourism. Cities are often located in areas with highly productive farmlands, unique ecological lands, and important cultural sites, so these impacts can be large.

In addition to its direct benefits to owners, open space provides various external benefits to society (Harnik and Welle 2009; Litman 2009; 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 provide modest ecological benefits since they 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). These negative impacts can be reduced somewhat with design features such as rooftop gardens, street trees and pervious pavements, but this does not eliminate the importance of open space preservation. Below is a ranking of external benefits of various land use types.

Ranking of External Value of Land Use Types (McConnel and Walls 2005)
1. Shorelands and wetlands such as lake and marshes.
2. Unique natural lands such as forests and deserts, and cultural sites.
3. Farmlands
4. Parks and gardens
5. Lawns
6. Impervious surfaces (buildings, parking lots and roads)

Smart growth tends to reduce development area but increases its intensity, as indicated by the portion of land that is impervious surface. Described differently, smart growth tends to reduce land use impacts per capita but increases impacts per hectare of developed land. Figure 10 illustrates the impervious surface coverage of various land uses. Impervious surface typically represents 5-10% of land in suburban areas, 20-30% of land in compact urban neighborhoods, and 40-60% of land in dense commercial centers.

Figure 10
Surface Coverage
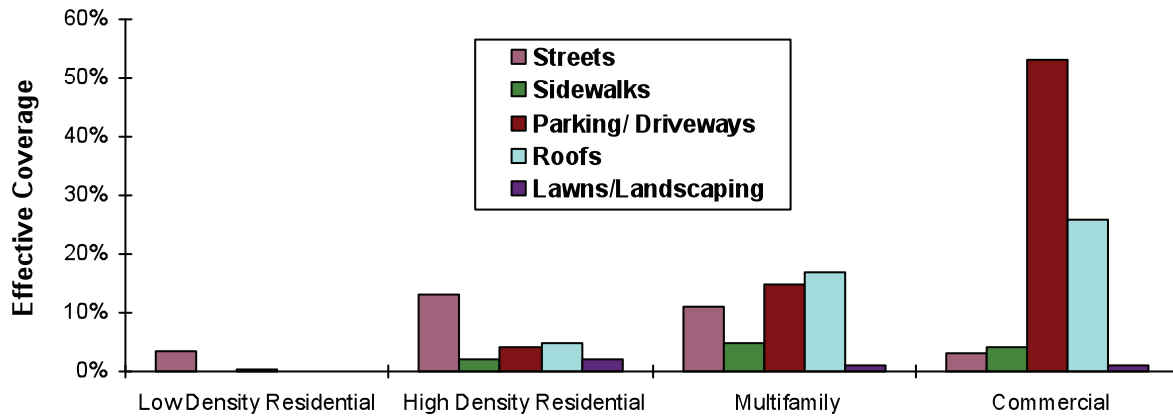
Arnold and Gibbons 1996
This figure illustrates land coverage in various urban conditions.

Sprawl tends to increase per capita road and parking area. Figure 11 shows how per capita lane-miles tend to decline with increased density. U.S. cities with less than 1,000 residents per square mile (approximately 8 residents per hectare) have nearly three times as much roadway area per capita as denser cities with more than 4,000 residents per square mile (approximately 30 residents per hectare). This suggests that sprawled communities require approximately 55 square meters of road area per motor vehicle, compared with 19 square meters in smart growth communities.

Figure 11
Urban Density Versus Roadway Supply
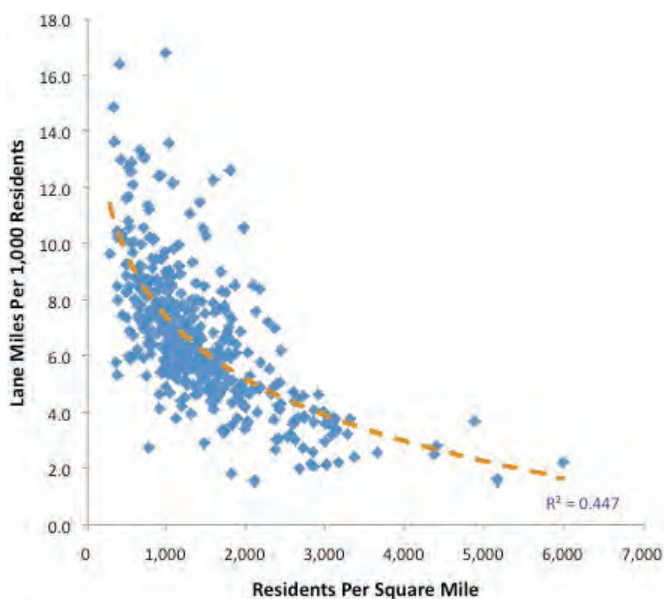
Source: FHWA 2012, Table HM72
As urban densities decline, per capita roadway increases. This increases infrastructure costs, hydrologic and stormwater management costs and environmental impacts. (Each dot represents a U.S. urban region.)

Motor vehicles also require parking facilities at each destination. A typical parking space is 2.4-3.0 meters wide and 5.5-6.0 meters deep, totaling 13 to 19 square meters ("Parking Costs," Litman 2009; ULI 2014). Off-street parking also requires driveways (connecting the parking lot to a road) and access lanes (for circulation within a parking lot), and so typically requires 28 to 37 total square meters per space. Various studies have estimated the number of parking spaces in a community (McCahill and Garrick 2012). Using detailed aerial photo analysis of Midwest urban areas, Davis, et al. (2010) estimated there are 2.5 to 3.0 off-street, non-residential parking spaces per motor vehicle. This represents a lower-bound estimate because it excluded residential, structured and covered parking. This and other studies suggest that in sprawled areas there are 2 to 6 off-street parking spaces per vehicle, using 60 to 200 square meters of land, with lower rates in smart growth areas where parking facilities are managed for efficiency. More compact, multi-modal development tends to reduce motor vehicle ownership, typically by 20-50% (Arrington and Sloop 2008), and allows more efficient parking management, such as more use of shared facilities that serve multiple destinations rather than single use parking lots (USEPA 2006). As a result smart growth development can significantly reduce per capita parking requirements.

This suggests that for convenient driving and parking, compact urban areas must devote 20 square meters of land to roads and 60 square meters to parking (two off-street parking spaces), totaling 80 square meters per vehicle. Sprawled areas must devote about 60 square meters to roads and 180 square meters to parking (six off-street parking spaces), totaling 240 square meters per vehicle, which is more than the amount of land typically devoted to an urban house, as illustrated in Figure 12.

Figure 12
Urban Density Versus Roadway Supply
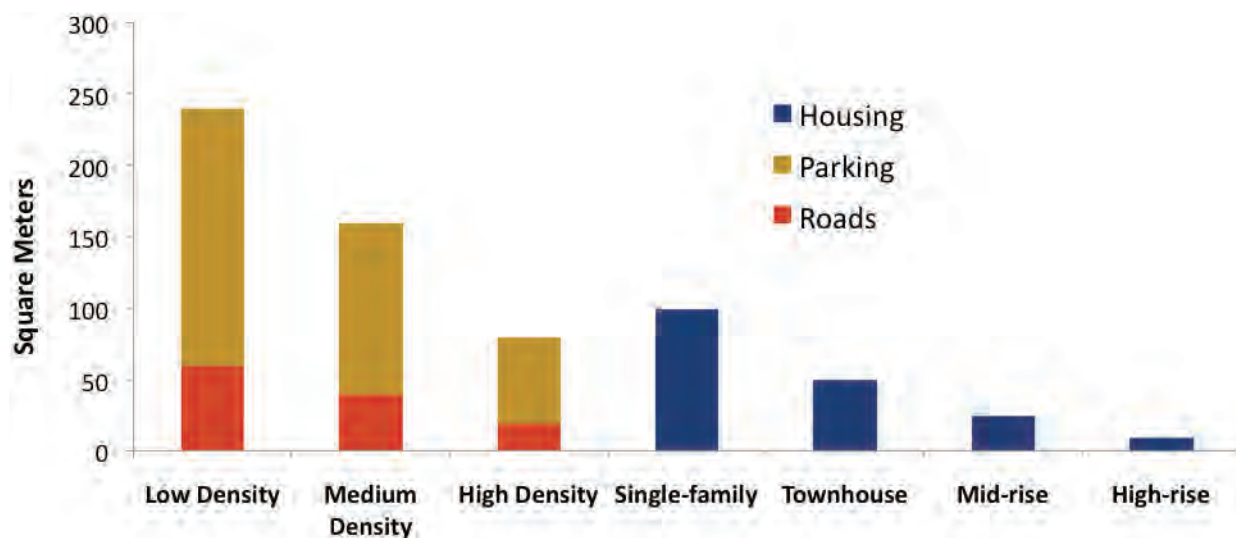
Source: FHWA 2012, Table HM72

In high density urban areas each automobile requires about 80 square meters of land for roads and off-street parking facilities. In lower-density, sprawled areas each automobile requires about 240 square meters of land for roads and parking, which significantly exceeds the amount of land devoted to most urban houses.

Figure 13 indicates total land area typically required for various housing types that provide the same 200 square meters of interior floor area. This illustrates how factors such as development density, building type, vehicle ownership, parking and road supply affect per capita impervious surface coverage.

Figure 13
Impervious Surface Area Of Various Housing Types
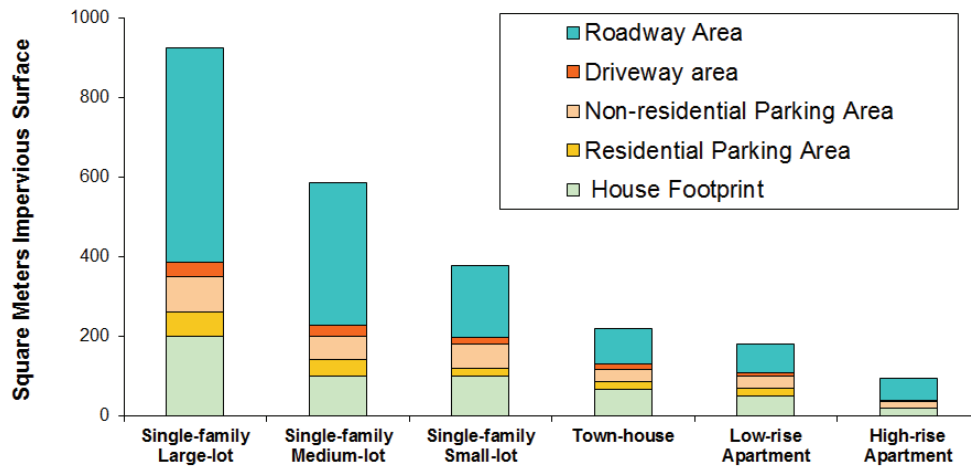
Source: Litman 2011b

Sprawl tends to increase per capita impervious surface (buildings and pavement) by encouraging lower larger building footprints and requiring more parking and roadway supply.

Because automobiles require so much land for roads and parking facilities, reducing vehicle ownership rates is a key strategy for reducing per capita land consumption. Figure 14 illustrates how the portion of urban land devoted to roads and parking increases with per capita vehicle ownership. This impact is particularly significant in compact cities where high vehicle ownership rates requires a major portion of land to be paved for roads and parking facilities. This reduces the amount of land available for building and greenspace, imposing economic and environmental costs.

Figure 14
Portion of Land Used for Roads and Parking[2]
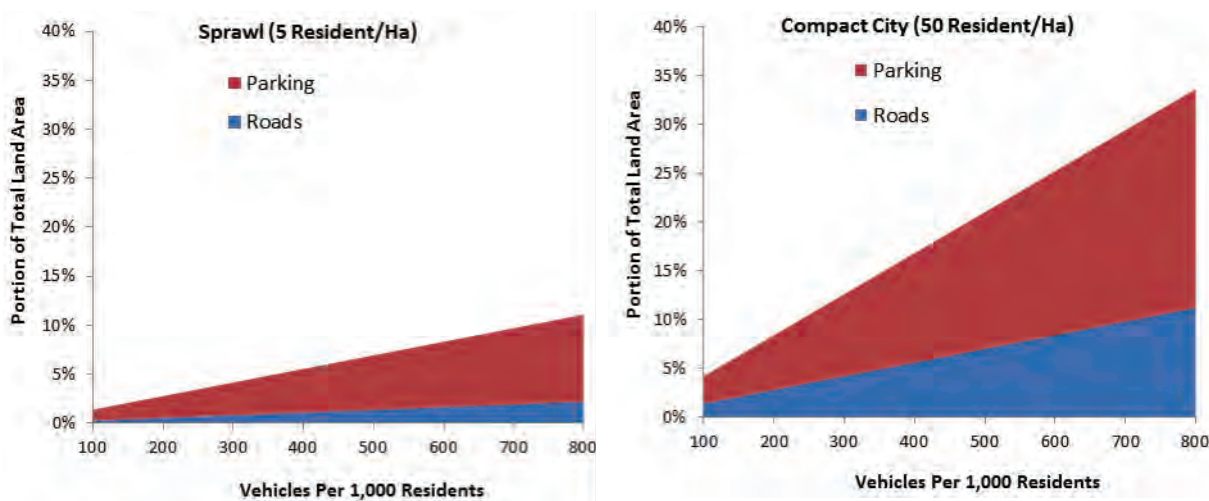
The portion of land devoted to roads and parking increases with vehicle ownership, which reduces the amount of land available for housing and urban greenspace. This impact is particularly significant in compact cities.

2   Assumes each vehicle requires 55 m2 of roads and 222 m2 of parking in sprawled areas, and 28 m2 of roads and 56 m2 of parking in compact cities.

A common justification for sprawl is that it increases residents' access to "nature" (open space). Sprawl advocates sometimes argue that urban living results in "nature deficit disorder." However, smart growth does include open space, including local and regional public parks, street trees and preserved farmlands. Although sprawl residents may have more private open space, they displace more total open space per capita, so sprawl residents can be considered to consume nature while smart growth residents preserve nature, resulting in more open space overall.

Open space external benefits are well recognized, including agricultural productivity, wildlife habitat, stormwater percolation, and support for tourism. The loss of these benefits can sometimes be quantified and monetized based on direct economic costs, such as reduced agricultural production or tourism activity, or increased stormwater management costs, or based on the value nearby residents place on greenspace (Banzhaf and Jawahar 2005; EDRB 2007; Litman 2009; McConnel and Walls 2005). However, there is no standard method for measuring total open space displacement costs. These costs tend to be particularly high for development that degrades high value farmlands, productive natural lands, or unique cultural sites."

Public Infrastructure and Service Costs

Dispersed development tends to increase the per capita length of roads and utility lines (water, sewage, power, etc.), and the travel distances needed to provide public services (garbage collection, policing, emergency response, etc.). Rural residents tend to accept lower service quality (unpaved roads, slower emergency response times, etc.) and provide many of their own services (well water, septic systems, garbage disposal, etc.), but suburban development tends to attract residents who demand urban quality services in dispersed locations, which increases government cost burdens (Stantec 2013). Various studies have quantified these costs.

- Burchell and Mukherji (2003) found that sprawl increases local road lane-miles 10%, annual public service costs about 10%, and housing costs about 8%, increasing total costs an average of $13,000 per dwelling unit, or about $550 in annualized costs.
- A Charlotte, North Carolina study found that a fire station in a low-density neighborhood with disconnected streets serves one-quarter the number of households at four times the cost of an otherwise identical fire station in a more compact and connected neighborhood (CDOT 2012).
- In a detailed analysis of 2,500 Spanish municipalities' expenditures, Rico and Solé-Ollé (2013) found that lower-density development patterns tend to increase per capita local public service costs.
- The Delaware Valley Regional Planning Commission (DVRPC 2003) estimated the infrastructure costs of five alternative development scenarios for the Philadelphia region. They found that roads, schools and utilities would cost $25,000 per household for the most compact scenario, 44% less than the $45,000 required by the most sprawled scenario. The compact option provides approximately $850 in annual savings per household.
- Analysis of options for accommodating 1.25 million additional residents and 800,000 additional jobs in Central Texas found $3.2 billion ($2,560 per capita) lower infrastructure costs if development is concentrated in existing urban areas, 70% less than the $10.7 billion ($8,560 per capita) required if lower-density development trends continue (Envision Central Texas 2003).
- Using data from three U.S. case studies, the study, Smart Growth & Conventional Suburban Development: Which Costs More? (Ford 2010) found that more compact residential development can reduce infrastructure costs by 30-50% compared with conventional suburban development.
- More compact development could save Calgary, Canada about a third in capital costs and 14% in operating costs for roads, transit services, water and wastewater, emergency response, recreation services and schools (IBI 2008).
- Building Better Budgets: A National Examination of the Fiscal Benefits of Smart Growth Development (SGA 2013) found that smart growth development costs one-third less for upfront infrastructure costs and saves an average of 10% on ongoing public services costs.
- The Utah Governor's Office (2003) sponsored the Municipal Infrastructure Planning and Cost Model (MIPCOM), an easy-to-use spreadsheet model that estimates how factors such as development location and density affect various costs including regional (regional roads, transit and water supply facilities), subregional (water, sewage and stormwater networks, and minor arterials) and on-site infrastructure (local roads, water and sewer lines, stormwater systems, telephone, electricity, etc.).

These relationships are complex (Ewing 1997). Denser, infill development can increase some costs due to higher design standards and infrastructure development costs in dense areas, and sometimes brownfield remediation (cleaning up hazardous conditions such as polluted soils), but such costs are not significantly related to development density. A tall building has similar utility connection and brownfield remediation costs as a smaller building, so unit costs often decline with smart growth policies that allow higher densities. Critics argue that sprawl infrastructure costs are exaggerated (Cox and Utt 2004; Richardson and Gordon 1997), citing studies which indicate that per capita government expenditures are often higher in higher-density counties, although such aggregate analyses do not account for important factors such as the tendency of rural residents to supply their own utilities and services (such as water, sewage and garbage collection), and incomes (including those for municipal employees which tend to be higher in larger cities, so urban-rural differences are smaller when measured as a portion of income), and the additional public service costs borne by cities because they contain a disproportionate share of businesses and low income residents (Litman 2015). In addition, such aggregate analysis, which only considers population density at a jurisdictional scale, does not accurately reflect smart growth policies which include other factors related to the location and type of development that occurs within a jurisdiction. Two cities or counties can have the same overall density but differ significantly to the degree that they reflect smart growth principles. If evaluated at an aggregate scale, any smart growth public service cost savings would be invisible.

This review indicates that numerous credible studies demonstrate that sprawl typically increases the costs of providing a given level of infrastructure and public services by 10-40%, and sometimes more. These studies reflect lower-bound impacts since most only consider a subset of total public service costs and relatively modest smart growth policies, such as more compact single-family development, as opposed to substantial shifts from single-family to multi-family housing. Comprehensive smart growth policies that result in greater density increases can provide even larger savings and efficiency benefits.

Transportation Costs

Sprawl increases the distances that must be traveled to reach activities and reduces the efficiency of walking and public transit, and so tends to increase per capita vehicle travel (CTS 2010; Rode and Floater 2014). It typically increases motor vehicle travel 20-50%, and reduces walking, cycling and public transit use by 40-80%, compared with compact, multi-modal development (Ewing and Cervero 2010; JICA 2011; Mackett and Brown 2011; Marshall and Garrick 2012; USEPA 2013; Zhang, et al. 2012).

To understand how these development patterns affect travel activity, consider how residents make common trips. In sprawled communities, most trips are made by automobile due to inadequate alternatives and dispersed destinations. Smart growth communities have more diverse transport systems and shorter distances between destinations so most local errands are made by walking and cycling, many trips along major travel corridors are made by public transit, and trips are shorter. As a result, smart growth community residents typically drive 20-60% fewer annual kilometers than in sprawled, automobile-dependent areas.

The increased vehicle travel in sprawled communities increases various costs (Ewing, et al. 2007). For example, Ewing and Hamidi (2014) find that a 10% change in their sprawl index increases household transport expenditures 3.5% and auto commute travel time 0.5. Kuzmyak (2012) found that households in more compact, mixed neighborhoods experience less traffic congestion delay than residents of sprawled neighborhoods. Conventional transport economic evaluation tends to overlook many of these impacts and so underestimates the full costs of policies that increase vehicle travel. For example, when evaluating transport or land use policies, conventional evaluation usually ignores the incremental road and parking facility costs caused by planning decisions that stimulate vehicle ownership and use, and so underestimates the benefits of improving alternative modes and more compact development.

Several studies have monetized these costs (Becker, Becker and Gerlach 2012; Litman, 2009; Maibach, et al. 2009; Park 2009; Timilsina and Dulal 2011; Zhang, et al., 2005), including some in developing countries (Adaku 2014; JICA 2011; Zegras 1997). Figure 15 illustrates one comprehensive estimate. These costs are classified as internal-fixed (vehicle ownership and residential parking), internal-variable (travel time, vehicle operation and vehicle occupants' uncompensated crash injuries), and external costs (accident risk, congestion, parking costs and environmental damages imposed on other people).

Figure 15
Estimated Urban Automobile Costs
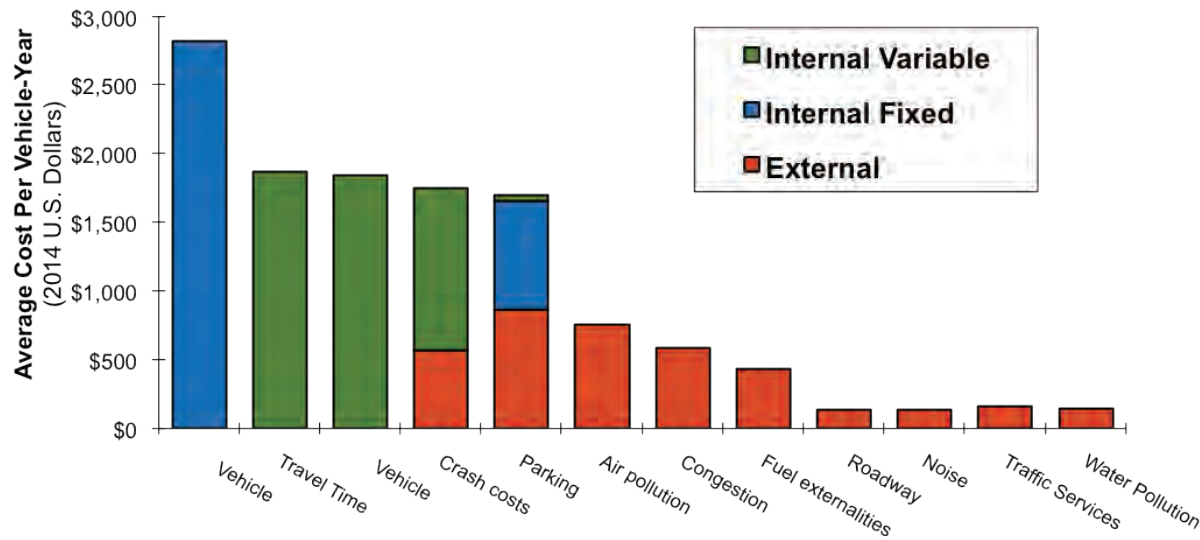
Source: based on Litman 2009
This figure illustrates the estimated costs of motor vehicle ownership and use.

These studies indicate that motor vehicle ownership has fixed costs that average $2,000-4,000 per vehicle-year, internal-variable costs (vehicle operation, travel time and users' accident risk) that average 20-50¢ per vehicle-kilometer, plus external costs (parking subsidies, crash risks imposed on other road users, congestion, air and noise pollution, and roadway costs not borne by user fees) that average 20-60¢ per vehicle-kilometer, with higher external costs under urban-peak conditions. Some of these costs may be somewhat lower in developing countries. Sprawl impacts on traffic safety and health are discussed in more detail below.

Traffic Risk

One particularly important transport cost is traffic accident risk. Various studies using a variety of analysis methods and data sets indicate that sprawl increases traffic casualty (injury and death) rates. For example, comparing 280 U.S. counties, per capita traffic fatality rates are about five times higher in the ten most sprawled counties compared with the ten smartest growth counties, as indicated in Figure 16.

Figure 16
Annual Traffic Death Rate
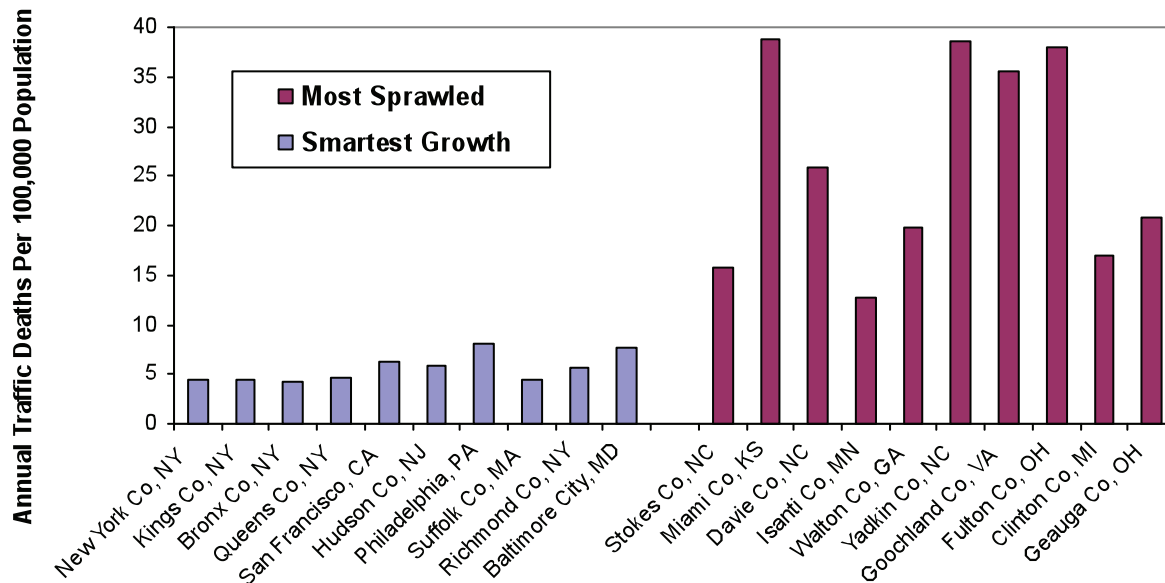
Source: Ewing, Schieber and Zegeer 2003
The ten counties with the lowest sprawl rating have about a quarter of the per capita annual traffic fatality rates of the most sprawled counties.

Ewing and Hamidi (2014) found that a 10% increase in their smart growth index reduces per capita crash fatality rates by 13.8%. Dumbaugh and Rae (2009) analyzed crash rates in San Antonio, Texas neighborhoods. Accounting for various demographic and geographic factors they found that:

* Increased vehicle travel tends to increase crash rates, with approximately 0.75% more crashes for every additional million miles of vehicle travel in a neighborhood.
* Population density is significantly associated with fewer crashes, with each additional person per net residential acre decreasing crash incidence 0.05%.
* Each additional mile of arterial roadway is associated with a 15% increase in total crashes.
* Each additional arterial-oriented retail or commercial parcel increased total crashes 1.3%, and each additional big box store increased total crashes 6.6%, while pedestrian-scaled commercial or retail uses were associated with a 2.2% reduction in crashes.
* The numbers of both young and older drivers were associated with increased total crashes.
* Each additional freeway mile within a neighborhood is associated with a 5% increase in fatal crashes, and each additional arterial mile is associated with a 20% increase in fatal crashes.

Scheiner and Holz-Rau (2011) find considerably higher per capita crash injury rates in suburban and rural locations than in urban areas in Germany. Evaluating factors that affect crash rates in California cities, Garrick and Marshall (2011) found that more compact, connected and multi-modal urban areas have about a third of the traffic fatality rates as those that are more sprawled, automobile dependent.

Safer Cities
- 106/sq mile average intersection density.
- 16% walking/biking/transit mode share.
- 3.2 average annual traffic deaths per 100,000 population.

Less Safe Cities
- 63/sq mile average intersection density.
- 4% walking/biking/transit mode share.
- 10.5 average annual traffic deaths per 100,000 population.

Several factors help explain why sprawl causes such large increases in crash casualty rates. Sprawl increases total vehicle travel, including higher-risk driving (youths, seniors, alcohol drinkers, etc.) because they lack alternative mobility options. Sprawl also increases traffic speeds, which increases the severity of crashes which occur, and increases emergency response times.

Traffic casualty rates tend to be particularly high in lower-income countries and decline with economic development. Figure 17 compares traffic fatality rates of various world cities. Most lower-income cities have more than 20 deaths per 100,000 residents, compared with 10-20 deaths in North American cities, and fewer than 5 deaths in high-income European and Asian cities.

Figure 17
Traffic Death Rates For Selected Cities
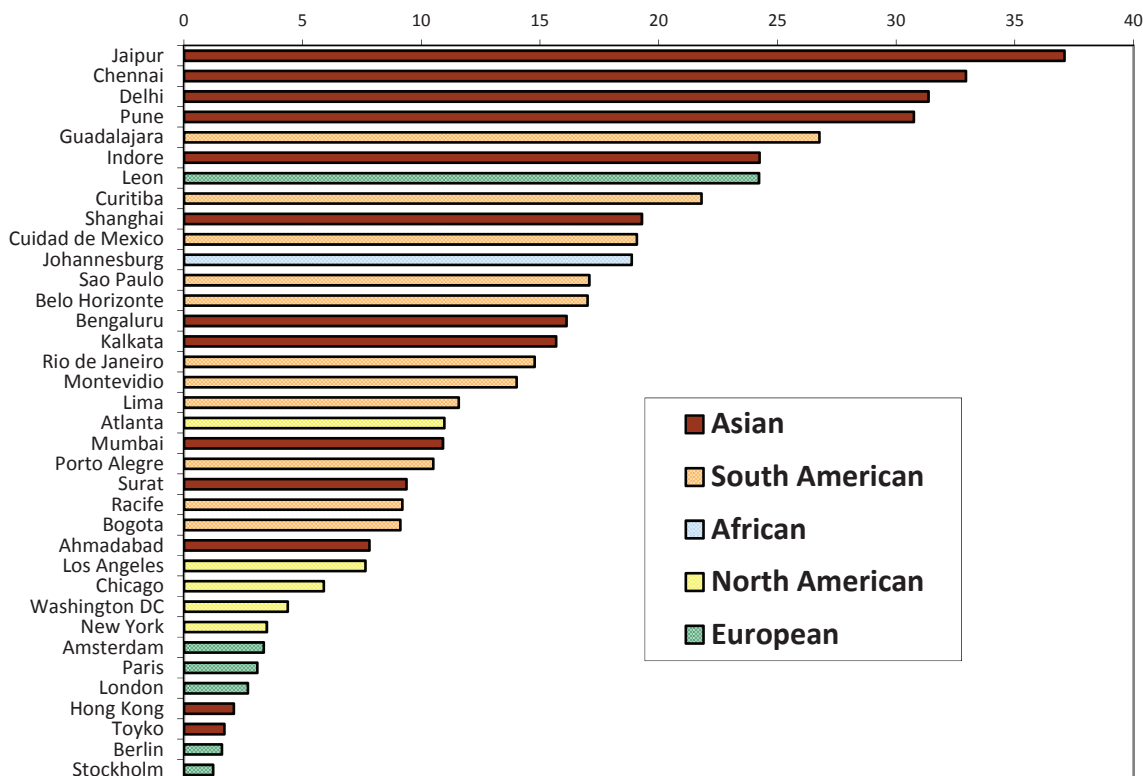
Source: Welle 2014

Traffic fatality rates tend to be highest in lower-income cities and decline as they develop economically, but the amount they decline depends on transport and land use policies. The lowest fatality rates occur in affluent cities with aggressive policies that limit automobile traffic, such as Berlin, Hong Kong, London, Stockholm and Tokyo.

This indicates that, all else being equal, sprawl increases traffic risk. Sprawled areas typically have two to five times the traffic fatality rates as in smart growth communities Very low crash casualty rates (under 5 annual traffic fatalities per 100,000 residents) generally require a combination of smart growth development and transportation demand management strategies, as indicated in Figure 18.

Figure 18
Traffic Deaths Trends

Traffic fatalities per 100,000 residents typically average 20-30 in developing country cities, 10-20 in affluent, automobile-dependent cities, 5-10 in affluent, compact cities, and just 1.5-3 in affluent, compact cities with strong transportation demand management (TDM) programs.

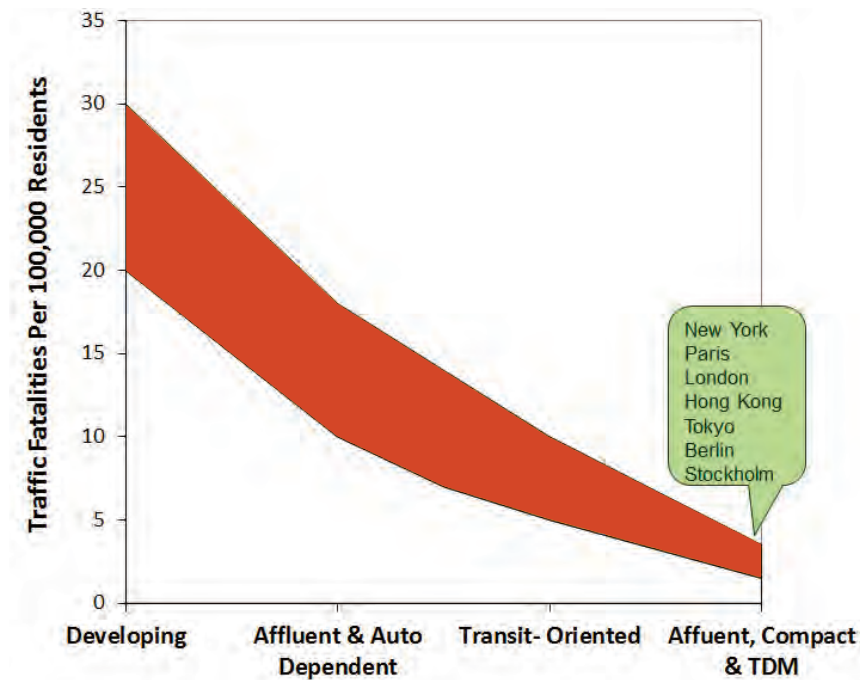There is extensive literature on traffic crash costs (Blincoe, et al. 2014; EDRG 2007; Litman 2009; Zhang, et al. 2005). Some studies only consider direct economic costs, such as vehicle damages, emergency response, medical and disability expenses, and lost productivity due to crashes; others also include pain and suffering, which results in substantially higher cost estimates. Described differently, the value of preventing accidents tends to be much higher than economic damages or compensation costs of accidents that occur. In 2009, the U.S. Department of Transportation valued a statistical life at $6.0 million, with lower values for various types of non-fatal crashes (Trottenberg 2011). A major portion of these costs are external (i.e., borne by somebody other than the individual making a travel decision), although there is some debate concerning how these externalities should be calculated (Edlin and Mandic 2001). Total crash costs are estimated to range from about 10¢ to 30¢ per vehicle-kilometer in developed countries, and can be scaled to other countries based on incomes (IRAP 2009).

Public Fitness and Health

Sprawl tends to increase sedentary living, and therefore obesity rates and associated health problems (Frumkin, Frank and Jackson 2004; 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 (Ball, et al. 2009; CDC 2009).

Frank, et al. (2010) measured how neighborhood walkability factors affect residents' travel activity, physical activity and fitness. They found that after normalizing for other factors:

- Adults living in the top 25% most walkable neighborhoods walk, bike and take transit 2-3 times more, and drive approximately 58% less than those in more auto-oriented areas.
- Residents living in the most walkable areas were half as likely to be overweight than those in the least walkable neighborhoods.
- Living in a neighbourhood with at least one grocery store was associated with a nearly 1.5 times likelihood of getting sufficient physical activity, as compared to living in an area with no grocery store, and each additional grocery store within a 1-kilometer distance from an individual's residence was associated with an 11% reduction in the likelihood of being overweight.

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). The study examined the impact of urban planning on active living in metropolitan Perth, Western Australia. The study found that for every local shop, residents' physical activity increased an extra 5-6 minutes of walking per week, and for every recreational facility available such as a park or beach, residents' physical activity increased by another 21 minutes per week. 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. For the average American with a life expectancy of 78 years, doubling the index translates into a three year difference. However, increased urban densities can increase some health risks such as exposure to noise and local air pollutants. Public safety and health therefore justifies smart growth strategies that create communities where residents drive less and rely more on active modes, plus targeted strategies to reduce urban noise and air pollution emissions.

Overall, sprawled community residents are less safe and healthy than in smart growth communities (Lucy 2003; Myers, et al. 2013).

Various studies have monetized active travel health benefits (Ball, et al. 2009; Fishman, et al. 2012). Applying values of statistical life commonly used to calculate crash casualty costs indicates that each additional kilometer of walking and cycling provides $1.00 to $3.00 in health benefits (WHO 2014).

Energy Consumption and Pollution Emissions

By increasing motor vehicle travel, building heating requirements (due to more single-story buildings) and infrastructure energy requirements (e.g., longer utility lines which increases embodied energy, water and sewage pumping loads, street lighting, etc.) sprawl tends to increase per capita energy consumption and associated pollution emissions (Ewing and Rong 2008; Lefèvre 2009; Litman 2011). Figure 19 illustrates one estimate of how housing type affects energy consumption in U.S. conditions.

Figure 19
Household Transportation Energy Use By Location
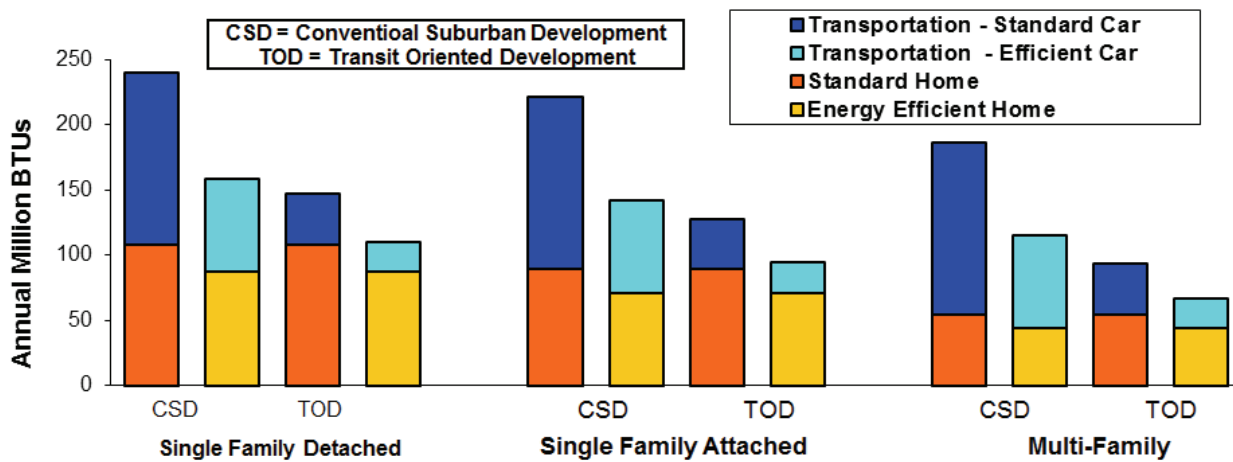
Source: JRC 2011

Housing location and type have more impact on household energy use than vehicle or home efficiency.

Other studies indicate that more compact development can provide substantial energy savings (Ewing, et al., 2009; UNEP 2011). For example, at similar wealth levels, sprawling Atlanta produced six times more transport-related carbon emissions than relatively compact Barcelona, as illustrated in Figure 20 (ATM 2013; D'Onofrio 2014; LSE Cities 2014). Even modest policy changes can have large impacts. For example, increasing from less than 20 to more than 40 residents per hectare typically reduces per capita transport energy consumption by 40-60%, as illustrated in Figure 21.

Figure 20
Land Use Impacts on Transport Emissions

ATLANTA

Population	Urban area	Transport carbon emissions p.c
5.3 million	**7,692** km²	**6.9** tonnes

BARCELONA

Population	Urban area	Transport carbon emissions p.c
5 million	**648** km²	**1.16** tonnes
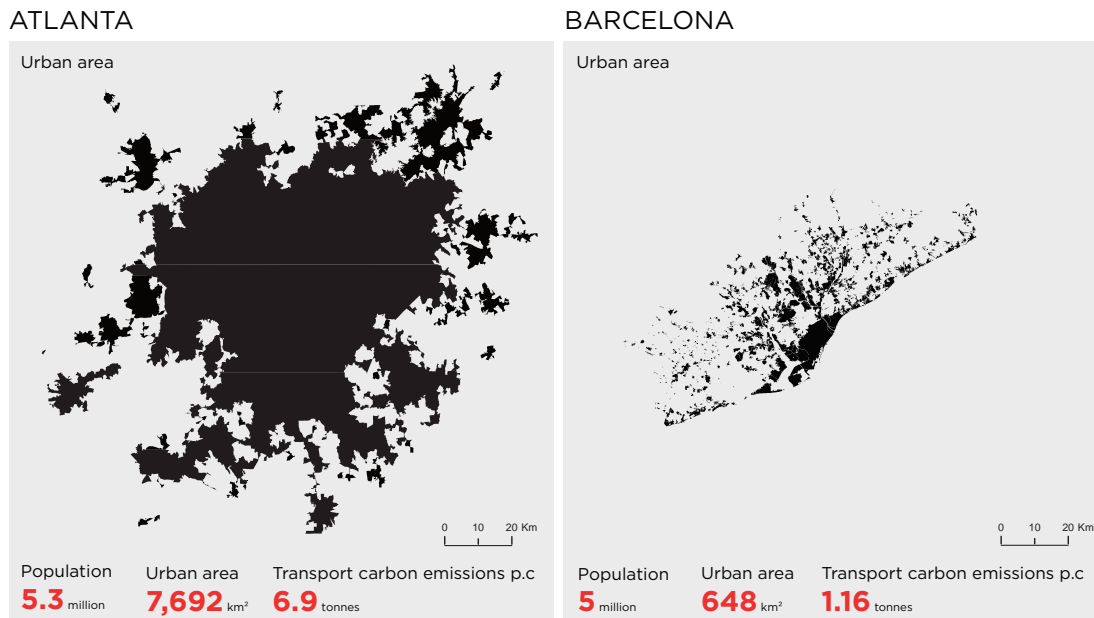
Source: LSE Cities 2014

More compact development can reduce transport emissions by an order of magnitude.

Critics argue that there is no evidence that compact development reduces pollution emissions (Fruits 2011), but that research has been discredited (Litman 2011).

Figure 21
Urban Density and Transport-Related Energy Consumption
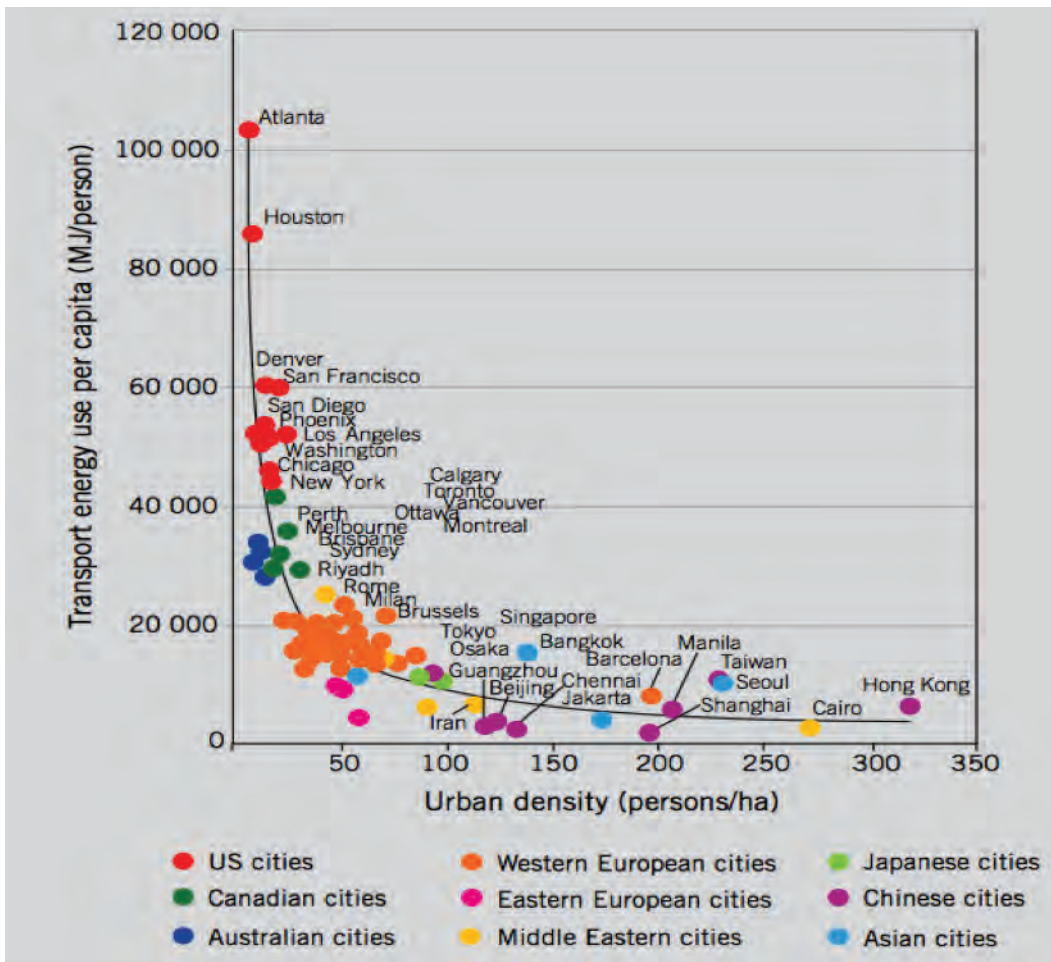
Source: WHO 2011
Energy efficiency tends to increase with densities, particularly from 5 to 50 residents per hectare.

Energy consumption and pollution emissions impose various external costs. These include fuel subsidy costs, environmental costs of petroleum production, economic costs of importing fuel, political and military costs of maintaining access to petroleum markets (for example, U.S. military interventions in Iraq), and various pollution health and environmental damage costs (CE, INFRAS, ISI 2011; del Granado and Coady 2010; Litman 2009; Maibach, et al. 2009; NRC 2009; Park 2009; Timilsina and Dulal 2011; Zhang, et al., 2005). Some of these studies include monetized estimates of these external costs. Aggregating these together indicates that total energy external costs are 10-50% of the internal costs (i.e., if fuel prices are $1.00 per liter, external costs are 10-50¢ per liter), depending on which costs are included, how they are calculated and when and where the energy is consumed. Fuel subsidy and import economic costs tend to be particularly large for lower-income countries that are heavily dependent on imported petroleum. Pollution costs tend to be particularly large in dense cities.

Social Equity

Social equity refers to the distribution of impacts (benefits and costs), and the degree that this is considered fair and appropriate (DfT 2014; Litman 2002). Sprawl can have various social equity impacts:

- To the degree that sprawl increases external costs, it is horizontally inequitable. As previously discussed, sprawl tends to increase the costs of providing public services, which causes urban residents to cross-subsidize these costs (Blais 2010). Sprawl also increases vehicle travel, and therefore road and parking facility costs, congestion, accident risk and pollution costs imposed on other people. Unless these are efficiently priced with significantly higher development fees, utility rates and taxes in sprawled areas, plus road tolls, parking fees and fuel taxes to internalize all vehicle costs, sprawl tends to be horizontally inequitable.
- Sprawl tends to degrade walking and cycling conditions, and public transit service quality, and increases the distances between destinations, which reduces non-drivers accessibility and increases transport financial costs (CNT 2013). This tends to harm physically, economically and socially disadvantaged groups, leading to social exclusion (physical, social and economic isolation). This is vertically inequitable.
- Sprawl tends to reduce single-family housing costs, but tends to reduce compact housing options and increases household transport costs. This benefits some households (those that prefer larger-lot housing and automobile travel) but harms others (those that prefer adjacent and multi-family housing, and cannot drive).

This indicates that sprawl can reduce social equity by imposing unjustified external costs, and reducing affordable housing and transport options used by disadvantaged populations. Social equity is an important planning objective. There are various ways to evaluate it, for example, by quantifying specific impacts, and using stakeholder surveys to assess a community's social equity objectives and priorities (Arora and Tiwari 2007; CTE 2008; DFID 2013; DfT 2014; EDRG 2007; Litman 2002). There are no standard methods for monetizing social equity impacts.

Social Problems

Social problems such as poverty, crime, and mental illness tend to be more concentrated and visible in cities. This occurs because poor people tend to locate in cities in order to access services and economic opportunities (Glaeser, Kahn and Rappaport 2008), while suburbs tend to exclude disadvantaged people by discouraging affordable housing and affordable transport modes (walking, cycling and public transit). As a result, suburban residents tend to be more economically successful and satisfied than urban residents (Mathis 2014; NAR 2013). People sometimes assume that denser development increases social problems and lower density development can reduce them. However, this confuses cause and effect. There is actually no evidence that compact development increases total poverty, crime or mental illness (1000 Friends 1999), on the contrary, research suggests that smart growth policies can reduce total social problems.

For example, studies show that more compact, multi-modal development tends to increase poor resident's economic opportunity by reducing concentrated poverty and improving access to education and employment (Cortright and Mahmoudi 2014). Using data from the Equality of Opportunity Project (Chetty, et. al. 2014), Ewing and Hamidi (2014) found that in the U.S., each 10% increase in their smart growth index is associated with a 4.1% increase in residents' upward mobility (probability a child born in the lowest income quintile reaches the top quintile by age 30).

All else being equal, per capita crime rates tend to decline with urban density and mix (Litman 2014c). 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) analyzed residential burglary and robbery rates in an economically and socially diverse London neighborhood. They found that, all else being equal, these crime rates were inversely related to the number and density of dwellings on a street, on both through streets and cul-de-sacs. For example, the mean cul-de-sacs burglary rate is 0.105, but those with fewer than 11 dwellings have a higher 0.209 rate. Similarly, grid street segments with more than 50 dwellings have 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 crime are lower if commercial and residential buildings are located close together.

Similar impacts occur in developing country cities: crime rates declined after the TranMilenio Bus Rapid Transit system started operating in Bogota's lower-income neighborhoods. Overall, cities tend to be safer and healthier than sprawled communities (Lucy 2003). Several factors can help explain how smart growth tends to reduce crime rates. More compact, mixed development reduces poverty concentration and increases disadvantaged people's economic opportunity, it increases passive surveillance (by-passers who might report threats and intervene in conflicts), it can improve policing efficiency and response times, and it reduces the large number of motor vehicle crimes such as vehicle thefts and assaults. Figure 22 illustrates how smart growth can contribute to a positive security cycle.

Figure 22
The Positive Security Cycle
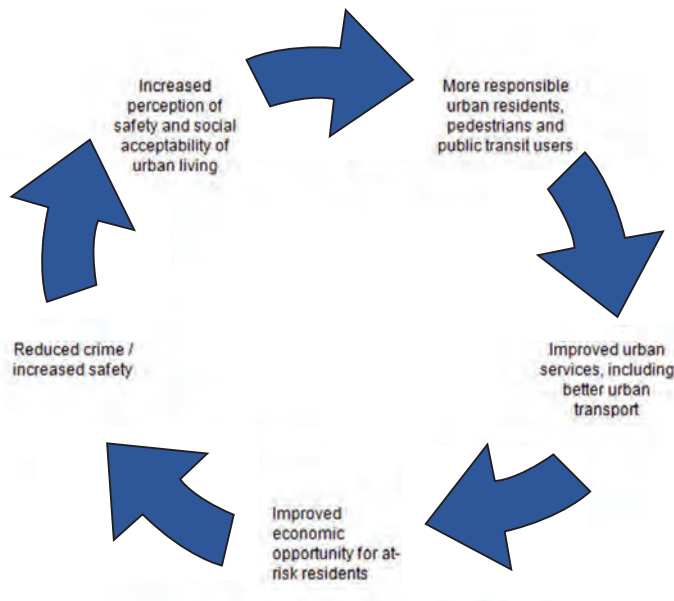
Communities tend to become safer as more compact and mixed development increases the number of responsible (non-criminal) people who live and walk in an urban neighborhood, creating a positive feedback cycle.

Poverty, crime and mental illness impose large costs on individuals and society, so reducing these problems is an important planning objective. However, they are difficult to measure so there is no standard way to quantify or monetize the amount that sprawl increases these cost (CTE 2008; DFID 2013; DfT 2014; EDRG 2007).

Affordability

Affordability refers to households' ability to afford basic goods such as 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).

Sprawl tends to reduce some household costs but increase others, as indicated in Table 7. It allows development of inexpensive urban-fringe land, which reduces land costs per hectare but increases lot size and therefore land per housing unit. Pro-sprawl policies such as minimum lot sizes, building density and height limits, restrictions on multi-family housing and minimum setback requirements tend to reduce development of less expensive housing types, such as adjacent and multi-family housing. Sprawl increases residential parking costs and total transport expenses (Glaeser and Ward 2008; Ewing and Hamidi 2014). As previously described, sprawl increases the costs of providing infrastructure and public services which can increase housing costs and general tax burdens.

Table 7
Sprawl Household Affordability Impacts

Increases Affordability	Reduces Affordability
• Reduces land unit costs (per square meter). • Reduces some infrastructure requirements (curbs, sidewalks, sound barriers, etc.).	• Increases land use per housing unit • Reduces affordable (adjacent and multi-family) housing options. • Increases parking requirements and associated costs. • Increases transport costs. • Increases infrastructure and utility costs.

Sprawl reduces some household costs but increases others.

Critics claim that by restricting urban expansion, smart growth reduces housing affordability (Cheshire 2009; Demographia 2009; Mildner 2014) but their analysis is incomplete. Restrictions on urban expansion may increase land unit costs (per square meter), but smart growth reduces other costs including land required per housing unit, residential parking requirements, infrastructure and utility costs, and household transport expenses. As a result, smart growth policies can increase affordability overall, particularly for lower-income urban residents who live in multi-family housing and rely on walking, cycling and public transit.

Academic studies indicate that regulations that restrict development density and require large amounts of parking are a major cause of housing inaffordability (Ganong and Shoag 2012; Manville 2010; Nelson, et al. 2002). Lewyn and Jackson (2014) analyzed land use regulations in 25 typical jurisdictions. They found that sprawl-inducing regulations, such as density limits and minimum parking requirements, are far more common than sprawl-reducing regulations such as urban growth boundaries, parking maxima and density minima.

Overall, low-rise, wood frame, multi-family housing in accessible, multi-modal neighborhoods tends to be most affordable type of housing to develop because it minimizes land, construction and parking costs. High-rise, concrete buildings cost more to construct but require less land per unit, and so become cost-effective when land prices are very high (over about $10 million per hectare), as illustrated in Figure 23. This indicates that smart growth policies that encourage development of low-rise, multi-family housing in accessible, multi-modal neighborhoods tends to maximize overall affordability.

Figure 23
Typical Building Construction Costs (ICC 2014) [3]
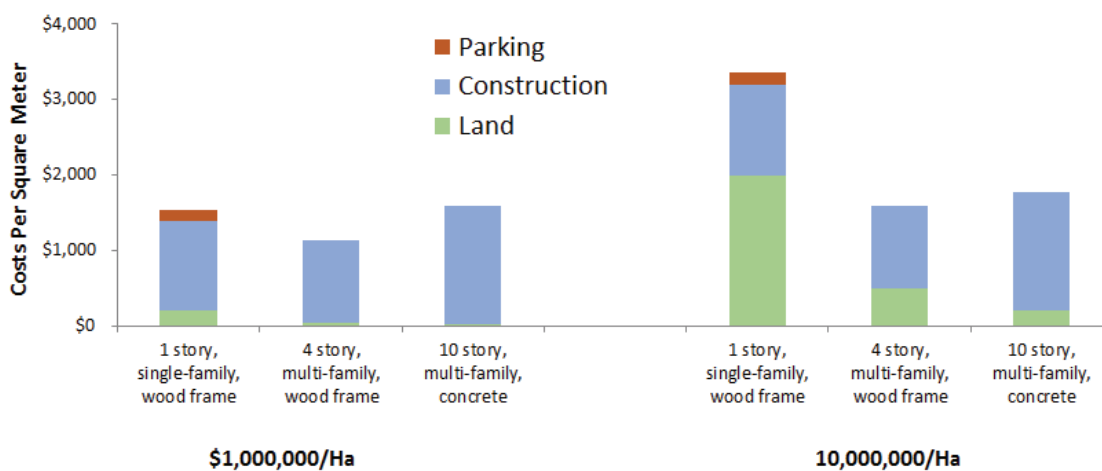
Wood frame tends to have the lowest construction costs. Concrete construction costs about 50% more, but can be taller, which reduces land costs and so becomes cost-effective with high land prices.

Critics cite correlations between density and housing costs as evidence that smart growth policies reduce housing affordability (Cox and Pavletich 2015), but their analysis is incomplete. Cox and Pavletich (2015) appear to oversample single-family housing, ignore utility and transport costs, and exclude the often substantial portion of lower-priced housing that is supplied by government agencies and non-profit organizations, or obtained informally (Arnott 2009; Litman 2015). Denser cities tend to have higher average incomes and lower transport costs, so residents can afford to spend more on housing. Geographic features such as shorelines and mountains tend to limit urban expansion and make a city attractive, which increases real estate prices. It is the combination of restrictions on expansion and on higher density infill development which tend to reduce housing affordability (Cutler 2014). These factors tend to exaggerate actual housing costs and housing inaffordability problems in more compact cities.

A few 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.

3 Construction cost data from the International Code Council's Building Validation Data – August 2014 (www.iccsafe.org/cs/Documents/BVD/BVD-0814.pdf) for R-3 Residential, VB ($111.36/sf), R-2 Residential, VB ($101.14/sf), and R-2 Residential, IB ($145.39/sf), assuming 50% lot coverage, and 10% additional costs for parking for single-family housing. For more analysis of urban building costs see Chung (2014).

Economic Development

Economic development refers to progress toward a community's economic objectives including increased productivity, employment, incomes, property development and tax revenues. Both theoretical and empirical evidence indicates that sprawl tends to reduce economic development because it (Ecola and Wachs 2012; Kooshian and Winkelman 2011):

- Increases per capita land consumption, which leaves less land for agriculture.
- Reduces accessibility and agglomeration efficiencies (Melo, Graham, and Noland 2009).
- Increases transport costs including road and parking facilities, accidents and pollution damages.
- Increase public infrastructure and service costs, which tends to increase tax and utility costs.
- Increase expenditures on vehicles and fuel, which most regions must import. This tends to reduce local employment and business activity.

When cities at similar levels of economic development are compared, more compact and multi-modal cities tend to be more economically productive than sprawled, automobile-dependent cities (Litman 2014a). Compact development is particularly important for knowledge-based industries such as education, technology and the arts (Abel, Dey, and Gabe 2011).

Of course, motor vehicle transport contributes to economic productivity in many ways: it delivers raw materials, distributes final products, and transport employees to worksites, but like most economic inputs, there is an optimal level beyond which marginal costs exceed marginal benefits (McMullen and Eckstein 2011; Litman 2014a). Policies that increase land use accessibility and transport system efficiency are likely to support economic productivity, while policies which underprice motor vehicle travel and encourage sprawl tend to reduce economic productivity overall. For example, Hsieh and Moretti (2014) analyzed the economic impacts of density-limiting policies in large, highly-productive U.S. cities. They estimate that such policies reduce aggregate national economic output by 13%, or more than $1 trillion annually.

External Benefits of Sprawl?

Sprawl can provide various benefits, including larger residential lot sizes which allow residents to have larger gardens and more privacy, reduced exposure to noise and some air pollutants, lower crime rates and better schools (Burchell, et al, Table ES-17). However, these are mostly internal benefits or economic transfers (one group benefits at another's expense). For example, the lower crime rates and better schools in sprawled neighborhoods largely results from their ability to exclude poor households that cannot afford cars. This can benefit those community's residents but concentrates poverty and associated costs (crime, inferior schools and increased burdens on social service agencies) in urban areas. Similarly, sprawl residents' lower exposure to noise and air pollution is often offset by their increased vehicle travel which increases noise and air pollution imposed on urban neighborhoods.

There is little evidence that increased sprawl can provide significant external benefits (benefits to people who live outside the sprawled community). This absence of external benefits is expected since rational people and businesses externalize costs and internalize benefits (Rothengatter 1991; Swiss ARE). If sprawl really did provide external benefits, developers or occupants would find ways to capture those benefits, for example, by demanding subsidies.

Sprawl Impacts Summary

Table 8 summarizes various benefits and costs of sprawl. Some are internal (they directly affect the people who choose sprawled locations) and others are external (they affect other people). These have a mirror image relationship with smart growth: a sprawl cost is a smart growth benefit and vice versa.

Table 8
Sprawl Costs and Benefits

	Internal (Users)	External (Other People)
Costs	Reduced accessibility, increased distances between destinations. Increased transport costs (vehicle expenses and time). Reduced mobility options for non-drivers. Increased drivers' chauffeuring responsibilities. Reduced economic mobility (less economic opportunity for lower-income residents). More traffic accident risk. Reduced fitness and health.	Reduced open space (farm and environmental lands). Increased infrastructure and public service costs (utilities, policing, emergency services, etc.). Increased roadway and parking facility costs. Increased traffic congestion imposed on others. Increased crash risk imposed on others. Healthcare and disability costs due to reduced physical activity. Reduced community cohesion (fewer positive interactions among neighbors due to use of local services). Less efficient public transit services (higher costs per passenger-mile). Increased fuel consumption and pollution emissions.
Benefits	Lower land prices (cost per hectare). More private greenspace (lawns and gardens). More privacy. Cheaper vehicle parking. Reduced local traffic congestion. Less exposure to some local pollutants. Reductions in some infrastructure costs such as curbs and sidewalk.	More greenspace per hectare of developed land. Savings on some public infrastructure costs, such as reduced curbs and sidewalks.

Source: (Burchell, et al 2002; Litman 2013)
This summarizes various sprawl costs and benefits. These impacts can vary depending on specific conditions.

Some of these impacts are both internal and external. For example, sedentary living causes health problems which directly burden sprawl-community residents, and can increase healthcare and reduce productivity costs which burden people and businesses regardless of where they are located.

These impacts can vary depending on conditions and perspectives. For example, more dispersed development tends to reduce the intensity of impacts such as traffic congestion and pollution emissions, measured per hectare of developed land, but increases the number of hectares that are developed. As a result, sprawl may reduce local congestion and pollution costs, but increase total regional costs.

What is the Estimated Magnitude of Sprawl Costs?

This section describes modeling analysis for this study which estimates the magnitude of sprawl costs.

For this analysis, the Sprawl Cost Analysis Spreadsheet Model was built to calculate sprawl costs (VTPI 2015). It categorizes U.S. urban regions into quintiles (fifths) from 1 (Smartest Growth) to 5 (Most Sprawled). This model incorporates Sprawl Factors which reflect the average percentage change in an impact's magnitude resulting from a one-Quintile shift. Quintile 1 (Q1) is used as a baseline. For example, a 10% Sprawl Factor for infrastructure costs indicates that, compared with Q1, infrastructure costs average 10% higher in Q2, 20% higher in Q3, 30% higher in Q4, and 40% higher in Q5 cities. This baseline is modest by international standards. For example, the Smartest Growth quintile (Q1) has an average density of 23.5 residents per hectare, which is dense by North American standards but about half the typical densities found in European cities, and about a tenth of the densities found in some Asian cities (Figure 4). Similarly, per capita vehicle ownership exceeds 600 vehicles per 1,000 residents in most North American cities, about twice the rate in affluent European cities such as Berlin, London and Stockholm, and three times the rate in affluent Asian cities such as Seoul, Taipei and Tokyo (Di 2013).

The Sprawl Factors and cost estimates are based on the various sources indicated in footnotes. Quintile 3 reflects overall average values. For example, the U.S. Bureau of Labor Statistic's Consumer Expenditure Survey indicates that local property taxes and utility fees affected by land use development patterns average $1,482 annually per capita, so that is the Q3 value. A 10% Sprawl Factor means that this cost declines 10%, to $1,344 in Quintile 2, and to $1,201 in Q1. Incremental infrastructure and public service costs are estimated based on studies such as Burchell, et al (2002), DVRPC (2003) and the Utah Governor's Office (2003). Previously described studies indicate that shifts from sprawl to more compact, infill development can reduce public infrastructure and services costs by 10-50%. Those studies only consider relatively modest smart growth policies (for example, none include major shifts from single- to multi-family housing, or comprehensive road pricing), which suggests that a more comprehensive set of reforms would provide greater impacts and savings.

Targeted research was required to determine how sprawl affects some of these costs. For example, not all government and utility costs are directly affected by land use development patterns. This value was estimated based on a typical municipal government's budget, as summarized in Table 9. This indicates that sprawl affects about two-thirds of municipal expenditure categories, by requiring longer road and utility lines, and increasing travel distances needed for policing, emergency response and garbage collection. This analysis assumes 66%.

Table 9
Municipal Expenditures Affected By Sprawl

Budget Category	How Affected by Sprawl	Percent
Policing	Longer travel distances to serve a given population.	24%
Engineering	More road-kilometers, street lighting, etc. to build and maintain	11%
Water utility	Longer water lines to build, maintain and pump	8.6%
Parks and recreation	More dispersed facilities, increased travel distances	7.7%
Emergency services	Longer distances to travel to serve a given population	6.8%
Sewers	Longer sewer lines to build, maintain and pump	3.7%
Planning and development	Longer distances to travel to serve a given population	2.5%
Public library	More dispersed buildings and services	2.1%
Total		**66.40%**

Source: Victoria 2012
About two-thirds of this municipal budget is affected by development density and per capita vehicle travel.

Another issue of uncertainty is the portion of sprawl costs that are currently internalized through location-based fees, such as development impact fees. Since few jurisdictions currently apply location-based development and utility fees, this value is probably small, so the model assumes 10%.

Some of the largest impacts result from the way that sprawl increases per capita vehicle travel, which increases transport costs including road and parking facility costs, consumer expenditures, traffic accidents and pollution emissions. The vehicle travel Sprawl Factors are based on data from the Federal Highway Administration's Highway Statistics Report (FHWA 2013, Table HM72). The results are close to Ewing and Hamidi's (2014) analysis which indicates that each 10% increase in their Sprawl Index reduces per capita vehicle mileage by 7.8% to 9.5%. Motor vehicle cost values are from the report, Transportation Cost and Benefit Analysis and the associated Transportation Cost Analysis Spreadsheet (Litman 2009). That spreadsheet was adjusted in the following ways:

• Units converted from miles to kilometers, and cost values increased 15% to account for 2007 to 2014 inflation.
• Assumes 33% urban-peak and 66% urban off-peak vehicle travel; since this analysis applies to urban conditions it excludes rural travel.
• Excludes "Operating Subsidy" (which only applies to public transit), "Transport Diversity" and "Land Use Impacts," assuming that they are inappropriate for this analysis.

Table 10 summarizes the results, showing estimated costs for an average automobile traveling under urban conditions.

Table 10
Estimated Urban Automobile Costs, 2014 U.S. Dollars

	Internal Fixed	Internal Variable	External	Totals	
	Per Vehicle-Kilometer				Annual Per Capita
Vehicle ownership	$0.187			$0.187	$2,861
Vehicle operation		$0.122		$0.122	$1,865
Internal crash		$0.078		$0.078	$1,193
External crash			$0.038	$0.038	$578
Internal parking	$0.050	0.0051		$0.055	$841
External parking			$0.057	$0.057	$876
Congestion costs imposed on others			$0.039	$0.039	$596
Road facilities financed by general taxes			$0.018	$0.018	$273
Roadway land value			$0.023	$0.023	$358
Traffic services financed by general taxes			$0.011	$0.011	$161
Air pollution			$0.038	$0.038	$582
GHG			$0.012	$0.012	$186
Noise			$0.009	$0.009	$137
Resource externalities			$0.029	$0.029	$442
Barrier effect			$0.012	$0.012	$186
Water pollution			$0.010	$0.010	$147
Waste			$0.000	$0.000	$4
Totals – Per vehicle-kilometer	**$0.237**	**$0.206**	**$0.297**	**$0.740**	
Totals - Annual per capita	**$3,623**	**$3,136**	**$4,526**		**$11,286**

Source: Litman 2009
This table summarizes vehicle costs, which are categorized as Internal-Fixed, Internal-Variable and External.

Tables 11 summarizes the analysis results. For example, this indicates that sprawl increased infrastructure costs from $502 annual per capita for cities in the Smartest Growth category up to $750 annual per capita in the Most Sprawled quintile cities. The bottom of the table indicates total annual costs per capita; for example, residents of the Most Sprawled quintile cities bear an estimated $5,825 in internal costs and impose about $4,467 in external costs.

Table 11
Sprawl Costs Measured Annual Per Capita

Impact	Units	Sprawl Factor[1]	Sprawl Index Quintile				
			1	2	3	4	5
			Smartest Growth		Average		Most Sprawled
Urban density[2]	People/hectare	40%	23.5	16.8	12.0	7.2	4.3
Infrastructure capital costs[3]	Annualized $/capita	10%	$502	$558	$620	$682	$750
Public service costs[4]	Annual $/capita	10%	$1,201	$1,334	$1,482	$1,631	$1,794
Motor vehicle travel[5]	Annual km/capita	17%[6]	10,389	13,182	15,174	17,684	22,896
Fuel consumption[7]	Annual litres/capita	17%	1,039	1,318	1,517	1,768	2,290
Vehicle internal costs[8]	Annual $/capita	17%	$4,603	$5,840	$6,723	$7,835	$10,144
Vehicle external costs[7]	Annual $/capita	17%	$3,082	$3,911	$4,502	$5,246	$6,793
Active transport[9]	Annual walk-bike km/ca.	20%	360	300	250	200	160
Active transport benefit[10]	$/km walked/biked	$1.00	-$360	-$300	-$250	-$200	-$160
Traffic fatalities	Deaths/100,000 pop.	28%	4.3	5.9	8.2	10.5	13.4
			Total Per Capita Costs				
Internal costs			*$4,414*	*$5,730*	*$6,683*	*$7,866*	*$10,239*
Incremental internal costs			*$0*	*$1,316*	*$2,270*	*$3,453*	*$5,825*
External costs			*$4,615*	*$5,614*	*$6,394*	*$7,328*	*$9,082*
Incremental external costs			*$0*	*$999*	*$1,779*	*$2,713*	*$4,467*
Total costs			**$9,028**	**$11,343**	**$13,077**	**$15,194**	**$19,321**
Total incremental costs			**$0**	**$2,315**	**$4,049**	**$6,165**	**$10,293**

Source: (www.vtpi.org/Sprawl_Cost.xls)

This table summarizes sprawl costs analysis. It indicates how various costs change between smart growth and sprawl. For example, governments spend, on average, about $1,482 on public services that are affected by development patterns, ranging from a low of $1,201 in Smart Growth locations and up to $1,794 in the most sprawled locations. Smart growth also increases active transport which provides health benefits, since the spreadsheet measures costs these are indicated by negative values.

4   Sprawl Factors reflect the change in an impact (e.g., density, vehicle travel) for each one-quintile Sprawl Index shift. The values are based various studies described in this report. These represent lower-bound impacts since most studies only consider a limited set of changes, so more comprehensive Smart Growth programs could provide greater benefits.

5   Based on the range of densities in large U.S. urban areas reported in FHWA 2012, Table HM-72.

6   DVRPC (2003) estimate of $35,000 average infrastructure costs, or $14,000 per capita at 2.5 residents per household. Increased 26% for inflation to $17,650, and annualized over 30 years at 4%.

7   BLS (2012). Average urban household property taxes ($1,892) and utilities, heating fuel and public services ($3,723), divided by 2.5 persons per household.

8   FHWA (2013), Table VM202, 2,968 billion VMT divided by 313 million U.S. residents = 9,482 VMT or 15,257 vehicle-kilometers per capita.

9   Based on the range of average per capita VMT in large U.S. urban areas reported in FHWA 2012, Table HM-72.

10   Assumes 10 liters/100 km fleet average.

11   Litman (2009) and associated Transportation Cost Analysis Spreadsheet (www.vtpi.org/tca/tca.xls). See notes below.

12   Based on Pucher, et al. 2011.

13   Ball, et al. (2009) and WHO (2014). Also see the "Health and Safety" chapter of Litman (2009).

Table 12 estimates the total magnitude of these costs in the U.S. This indicates that sprawl imposes incremental external costs totaling nearly $500 billion annually, plus nearly $650 billion in internal costs.

Table 12
Best Sprawl Cost Estimate

	Sprawl Index Quintiles					Totals
	1	2	3	4	5	
Urban residents (millions)	**50**	**50**	**50**	**50**	**50**	**250**
Total incremental internal costs	$0	$66	$112	$173	$291	**$642**
Total incremental external costs	$0	$50	$88	$136	$223	**$497**
Total incremental costs	$0	$116	$200	$308	$515	**$1,139**

Source: 2014 U.S. Billions
According to this estimate, the incremental external costs of sprawl total nearly $500 billion annually, plus nearly $650 in internal costs. External costs tend to reduce economic productivity and equity.

This "best estimate" of sprawl costs includes a comprehensive set of economic impacts. Such analyses are sometimes criticized for including cost categories not traditionally included in economic evaluations. Conventional economics generally recognizes a more limited set of external costs which typically consists of roadway and parking subsidies, traffic congestion, accident and air pollution external costs (FHWA 1997 and 2000; Maibach, et al. 2009; Zhang, et al. 2005). Table 13 illustrates a lower-bound estimate that excludes the value of land used for road rights-of-way, greenhouse gases, resource externalities (external costs of producing and importing petroleum and other natural resources), the barrier effect (the delay that motor vehicle traffic causes to walking and cycling), water pollution, and the health benefits of increased walking and cycling, and assumes that 20% of infrastructure costs are internalized through user fees. Even using these lower-bound assumptions, sprawl imposes at least $400 billion in external cots and $626 billion in internal costs in the U.S..

Table 13
Lower-Bound Sprawl Cost Estimate

	Sprawl Index Quintiles					Totals
	1	2	3	4	5	
Urban residents (millions)	**50**	**50**	**50**	**50**	**50**	**250**
Total incremental internal costs	$0	$64	$109	$168	$286	**$626**
Total incremental external costs	$0	$40	$71	$109	$179	**$400**
Total incremental costs	$0	$104	$180	$277	$465	**$1,026**

Source: 2014 U.S. Billions
Lower-bound values indicate that sprawl imposes at least $400 billion in external costs and $626 billion in internal costs annually in the U.S.

There are two additional reasons to consider these estimates lower-bound values. First, the sprawl impact studies used for much of this analysis (Burchell, et al. 2005; SP 2013, etc.) only consider relatively modest changes; most compare current development patterns with somewhat more compact development options that require minimal shifts from single-family to multi-family and modest reductions in automobile ownership or mode share. Much larger impacts and benefits could be expected from full implementation of all the economically-justified smart growth policies, discussed later in this report, including efficient pricing of roads, parking, development and utility fees.

Second, this analysis only considers a limited set of sprawl costs. Table 14 lists the various sprawl costs identified in this report and indicates which were included in this model. It does not quantify or monetize reduced open space, social impacts such as reduced accessibility for non-drivers, or reduced economic productivity, although these are generally considered important.

Table 14
Scope of Sprawl Cost Analysis

Sprawl Cost Categories	Consideration In Analysis
Land development (open space displacement and disruption)	Quantified but not monetized
Increased infrastructure and public service costs	Quantified and monetized
Increased traffic risk	Quantified
Reduced public fitness and health	Quantified and monetized
Increased motor vehicle internal and external costs	Quantified and monetized
Increased energy consumption and pollution emissions	Quantified but not monetized
Social equity (external costs, and opportunity for disadvantaged people)	Not quantified
Social problems (poverty, crime and mental illness)	Not quantified
Affordability (housing and transport cost burdens to lower-income people)	Not quantified
Economic development (increased employment and productivity)	Not quantified

This analysis only quantified and monetized a subset of sprawl costs, so results represent a lower-bound estimate.

This analysis provides order-of-magnitude estimates of sprawl costs, and potential smart growth benefits. The model reflects U.S. conditions, since that is where suitable data are most available, but most of the sprawl cost functions are transferable to other regions. In some urban areas, smart growth policies might increase densities from 5 to 10 residents per hectare and reduce average automobile travel from 10,000 to 8,000 annual kilometers, and in other areas they might increase densities from 30 to 60 residents per hectare and reduce vehicle travel from 2,500 to 2,000 annual kilometers, but the savings and benefits should be approximately proportionate since a 50% reduction in per capita land consumption and a 20% reduction in per capita vehicle travel should provide similar percentage savings and benefits in both types of cities. Table 15 indicates sprawl costs relative to average household incomes; this approach allows sprawl cost estimates to be scaled to different economies.

Table 15
Estimated External Costs of Sprawl Relative To Incomes

	Sprawl Index Quintiles				
	1	2	3	4	5
External costs relative to average income	18%	22%	25%	29%	36%
Incremental external costs relative to average income	0.0%	4.0%	7.1%	10.8%	17.8%

Assuming that the basic relationships are universal (more compact development and reduced automobile travel tends to reduce external costs), these impacts can be scaled to developing country conditions.

HOW MUCH URBAN EXPANSION IS OPTIMAL?

This section describes various factors that should be considered when evaluating optimal urban expansion, density and therefore development policies.

The optimal amount of urban expansion, and optimal densities and development policies can vary significantly depending on specific geographic conditions. For this analysis, cities are divided into three categories:

1. Unconstrained (they can easily expand into adjacent lands that have low agricultural, environmental and cultural values).
2. Semi-constrained (they can expand, but the economic, environmental and social costs of land displacement are moderate to high).
3. Constrained (they cannot expand due to significant physical or political boundaries).

Various planning objectives should be considered when evaluating optimal densities and development policies, as discussed below.

Open Space Preservation

Open space (farmlands and environmentally productive lands) provides various external benefits. Even apparently unproductive lands, such as deserts, often provide unique wildlife habitat and aesthetic value. Open space preservation justifies minimizing urban expansion, particularly into productive farmlands, and ecologically or culturally valuable lands. Policies should strive to protect these values with strategies such as natural landscaping and on-site stormwater percolation.

Cities surrounded by relatively low value open space are considered "unconstrained," and so can expand sufficiently to allow most households to live in small-lot single-family housing. Semi-constrained cities can accommodate moderate expansion, resulting in approximately equal shares of small-lot single-family, attached, and multi-family housing. In highly constrained cities, most population growth must be accommodated by infill development, resulting in primarily attached and multi-family housing, including high-rise.

Housing And Neighborhood Demands

Housing demands are diverse: households vary in their housing needs and preferences, and their ability to pay. In response, cities should develop diverse housing options, including various types, sizes and prices (Bertaud 2014). For example, households with young children or space-intensive hobbies such as gardening or vehicle repair, demand larger homes. In unconstrained cities these demands can be met with single-family houses that include private yards and garages. In constrained cities these demand can be accommodated with more compact housing types, such as townhouses and apartment with yards and rooftop gardens, located near parks and schools, and with flexible workspaces such as lofts, studios and garages incorporated into the building or available for rent nearby. Higher density buildings can be designed with features such operable windows, roof-top gardens and balconies in order to provide natural lighting, fresh air, greenspace and privacy (Urban Strategies 2012). Neighborhoods can be designed with attractive, walkable streets, local parks and trails, and allotment gardens. The most affordable housing overall generally consists of low-rise, wood frame, multi-family homes located in accessible, multi-modal neighborhoods, with densities up to 100 residents per hectare. In highly constrained cities, affordable housing may require special policies and subsidies to provide high-quality, highrise housing at prices affordable to lower-income households.

Demand can also be evaluated at the neighborhood level, which affects optimal neighborhood densities, and therefore, the optimal amount of urban infill, urban expansion, development policies, and mix of housing types that should occur in a region. This can be defined from three perspectives:

- Current residents select a neighborhood that reflects their preferences.They often bear costs from urban infill development, including the disruption (noise, traffic, etc.) caused by construction, plus increased local traffic and parking congestion, and lost privacy, once the new residences are occupied. Existing residents are often particularly threatened by any significant increase in lower-income residents since this may increase local social problems. They often perceive little direct benefit, although they may benefit from more local economic activity, such as more neighborhood services and jobs, and those that own land in the neighborhood may benefit economically over the long run. As a result, from current residents' perspective the optimal neighborhood density is what currently exists, lower-priced housing is undesirable, and any regional population growth should be accommodated by urban expansion.

- Potential future residents are households that would live in a neighborhood if suitable housing were available there. They benefit from the additional housing in accessible urban neighborhoods, and self-select for those who accept the resulting level of density. For example, if a high-rise replaces single-family housing, the new residents will consist of households that are willing to live in high-rise housing and those that insist on single-family will choose a different location. They therefore generally favor affordable urban infill development. However, they often have little influence on local planning decisions: they are generally unaware of which house they will eventually live in, and they often do not live or vote in the neighborhood being considered for development. As a result, their demands are represented by developers motivated by potential future rents, and sometimes by public officials or advocates who support more development of affordable-accessible housing (affordable housing located in an accessible location).

- Regional economic, social and environmental interests are people who live outside the neighborhood but are impacted by the development that occurs there, including businesses that want a pool of suitable employees, residents who want regional economic development, and anybody concerned with environmental protection. These interests generally benefit from more compact development which supports agglomeration efficiencies and urban fringe open space preservation.

As a result, the development density considered optimal by existing urban neighborhood residents will usually be much lower than what is considered optimal by households that want more affordable urban housing, or for achieving regional economic, social and environmental objectives. Conversely, the density considered optimal by regional interests will be higher than what nearby residents want. This helps explain many land use conflicts, such as local opposition to infill development, conflicts between residents and developers, and conflicts between local and regional officials concerning the location and type of development. Described differently, to achieve urban densities that are overall optimal from a regional perspective it will be necessary to overcome local opposition to infill development (Glaeser and Ward 2008; Hsieh and Moretti 2014). Smart growth therefore requires policy instruments that compensate local neighbors for the negative impacts of infill development and can overcome local opposition, so urban communities will shift from "not in my backyard" to "yes in my backyard."

Public Infrastructure and Services Cost Efficiency

Previously described studies indicate that compact development can significantly reduce infrastructure and public service, although some of these costs may increase at very high densities. The greatest savings are achieved by shifting from dispersed development at low densities (under 5 residents per hectare), to infill or urban fringe development at moderate densities (40-60 residents per hectare); very high densities (more than 80 residents per hectare) are generally not needed to maximize infrastructure efficiency. To achieve this objective, it is desirable to encourage urban infill, maintain moderate to high development densities, and where urban expansion occurs, to be systematic and efficient by concentrating development along major utility corridors.
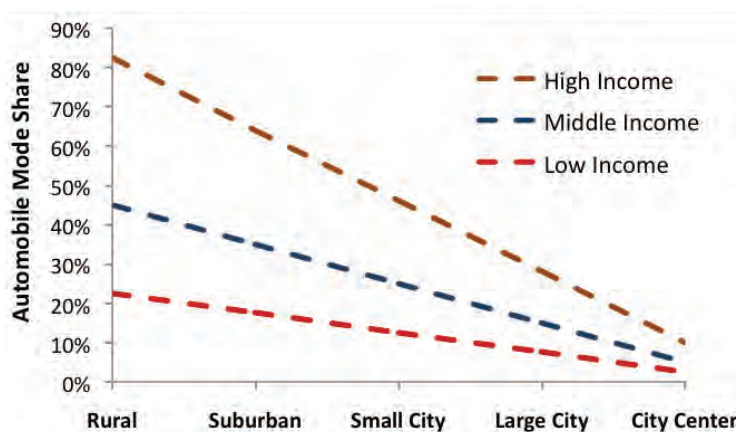
Transport System Efficiency

An efficient transport system maximizes overall accessibility (Rode and Floater 2014). The following factors can affect overall accessibility:

- Development density and mix. This reduces the distance between destinations.
- Roadway and path network connectivity. This allows more direct travel between destinations.
- Improved walking and cycling conditions, and improved public transit service quality and affordability. This improves mobility options.
- Increase automobile travel speed and affordability. This improves motorists' mobility.
- Transportation demand management that encourages travelers to use the most efficient mode for each trip. This maximizes system efficiency and reduces problems such as congestion.

Smart growth tends to support these objectives and so tends to increase overall transport system efficiency, affordability and equity. As cities become larger and denser, and where incomes are lower, the optimal automobile mode share declines, as illustrated in Figure 25. Critics sometimes argue that, by increasing development density, smart growth increases traffic congestion, but this is not necessarily true. Although density tends to increase congestion intensity (the amount traffic speeds decline during peak periods), this is often offset by shorter trip distances and improved travel options, so more compact, multi-modal neighborhoods tend to have lower per capita congestion delays (Kuzmyak 2012; Levine, et al. 2012).

Figure 25
Optimal Automobile Mode Share

As cities become larger and denser, the portion of trips made by automobiles should decline. With an efficient transport system, event wealthy people walk, bicycle and use public transit for a major portion of urban trips.

Public transit services experience scale economies (unit costs decline with increased use), so increasing development near transit lines, and providing incentives for travelers to use transit, tend to increase transit system efficiency (Cervero and Guerra 2011). Table 16 indicates threshold densities typically considered necessary for various types of transit services, although higher densities provide additional efficiencies and benefits. For example, if 30 residents per hectare justifies hourly service, 40 residents per hectare can justify half-hourly service, 50 residents per hectare can justify fifteen-minute service, and 60 residents per hectare can justify five-minute service.

Table 16
Transit Density Requirements

Mode	Service Type	Minimum Density (DU Per Hectare)	Area and Location
Dial-a-Bus	Demand response.	10 to 15	Community-wide
Minimum Local Bus	1/2-mile route spacing, 20 buses per day	10	Neighborhood
Intermediate Local Bus	1/2-mile route spacing, 40 buses per day	20	Neighborhood
Frequent Local Bus	1/2-mile route spacing, 120 buses per day	35	Neighborhood
Express Bus – Foot access	Five buses during two-hour peak period	35	Average density over 50-square-km area around a large city.
Express Bus – Auto access	Five to ten buses during two-hour peak period	35	Average density over 50-square-km area around a large city.
Light Rail	Five minute headways or better during peak hour.	25	Within walking distance of transit line, serving large downtown.
Rapid Transit	Five minute headways or better during peak hour.	30	Within walking distance of transit stations serving large downtown.
Commuter Rail	Twenty trains a day.	2 to 5	Serving very large downtown.

based on Pushkarev and Zupan 1977
This table indicates minimal residential densities typically needed for various types of transit service. These values may vary due to additional demographic, geographic and economic factors.

As discussed earlier, because automobiles are more space-intensive than other modes, efficient transportation requires limiting vehicle ownership and use levels that can be accommodated by available road and parking supply. As cities become denser, vehicle ownership rates should decline.

Economic Development

More compact, multi-modal development tends to increase productivity due to agglomeration efficiencies and cost savings (Hsieh and Moretti 2014; Melo, Graham and Noland 2009). Increased livability can also support economic development by making a city more attractive to residents, workers and visitors, and therefore businesses. Economic development therefore justifies policies that encourage compact development and efficient transport, plus consideration of livability factors such as the quality of the public realm and housing affordability.

Safety and Health

More compact development tends to increase safety and health by reducing vehicle traffic speeds and per capita vehicle travel, and increasing active transport which increases public fitness and health (CDC 2010; WHO 2013). However, compact development can also increase residents' exposure to noise and air pollutants. As a result, public safety and health objectives justify smart growth policies that create compact, multi-modal communities where residents drive slower, drive less, and rely more on walking and cycling, plus targeted strategies to reduce urban noise and air pollution.

Social Equity

For this analysis, social equity refers to the degree that policies benefit physically, economically and socially disadvantaged people, including their health and wealth. Cities can play important roles in achieving social equity objectives. They can provide affordable basic services to disadvantaged residents, including healthcare, utilities, housing, education and transport, and they can increase economic opportunities, such as their ability to obtain jobs. Whereas, in traditional peasant societies farmland ownership provided economic security and opportunity to poor households, the modern equivalent in industrial societies is to provide affordable-accessible housing that lets lower-income households conveniently access urban jobs. Affordable urban housing and transport options are therefore key to achieving social equity objectives, as well as supporting urban economic development by increasing the pool of workers available to businesses.

Table 17 compares four possible poverty reduction strategies: policies that increase some households' incomes benefits those households, but if affordable-accessible housing supply is fixed, other groups will be displaced. Increasing affordable urban-fringe housing supply reduces housing costs but increases transport costs. Increasing affordable-accessible housing supply provides the greatest total benefits.

Table 17
Poverty Reduction Policy Equity Impacts

Policy	Equity Impacts
Rent subsidies for a particular group (e.g., people with disabilities, pensioners, poor households).	The group that receives the subsidy is better off, but unless the total supply of affordable-accessible housing increases, other low-income groups have fewer housing options.
Raise minimum wages.	Working poor are better off, but unless the total supply of affordable-accessible housing increases, other low-income groups (people living on public assistance or pensions) have fewer housing options.
Increase the supply of low-priced urban-fringe housing.	Helps low-income households that prefer urban-fringe locations, but increases transport costs, particularly for non-drivers.
Increase the supply of affordable-accessible housing (low-priced housing in accessible neighborhoods.	Helps low income households.

This table summarizes equity impacts of various poverty-reduction policies. If affordable-accessible housing supply is fixed, rent subsidies or wage increases benefit recipients but displace other households. Increasing affordable urban fringe housing reduces housing costs but increases transport costs. Increasing affordable-accessible housing supply tends to provide the greatest total benefits.

This analysis suggests that to achieve social equity objectives cities should develop affordable housing in accessible, walkable neighborhoods with good public services such as parks and schools (Rodier, et al. 2010). Exactly how this is done will vary depending on specific conditions. In some cities, some affordable housing can develop from informal and unserviced settlements that evolve into officially-recognized neighborhoods (Arnott 2009; FIG 2008). In other cities, particularly those that are geographically constrained and relatively affluent, affordable-accessible housing will consist of large, government-subsidized, multi-family housing projects. In many cities, affordable-accessible housing will be provided by allowing small private property owners to add housing units, for example, by allowing secondary suites, subdividing existing parcels to allow two houses where there was previously only one, and by adding additional floors to existing residential and commercial building. Public policies can allow, support and guide such development so it is consistent with strategic development goals.

Social Problems

Smart growth policies can help reduce multi-generational poverty, crime and mental illness by reducing poverty concentration, improving economic opportunities for at-risk residents, increasing daily physical activity, and increasing community cohesion. More research is needed to better understand these impacts and design policies to best achieve these goals.

Roadway Supply and Design

Urban areas need to dedicate the optimal amount of land to roads – not too little and not too much – and to design and manage urban streets to balance diverse and sometimes conflicting objectives. In dense city centers, 20-25% of land should be devoted to road rights-of-way, as development density declines this can decline to 10-15% of land (UN-Habitat 2013).

Table 18 summarizes various strategies that can help optimize roadway design and management.

Table 18
Roadway Design and Management Strategies

Objective	Design and Management Strategies
Active transport (walking and cycling) mobility, comfort and safety	Urban roads should be designed and managed to ensure safe walking and cycling. This requires well designed and maintained sidewalks and crosswalks, and where there is sufficient demand, bikelanes. All pedestrian facilities should reflect universal design features so they accommodate the widest range of possible users including people with disabilities, handcars and wheeled luggage, and other special needs.
High value vehicle trips.	Use dedicated lanes or pricing to favor higher-value vehicle travel (emergency, public service, high-occupant, and freight vehicles). On major urban arterials this should generally be center median lanes, since that tends to minimize traffic conflicts. Urban arterials should be designed with convenient, comfortable and attractive bus stops and stations.
General motor vehicle traffic	Provide capacity for motor vehicles, including large vehicles such as trucks and buses. Urban roadways should be designed for relatively low speeds with narrower lane widths and more traffic speed controls than what is optimal in rural areas.
Multi-modal traffic safety	For urban streets to be safe for all users they should be designed and managed to keep motor vehicle traffic speeds to 20-40 km/hr. With few exceptions, urban arterials should be no more than six lanes wide and all six-lane roads should have dedicated HOV lanes. Streets with four or more lanes should have center medians that provide pedestrian refuges, so pedestrians need only cross two lanes at a time.
Efficient parking	Efficient management uses pricing and regulations that make the most convenient spaces available to higher value uses. On-street parking can be very efficient, it can serve multiple users, for example, delivery vehicles in the morning, shoppers during the day, restaurant patrons during the evening, and local residents at night.
Local residents	To protect the livability of urban neighborhoods, urban streets should be designed and managed to control excessive traffic speeds, and managed to address specific problems, for example, some cities may choose to limit heavy diesel vehicle traffic to minimize neighborhood noise and air pollution. As much as possible, on-street parking should be managed to accommodate local residents' parking demands, for example, by allowing residents to park overnight.
Local businesses	Local businesses want attractive streets that provide good walking, cycling and automobile travel conditions, moderate traffic speeds, and efficient parking management which ensure that delivery vehicles, customers and employees can easily access businesses.
Aesthetics	Streets should be designed with attractive features including trees and awnings that provide shade and shelters, trash cans, seating and other amenities. These should be designed to be attractive and integrated.

Source: ADUPC 2009; NACTO 2012
Roadway design and management should balance various planning objectives.

In addition to devoting land for roads, cities may also need to devote land to off-street parking. Parking land requirements increase with per capita vehicle ownership. Cities should design and manage parking to minimize the amount of land that must be devoted to off-street parking lots through efficient sharing and pricing, and using structured (underground and multi-story) parking facilities where this is cost effective.

Summary

Table 19 summarizes various factors that should be considered when evaluating the overall optimal amount and type of urban expansion.

Table 19
Optimal Urban Expansion, Density and Development Policies

Factor	Optimal Expansion
Open space (farm and natural lands)	Policies should encourage compact development to minimize farm and ecologically productive land displacement.
Consumer demands	Cities should develop diverse housing options, including affordable housing in accessible, multi-modal areas. In unconstrained cities a majority of housing may be small-lot single-family. In constrained cities, more housing should be multi-family.
Infrastructure and public services	Policies should encourage moderate- to high-density development along major utility corridors, and discourage leapfrog development distant from existing services.
Transport system efficiency	Policies should encourage densities exceeding 30 residents per hectare along transit lines with frequent service and good walking and cycling conditions. Automobile ownership and use should be limited to what urban road and parking supply can efficiently accommodate without congestion. Vehicle ownership rates should decline with population density and should generally be less than 300 vehicles per 1,000 residents in compact, multi-modal urban areas.
Economic development	Policies should encourage compact, multi-modal development, favor resource-efficient transport modes, and preserve valuable farmland.
Safety and health	Favor compact development, lower traffic speeds, and transportation demand management to reduce automobile travel and encourage walking and cycling.
Social equity	Encourage development of affordable housing and transport options, and provide suitable neighborhood amenities that serve disadvantaged residents, such as local parks and healthcare services
Social problems	Encourage affordable compact development with features that improve at-risk residents' economic opportunities and quality of life.
Optimal roadway supply	Devote 20-25% of land to roads in denser areas, and 10-15% in less dense areas. Design and manage roads to balance various planning objectives. Minimize the amount of land devoted to off-street parking lots through efficient parking management.

Various factors should be considered when determining optimal urban expansion and development policies.

Table 20 summarizes optimal expansion, density and development policies for the three types of cities.

Table 20

Optimal Urban Expansion, Densities and Development Policies

Factor	Un-Constrained	Semi-Constrained	Constrained
Growth pattern	Expand as needed	Expand less than population growth	Minimal expansion
Optimal regional density (residents / hectare)	20-40	40-100	80 +
Optimal vehicle ownership (motor vehicles per 1,000 residents)	300-400	200-300	< 200
Housing types	A majority can be small-lot single-family and adjacent	Approximately equal portions of small-lot single-family, adjacent, and multi-family.	Mostly multi-family
Private auto mode share	20-50%	10-20%	Less than 10%
Portion of land devoted to roads and parking	10-15%	15-20%	20-25%

Different types of cities may have different growth patterns, densities and transport patterns.

WHAT POLICY DISTORTIONS LEAD TO ECONOMICALLY EXCESSIVE SPRAWL?

This section examines various land development policy distortions that result in economically excessive urban expansion (sprawl), and estimates the magnitude of these impacts.

Efficient markets ensure that resources are allocated efficiently, which maximizes benefits to consumers and society. To be efficient, markets must reflect certain principles:

- Consumer Sovereignty. An efficient market ensures that households have diverse housing and transport options, so they can choose the combination that best meets their demands.
- Cost-based Pricing. Efficient pricing (what users pay for a good) reflects marginal costs (the full incremental costs of producing that good), which ensures that society does not devote $2 to producing a good that consumers only value at $1.
- Policy Neutrality. Economic neutrality means that policies and planning practices do not arbitrarily favor one housing or transport option over others.

Current land use and transport markets often violate these principles. The following section examines these market distortions, their impacts on development patterns, and how they can be corrected.

Consumer Sovereignty

An efficient and responsive real estate market ensures that households have diverse housing types available in various types of neighborhoods, plus diverse transport options including walking, cycling, public transit, taxis and automobiles available for rent and purchase. In most cities, it is easy to find expensive housing in accessible locations, and low-priced housing in undesirable locations, but it is often difficult to find lower-priced housing in accessible neighborhoods with high quality services such as good schools. Similarly, in most cities, driving is relatively convenient and comfortable (although slow during peak periods), but walking, cycling and public transit travel are often difficult, uncomfortable and dangerous. The limited availability of affordable-accessible housing, and the inferiority of affordable transport modes results in part from development policies which unintentionally reduce consumer housing and transport options.

For example, most jurisdictions have policies and planning practices that limit development densities and mix, building heights, floor area ratios (FARs), multi-family housing, and heritage building redevelopment (Blais 2010; Levine 2006). Most zoning codes mandate high levels of parking supply, which are automatically bundled with building space, regardless of whether or not occupants demand parking (Manville 2010). These policies tend to reduce the supply of affordable housing in accessible urban neighborhoods (Cheshire and Vermeulen 2009; Glaeser and Ward 2008). For example, in efficient land markets it would be relatively easy for developers to respond to growing demand for affordable urban housing by converting lower-density single-family homes into larger, taller, multi-family housing, and developers would only build the amount of parking that households demand, but in most cities, development policies and regulations make this illegal or difficult (Bertaud 2014; Lewyn 2005).

Similarly, many current transport planning practices are biased in ways that favor automobile travel over walking, cycling and public transport, reduce affordable mobility options (ADB 2009). For example, current transport planning tends to evaluate transport system performance based primarily on motor vehicle travel conditions, using indicators such as roadway level-of-service and average traffic speed, but gives little consideration to active and public transport travel conditions (DeRobertis, et al. 2014). Most jurisdictions collect extensive data on motor vehicle travel activity, travel conditions and costs (such as fuel prices and accidents), but walking, cycling and public transit travel data are often incomplete, making it difficult for planners to value improvements to these modes. Conventional evaluation recognizes and quantifies motor vehicle congestion delay, but does not generally measure the delays that wider roads and increased vehicle traffic speeds cause pedestrians and cyclists (called the "barrier effect"). As a result, transport planning recognizes the benefits of expanding roadways to reduce motorists' delays, but ignores the costs this imposes on other road users.

Transport project economic evaluation is also biased in favor of automobile travel over other transport options (EVIDENCE 2014). For example, when comparing a highway expansion with a public transit improvement project to improve urban mobility, conventional evaluation assumes that all travelers (at least, all travelers who matter) have an automobile and parking space

available and so do not account for vehicle ownership and parking cost savings that result if commuters travel by transit rather than automobile. Conventional planning generally gives little consideration to indirect and external costs, such as the downstream congestion, accident risk and pollution costs that result, if roadway expansions induce additional vehicle traffic.

Transport funding practices also tend to favor the expansion of roads and parking facilities over improvements to other modes (Brown, Morris and Taylor 2009). Various tax policies encourage sprawl and automobile travel. For example, U.S. mortgage interest deductions encourage households to purchase larger homes, which tend to encourage sprawl (AIA 2010), and U.S. income tax policies favor automobile over transit commuting (Dutzik and Inglis 2014). This increases motor vehicle ownership and use beyond what consumers would choose if public policies were more neutral (Kodukula 2011).

Efficient Pricing

In efficient markets, prices reflect marginal costs. An efficient land market would charge development fees, utility rates and taxes that reflect the additional costs of providing infrastructure and public services to more dispersed locations. This is seldom done, which underprices sprawl compared with smart growth (Blais 2010). Efficient pricing would typically reduce development fees, utility rates and local taxes by 10-50% for smart growth compared with sprawl locations.

Similarly, efficient transport pricing would charge travelers directly for the costs they impose, as indicated in Table 21. Currently, many countries subsidize fuel (IMF 2010; Metschies 2013), roads user seldom pay the full costs of roadways and parking facilities (Henchman 2013; Litman 2009), and impacts such as congestion, accident risk and pollution are often underpriced (Clarke and Prentice 2009). More efficient pricing would significantly increase the costs of automobile travel, particularly in urban conditions where congestion, road, parking, accident risk and pollution costs are particularly high (Proost and Van Dender 2008).

Table 21
Efficient Pricing Of Various Transport Costs

Cost	Pricing Method	How Calculated
Congestion	Time and location based road tolls or vehicle fees.	Prices are higher under congested conditions. Price to reduce traffic volume to optimum flow.
Roadway costs	Road tolls or weight-distance fees.	Charge users for most or all roadway costs.
Accident risk	Distance-based fees.	Prorate vehicle insurance premiums by annual mileage.
Parking	Use time and location based fees to charge users directly for parking.	Fees set to recover parking facility costs and maintain 85% maximum occupancy during peak periods.
Pollution Emissions	Time and location based fees (if possible) or distance-based fee.	A vehicle's emission rate (such as grams per mile) times regional pollution unit costs (such as cents per gram).
Fuel externalities	Fuel tax.	Eliminate fuel subsidies. Charge for external costs of producing, importing and consuming fuel.
General taxes	General sales and property taxes.	General taxes should be applied in addition to any special vehicle and fuel taxes and fees.

Source: Litman 2014a; Metschies 2013
This table summarizes efficient pricing of various transport costs.

Summary of Market Distortions and Their Impacts

Table 22 describes various market distortions that encourage sprawl, their impacts, and reforms that can correct them.

Table 22
Sprawl-Encouraging Market Distortions

Distortions	Impacts	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 discourages infill development. Subsidizes automobile ownership and use.	Eliminate minimum parking requirements, set maxima, 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 providing public services to 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.).	Encourage 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.

Many current policies favor sprawl and automobile travel over compact development and multi-modal transport.

These distortions have cumulative and synergistic impacts, which significantly increases sprawl and vehicle travel beyond what consumers would choose with better housing and transport options, and more efficient pricing. For example, underpricing parking not only increases parking demand, it also increases traffic congestion, accidents and pollution problems. In a typical situation, with unpriced worksite parking, 80% of employees will drive to work, but if commuters pay directly for parking this declines to 60%, which not only reduces parking costs by 25%, it also causes similar reductions in traffic congestion, accident and pollution costs. Described more positively, more responsive planning and efficient pricing can help reduce a variety of problems and achieve various planning objectives; all of these benefits should be considered when evaluating a particular policy reform.

Table 23 illustrates policy reforms that reflect market principles including consumer sovereignty, efficient pricing and neutral planning. These reforms tend to increase economic efficiency and equity.

Table 23
Examples of Efficient Smart Growth Policies

Improved Consumer Options	More Efficient Pricing	More Neutral Planning
• Improved walking, cycling and public transit in response to consumer demands – such as better sidewalks, bike and bus lanes on most urban arterials. • Reduced and more flexible parking requirements and density limits in urban areas. • More diverse and affordable housing options such as secondary suites. • Improved public services (schools, policing, utilities) in smart growth locations.	• Efficient pricing of roads and parking, so motorists pay directly for using these facilities, with higher fees during congested periods. • Distance-based vehicle registration, insurance and emission fees. • Location-based development fees and utility rates so residents pay more for sprawled locations and save with smart growth. • Vehicle registration auctions in large cities where vehicle ownership should be limited.	• More comprehensive evaluation of all impacts and options in the planning process. • Accessibility- rather than mobility-based planning, so accessibility is given equal consideration as mobility when evaluating transport impacts. • "Least-cost" transport planning, which allocates resources to alternative modes and transportation demand management programs when they are effective investments, considering all impacts.

These smart growth policies reflect market and planning principles such as consumer sovereignty, efficient pricing and neutral planning. This analysis compares current costs with what would occur if such policies were fully implemented.

Some studies have modelled the impacts of comprehensive policy reforms. For example, Gao, et al. (2009) developed an integrated transport and land use mode which evaluated economic impacts, including consumer surplus, of various development scenarios in California. The results indicate that smarter growth options provide significant savings and benefits, including reduced development and transport costs, increased consumer surplus and more equitable distribution of benefits. Litman (2006) identified various transport market distortions which increase automobile travel, and in subsequent analysis (Litman 2014b) estimated that a combination of more responsive transport planning, more neutral development policies, and more efficient transport pricing would reduce U.S. automobile travel 35-50%. This conclusion is supported by international comparisons which indicate that urban residents of affluent European countries such as Germany and Norway travel 35-50% fewer annual motor vehicle kilometers than in North America, apparently due to policies that result in more compact development, and more multi-modal transport systems (Matthews and Nellthorp 2012).

This indicates that market distortions significantly increase automobile ownership and use. The difference in consumer welfare and external costs between current conditions and what would occur in a more efficient market can be considered the economic inefficiency of sprawl. The magnitude of these impacts is affected by consumer demands, including the amount of latent demand for more compact development, and consumers' responsiveness to incentives such as better housing and transport options, more efficient pricing, and urban neighborhood design improvements. The more responsive consumers are to smart growth reforms, the more they increase overall economic efficiency

As described earlier in the "Demand for Sprawl" section, there is evidence of significant latent demand and responsiveness: many households would prefer more compact, walkable and transit-oriented neighborhoods but cannot choose them due to limited supply which increases prices. Modest incentives, such as financial savings or better local services, would attract more households to smart growth (Levine, et al. 2002; Litman 2015b). As a result, full implementation of economically-justified market reforms would result in significantly more compact and multi-modal development than what is occurring in many cities, and like most policies and price changes, their impacts and benefits should increase over time as they influence long-term decisions.

Market Reform Examples

Below are three examples of specific market distortions and reforms.

Example 1
Parking Mandates

Assume that a city's zoning code currently requires developers in urban neighborhoods to provide one parking space per apartment unit. Each space adds $1,200 annual costs per unit. With bundled parking, 80% of occupants own a motor vehicle but if parking is unbundled (i.e., rather than paying $1,000 per month for an apartment that includes a parking space occupants pay $900 per month for the apartment and $100 for each parking space they want to use) only 60% of occupants own vehicles. This allows parking supply to be reduced to 0.6 spaces per unit, which allows 20% more housing units in an area. Under current conditions, the city's parking requirement has the following economic impacts:

- 20% of parking spaces are unoccupied, a wasted resource.
- 40% of occupants are paying for parking spaces they don't need, reducing consumer welfare.
- For occupants that do not need parking spaces, this reduces housing affordability. This tends to be regressive (it burdens lower-income households) since they are most likely to be car-free.
- 20% of occupants own more vehicles, and therefore drive more, and impose more external costs (congestion, accidents, pollution, etc.) than they otherwise would.
- Urban housing supply is reduced 20%, which forces more households to locate in sprawled, urban-fringe locations where they lead more automobile-dependent lifestyles than they prefer. This reduces those households' consumer welfare and increasing motor vehicle external costs.

Such zoning codes are economically inefficient to the degree that some households are forced to pay for parking spaces that they would not otherwise choose. Since this policy reduces development densities which increase sprawl, and leverages additional vehicle ownership and use, it increases various external costs. Reforming this policy would allow developers to decide how much parking to provide, which would increase economic efficiency and help achieve planning objectives such as more affordable housing, and reduced congestion, accidents and pollution.

Example 2
Automobile-oriented Transport Planning

Current transport planning practices often favor motorized over non-motorized travel by devoting more money and road space to accommodate local automobile travel than to comparable trips made by walking and cycling, and by favoring higher traffic speeds on urban arterials, which creates barriers to walking and cycling. This has the following impacts:

- People who rely on walking and cycling are harmed, and become less mobile. Since physically, economically and socially disadvantaged people tend to rely on these modes, this is inequitable.
- Walking, cycling and public transit travel (most transit trips including walking links) declines and automobile travel increases. Residents drive even for short neighborhood trips. This increases automobile external costs.
- The increased vehicle traffic degrades urban environments, which encourages more households to choose sprawled locations, and therefore lead more automobile-dependent lifestyles.

This planning bias is economically inefficient to the degree that some travelers would prefer to walk, bike and use public transit, but cannot due to inadequate facilities. The total inefficiency includes the loss of consumer welfare from people deprived for their preferred travel modes, plus the increased external costs that result from the increased vehicle travel. Reforms that result in more multi-modal planning would increase economic efficiency and help achieve planning objectives.

Example 3
Failure to Apply Location-Based Pricing

Although infrastructure and public service costs tend to be much lower for compact, infill development compared with dispersed, low-density development, these savings are not generally reflected in development and utility fees or local taxes. As a result, smart growth neighborhood residents tend to cross-subsidize the additional costs of residents of sprawled locations, and residents have less incentive to choose smart growth locations. With more efficient pricing, smart growth residents would typically save thousands of dollars annually in housing and utility fees compared with sprawled locations. Pricing differentials of this magnitude are likely to cause a significant portion of households to shift to somewhat more compact housing options, for example, some households would shift from larger- to smaller-lot single-family housing; others would shift from small-lot single-family to adjacent housing; and some would shift from adjacent to multi-family housing.

WHAT ARE THE POLICY IMPLICATIONS FOR RAPIDLY URBANIZING COUNTRY CITIES?

This section discusses the implications of this analysis for developing countries.

A key issue in this analysis is the degree to which these analysis results are transferable to developing country cities. Developing country cities tend to have higher densities, lower automobile ownership rates, and less urban expansion than in North America. Although sprawl costs may be smaller in absolute value in developing compared with developed countries, due to lower incomes and land prices, their magnitude as a portion of household and government budgets, and their impacts on economic development, are often equal or greater.

For example, zoning codes that have high minimum parking requirements are inefficient and unfair because they force residents to pay for parking spaces regardless of whether or not they own a car, reduce housing affordability, reduce development densities and increase total vehicle ownership. Such policies are particularly inefficient and unfair in developing country cities that have low vehicle ownership. Conversely, policy reforms that result in better walking and cycling conditions, and improved public transit services are particularly appropriate in developing country cities as a way to improve travel options for low-income residents and reduce severe traffic and parking congestion, pollution and accident costs.

Because land use development patterns have very durable effects, the decisions that developing countries make now can have large long-term effects. Developing countries now have the opportunity to establish more optimal transport and land use development patterns that help achieve various, economic, social and environmental objectives. For example, by designing walkable and bikeable cities where residents frequently use these modes for local trips, they can avoid future health problems associated with sedentary living. Thus, this analysis indicates the potential future savings and benefits that developing country cities can achieve by implementing smart growth policies, rather than just their current savings.

Many rapidly developing cities include informal settlements occupied by poor people, which over time evolve into more affluent and durable neighborhoods (Arnott 2009). This type of development provides affordable housing and supportive communities, but is often unplanned and unserviced. Governments should recognize the demand for very inexpensive (essentially free) housing, and the benefits to both occupants and the larger community if such settlements reflect smart growth principles, that is, they are located close to services and jobs. There is much that governments can do to support such communities so they are safe and healthy, and to guide such development so it is consistent with a city's strategic goals, including planning for adequate roadways, provision of essential services (water and sewage, electricity, policing, schools and medical services), and mechanisms that allow occupants to obtain legal ownership of land, provided it is in a suitable location (FIG 2008). This requires coordinated planning, engineering, government services and legal practices which are complex and will vary from one city to another.

SMART GROWTH EXAMPLES

This section describes examples of successful smart growth policies and programs.

Infilling Chinese Cities (World Bank 2014)

Chinese cities are rapidly growing, but much of the new development is scattered, and policies favor industrial over residential uses, resulting in urban fringe development and high housing prices. A World Bank report, Toward Efficient, Inclusive, and Sustainable Urbanization (World Bank 2014) recommends land policy reforms to encourage infill development and increase the supply of land available for high quality residential communities.

Urban Intensification Guides (Hamilton 2011)

Various cities have developed guidebooks and websites to help evaluate and implement more intense urban development. These guides include descriptions and illustrations of various buildings and street designs, discuss the advantages and disadvantages of various urban densities, and offer recommendations for maximizing benefits and minimizing problems with higher density development.

Complete Streets Planning

Complete Streets refers to roadway design and operating practices intended to safely accommodate diverse users and activities including pedestrians, cyclists, motorists, public transport users, people with disabilities, plus adjacent businesses and residents. Complete Streets planning recognizes that roadways often serve diverse functions including through travel, recreational walking, socializing, vending, and nearby living, which must be considered and balanced in roadway design and management. Complete streets policies are a practical way to improve walking, cycling and public transit, which increase transport system efficiency.

In recent years many jurisdictions have adopted complete streets policies, and many professional organizations, including some in developing countries, have developed complete streets design manuals which provide guidance on how to integrate motorized and non-motorized modes (ADUPC 2009; ITDP 2011; NACTO 2012; UTTIPEC 2009).

Walkability Improvements (Leather, et al. 2011)

A survey of pedestrians in 13 Asian cities found that:
- 37% of respondents rely primarily on walking for transportation.
- The median walkability rating was 58 out of 100.
- 41% of respondents rate their city's pedestrian facilities "bad" or "very bad."
- 67% of the respondents would shift their walking trips to motorized modes (with 29% shifting to cars and 10% to two-wheelers) if walking conditions do not improve.

The analysis indicates a lack of relevant policies, dedicated institutions, and political support to improve walkability. Proper allocation and use of funds for pedestrian facilities are also identified as major issues throughout Asia. Based on these findings the study made various recommendations for improving walkability and pedestrian conditions. City governments are identified as the key stakeholder group for pedestrian facility development and implementation. National governments and civil society (professional and non-profit organizations) and development agencies can also play important roles. They also recommend changing transport system performance indicators to better evaluate walking conditions, and developing appropriate roadway and pedestrian facility design guidelines, since existing guidelines are often ambiguous, inequitable, or not enforced.

Critical Evaluation of Indian Urban Transport (Mahadevia, Joshi and Datey 2013)

The report, Low-Carbon Mobility in India and the Challenges of Social Inclusion: Bus Rapid Transit (BRT) Case Studies in India critically evaluates the degree that urban transportation systems serve low-income households and other disadvantaged groups. It uses travel demand surveys to evaluate walking, cycling and public transit activity, and consumer expenditure survey data to evaluate transportation affordability. It discusses the quality and utility of Bus Rapid Transit (BRT) systems in various Indian cities, and identifies various problems and potential improvement strategies.

India's National Urban Transport Policy emphasizes the importance of building 'streets for people' rather than simply maximizing motor vehicle traffic speeds. It also emphasizes the need to improve transit service for disadvantaged groups. This offers an opportunity to improve public transit services and develop BRT systems. However, of the 63 cities eligible for national transportation funds, only about 10 built BRT systems, out of which only four have dedicated bus lanes. Some roadway expansion projects that were planned as BRT lanes have been converted to general traffic lanes, and some BRT infrastructure was badly designed, built or maintained, resulting in poor service. Some Indian cities have developed well-used walking and bicycle facilities as part of transportation improvement programs, but others have not, and police often fail to keep motorised vehicles from encroaching on cycle tracks. Sometimes inappropriate design of infrastructure has led to a lack of usage. For example, in Ahmedabad, many roadways lack footpaths and cycle tracks, and some facilities are so poorly designed that cyclists avoid using them. Another common conflict and barrier to efficient urban transportation involves motor vehicles parking on footpaths, cycle tracks and bus lanes. Most vehicle parking is unpriced.

Korean Sustainable Transport and Logistics Development Act (UN 2009)

The Korean Sustainable Transport and Logistics Development Act supports development of sustainable transportation systems. The act:

- Requires national and regional transport agencies to adopt and implement sustainable transportation and logistics' strategies. These must include energy consumption and greenhouse gas reduction goals, transport mode shifts and other related measures, and a financing plan.
- Requires the government to adopt a sustainability management index and standards, and to regularly inspect and evaluate these in order to scientifically and reasonably administrate greenhouse gas reduction, energy use reduction, and green transport.
- Introduces diverse programs to promote the shift to a sustainable transportation and logistics system. One of these programs is the "Total Automobile Traffic Load System by Zones", which sets the total automobile traffic for each zone, and in accordance with a voluntary agreement between local governments and the state, gives administrative or financial incentives to the regional or local governments that successfully reduce the total automobile traffic.
- Provides policy tools to stimulate Non-Motorized Transport (NMT). A comprehensive plan (5-year period) that aims to increase the transport share of NMT is to be devised, and shall consist of an analysis of the present state and prospects of NMT, the objectives and general outline of the policy, and a plan for the increase in the transport share of NMT.
- Provides a support basis to encourage collaboration with non-governmental organizations in developing and diffusing environmentally-friendly transport technology.
- Is implementing comprehensive Transportation Demand Management (Yun and Park 2010).

Improving Urban Walkability in India (CSE 2009)

The report Footfalls: Obstacle Course To Livable Cities (CSE 2009) evaluates walking conditions in Indian cities. Although walking represents 16% to 57% of urban trips in these cities, walking conditions are poor, with little investment, insufficient road space, and inadequate facility design and maintenance standards. The study argues that inadequate support for nonmotorized travel is inefficient and inequitable. The study developed a Transport Performance Index for evaluating urban transportation systems and prioritizing system improvements. It consists of the following factors:
- Public Transport Accessibility Index (the inverse of the average distance to the nearest transit stop or station).
- Service Accessibility Index (% of work trips accessible in 15 minutes time).
- Congestion Index (average peak-period journey speed relative to a target journey speed).
- Walkability Index (quantity and quality of walkways relative to roadway lengths).
- City Bus Transport Supply Index (bus service supply per capita).
- Para-Transit Supply Index (para-transit vehicle supply per capita).
- Safety Index (1/traffic fatality per 100,000 residents).
- Slow Moving Vehicle (Cycling) Index (availability of cycling facilities and cycling mode share).
- On-street Parking Interference Index (1/[portion of major road length used for on-street parking + on-street parking demand]).

Parking Management in Rapidly Developing Cities

The Parking Guidebook for Chinese Cities (Weinberger, et al. 2013) identifies strategies for efficiently managing parking resources in urban areas that are experiencing increased motorization and associated parking problems, in ways that support strategic, long-term goals. It uses Guangzhou as a case study which illustrates how a Chinese city manage parking in the best possible way. It recommends these eight strategies:
1. Establish a centralized management of all parking activities.
2. Implement performance standards for parking management.
3. Use appropriate technology for payment and data collection.
4. Reduce or eliminate parking minimums, establish maximum allowances or area-wide parking caps.
5. Decouple land use from off-street parking requirements and implement shared parking.
6. Price or tax off-street parking according to market cost.
7. Enhance enforcement with electronic technology and physical design.
8. Provide clear information on parking supply to ensure its effective use.

Similarly, collaboration between local and national governments, and international development organizations, had developed parking policy reforms for cities in Mexico which will lead to more efficient management of public parking facilities (ITDP 2014). Mexico City implemented a parking meter pilot project which has proven to be effective at reducing parking problems and generating revenues that are used to improve alternative modes in a busy urban neighborhood. The city is now expanding this program to other areas.

Transport Policy Reforms for Arab Environment and Development (AFED 2011)

The report, Green Economy: Sustainable Transition in a Changing Arab World by the Arab Forum for Environment and Development (AFED) identifies transportation policies that promote sustainable development and reduce poverty. It defines green transportation broadly to mean the provision of safe, affordable, and reliable mobility options that are energy efficient, while minimizing pollution, congestion, and random urban sprawl. It discusses the implications of green transport on economic growth, social cohesion, and environmental sustainability.

Common problems include:
- Government-subsidized gasoline and diesel fuel.
- Poorly maintained and ageing vehicle fleet which increase fuel consumption and emission rates.
- Inefficient and inadequate public transport systems and excessive reliance on private vehicles.
- Government policies that encourage private car ownership
- Inefficient traffic management systems and insufficient public awareness.
- Poor urban and physical planning resulting in rapid sprawling in major urban centers.
- Inadequate governance setup to adequately manage the transportation sector manifested by weak and insufficiently enforced environmental policies and regulations.
- Limited access in rural areas due to poor road networks and the inadequacy of basic transport services.
- Very high road traffic mortality rates.

In response, the report recommends:
- Invest in public transport and non-motorized modes, and provide incentives to promote their use.
- Invest in rail transport to move freight and to transport people within busy corridors.
- Adopt national fuel economy standards for vehicle fleets.
- Remove broad fuel subsidies, while employing targeted subsidies to protect low-income groups.
- Accelerate car replacement programs using incentives to take ageing cars off the road and establish vehicle emission testing.
- Upgrade the quality of fuels, particularly by reformulating gasoline and reducing sulfur content in diesel.
- Introduce and promote through incentives low carbon fuels, such as compressed natural gas.
- Apply mixed-use land management concepts in urban planning to reduce travel distances and protect land from degradation.
- Adopt transportation demand management practices that increase transport system efficiency.
- Accelerate the development of an electrification infrastructure for railway trains and vehicles.
- Improve public transportation planning capacity and technical expertise.
- Design appropriate interventions to reduce traffic fatalities and injuries.
- Raise awareness about fuel-saving purchasing, driving, and maintenance habits among fleet operators.

Developing Country Travel Demand Surveys

Comprehensive and accurate travel statistics are critical for transportation planning. Some developing country jurisdictions have performed travel demand surveys. For example, in 2003 the South African Department of Transportation commissioned that country's first National Household Travel Survey which sampled more than 50,000 residents, a larger than normal sample size for such a survey in order to ensure credible statistical data for all major demographic and geographic groups concerning both motorized and non-motorized travel (SADoT). During April and May 2012, researchers completed 2,068 travel survey interviews in three Rio de Janeiro favelas (informal, low-income communities) which provided information on vehicular ownership, non-motorized transport, modal share, vehicle parking, perception of road safety, plus data on the destination, mode, timing and purpose of 4,336 unique trips (Koch, Lindau and Nassi 2013).

Multi-Modal Planning in Historic Istanbul (Gehl Architects 2013)

Istanbul's Historic Peninsula is one of the most important urban areas in the world: an area of extraordinary beauty where 8,500 years of human history and culture embrace the sea. It is home to tens of thousands of residents and 2.5 million daily visitors including workers, students, business owners, shoppers, tourists and worshippers. This puts undue strain on the area, especially the transport system, which is forced to accommodate more travelers in one day than the total population of most European cities. This area is currently strangled by unsustainable transport infrastructure. The network of old, narrow streets that gives the area its charm also makes it challenging to access the historic sites seashore walkway. EMBARQ Turkey, an international sustainable transportation advocacy group, commissioned Gehl Architects, a world renown urban planning organization, to develop a comprehensive sustainable transportation plan titled, Istanbul: An Accessable City – A City For People which includes comprehensive data on walking, cycling and public transit conditions, detailed analysis, and specific recommendations for creating a more livable, sustainable, and more economically competitive city. It is a beautiful document which could serve as a model for livable community planning in other cities.

EVALUATING CRITICISM
This section evaluates criticisms of sprawl cost studies and smart growth policies.

Criticism of Sprawl Cost Studies

Critics argue that widely-cited studies such as Burchell, et al. (2002) exaggerate sprawl costs (Cox and Utt 2004; Gordon and Richardson 1997). They claim that at most, sprawl costs average households only $80 annually, and cite research concerning the relationships between population density and per capita local government expenditures to claim that sprawl does not significantly increase public service costs. However, their analysis only considers a small portion of total sprawl costs, and their jurisdictional-scale analysis fails to account for important factors such as the type of development that occurs in an area, public service quality (residents in lower-density areas tend to supply their own water, sewage and garbage collection, and often have unpaved roads and volunteer fire departments), incomes (all wages tend to increase with city size), and the additional public service costs borne by cities because they contain more businesses and low income residents (Litman 2015).

Similarly, Fruits (2011), Gordon and Richardson (1997), and Cox (2014) argue that sprawl does not significantly increase transport costs, citing evidence that compact, transit-oriented cities have longer average commute duration than sprawled, automobile-dependent cities. However, average commute duration is an inadequate indicator of overall transportation costs. Various studies indicate that sprawl tends to increase total per capita vehicle travel, travel time, transportation expenditures and associated costs such as traffic fatality rates (Ewing and Cervero 2010; Marshall and Garrick 2012; USEPA 2013; Zhang, et al. 2012). Although more compact cities tend to have more intense congestion (travel speeds decline more during peak periods), residents of such cities drive less during peak periods, which reduces the total time they spend traveling, and their total congestion delay (Ewing and Hamidi 2014; Kuzmyak 2012; Levine, et al. 2012; Litman 2013).

Researchers Melia, Barton and Parkhurst (2011) argue that planning policies which increase population densities tend to reduce overall vehicle use but increase local traffic and parking congestion, and noise and air pollution. They therefore suggest that planners avoid false expectations and implement complementary policies that further reduce local trip generation rates. Although this is sometimes interpreted as a criticism of compact development, it is actually consistent with smart growth, which involves integrated policies to maximize accessibility, minimize vehicle traffic, and mitigate local impacts.

Some critics argue that the amount of land displaced by sprawl is small relative to worldwide supply, and because agricultural productivity is increasing, there is no need to preserve farmland (Cheshire 2009; Gordon and Richardson 2097). However, this ignores many justifications for preserving open space. Many cities are surrounded by valuable farmlands and natural lands, Open space provides important ecological services including wildlife habitat, groundwater recharge, aesthetic and cultural values. As a result, open space displacement often imposes significant costs.

Critics sometimes argue that sprawl provides benefits that offset costs, but most of the benefits they cite (larger homes and gardens, larger play areas for children and pets, reduced exposure to noise and air pollution) are direct benefits to residents; there is no evidence of significant external benefits that would offset external costs. Overall, most sprawl cost study criticism appears to reflect incomplete and outdated information.

Criticism of Smart Growth Policies

Critics raise various objections to smart growth. Some criticism assumes that smart growth consists primarily of regulations that restrict housing and transport options, which increases consumer costs and reduces consumer welfare (Cheshire 2009; Demographia 2012; Mills 1999). This is incorrect. Although some smart growth policies increase regulations and consumer costs, others reduce regulations, improve housing and transport options, increase affordability, and reflect market principles such as efficient pricing, as summarized in Table 24.

Table 24
Smart Growth Impacts

Increased Regulations	Reduced Regulations	Improved Options	Efficient Pricing
Urban growth boundaries Vehicle traffic speed controls Increased parking fees Increased development design standards and review	Reduced and more flexible regulations regarding housing density, size and type Reduced and more flexible parking requirements	Allow more housing options (small-lots, multi-family) Allow more mixed development Improved transport options (walking, cycling, transit, taxi, etc.) Brownfield reclamation	Discounts for more compact development (reflecting their lower public service costs) More efficient transport pricing (cost-based pricing of roads, parking, insurance, fuel, etc.)

Smart growth increases some regulations but reduces others, improves consumer options and applies more efficient pricing which tends to benefit most residents overall.

Critics argue that smart growth contradicts consumer preferences for single-family housing (Kotkin 2013), but as discussed in the Demand for Sprawl section, housing preferences are diverse. Although surveys indicate that most North American households prefer single-family homes, they also value smart growth features such as convenient access to local services and shorter commutes, and many households would choose more compact housing options if given suitable incentives such as better schools or financial savings (Hunt 2001; NAR 2013). Current demographic and economic trends are increasing demand for more compact neighborhoods (Pembina 2014). Smart growth responds to these demands, for example, by expanding affordable housing options and improving public services in accessible, multi-modal neighborhoods.

Contrary to critics' assumptions, smart growth does not usually eliminate single-family housing. Analysis in this report suggests that in unconstrained cities, smart growth can allow more than half of all households to have single-family or attached housing that include private gardens; only highly constrained cities require most households to live in high-rise apartments. It is true that smart growth policies that discourage urban expansion may increase single-family housing prices, making them less affordable to lower-income households, but other smart growth policies reduce the costs of compact housing, as well as infrastructure and transport costs, and so can increase affordability overall. This criticism therefore depends on whether single-family housing affordability is more important than compact housing affordability, and whether house purchase affordability is more important than infrastructure and transport affordability. To the degree that smart growth reduces total resource costs (public infrastructure and service costs, traffic accidents, pollution damages, etc.) it can benefit all residents. All of these impacts should be considered when evaluating consumer welfare impacts.

A related criticism is that smart growth is regressive because it makes single-family housing unaffordable to lower-income households, forcing poor households into inferior, crowded neighborhoods (Kotkin 2013). However, as discussed previously in this report, by reducing restrictions on development density, supporting affordable housing options such as multi-family and secondary suites, and reducing parking requirements, smart growth reduces the costs of compact housing in accessible locations, and so tends to increase overall affordability (Rodier, et al. 2010). Ewing and Hamidi (2014) found that in the U.S., each 10% increase in their smart growth index is associated with a 4.1% increase in residents' upward mobility (probability a child born in the lowest income quintile reaches the top quintile by age 30). In these ways, smart growth tends to benefit most lower-income households.

Critics argue that smart growth causes housing price "bubbles" which increase foreclosure rates, based on the assumption that smart growth consists of urban containment policies that increase prices and speculation (Cheshire 2009; Cox 2011). However, as described in the Household Affordability section, it is the combination of urban containment and restrictions on compact infill development that drive up housing prices. Housing foreclosure rates are lower in more compact neighborhoods, suggesting that smart growth can support stable housing markets (Pivo 2013; Rauterkus, Thall, and Hangen 2010)

In research sponsored by the National Association of Home Builders, Fruits (2011) argues that there is little or no evidence that smart growth policies can reduce climate change emissions and concludes, "regional efforts to slow potential climate change through compact development are little more than showy, but costly, curiosities." However, he relies on outdated and inaccurate analysis. For example, he claims that "some studies have found that more compact development is associated with greater vehicle-miles traveled" citing a 1996 study by Crane which only presented theoretical analysis indicating that under some conditions a grid street system could increase vehicle travel. As previously discussed, extensive, peer reviewed research indicates that smart growth community residents tend to own fewer vehicles, drive less, consume less fuel, and produce less pollution emissions than they would in sprawled, automobile-dependent locations (ATM 2013; D'Onofrio 2014; Ewing, et al., 2009; LSE Cities 2014; UNEP 2011). Subsequent analysis discredited Fruits claims (Litman 2011).

By increasing density and encouraging infill development, smart growth can increases residents' exposure to noise and local air pollutants such as particulates and carbon monoxide. However, by reducing total per capita vehicle travel it reduces the generation of regional and global pollutants such as ozone and carbon dioxide. Targeted efforts to reduce local air pollution, such as policies that encourage use of lower-polluting vehicles and emissions inspections programs, can further improve urban air quality.

Some smart growth criticism reflects local concerns such as fears that more affordable infill housing will increase urban poverty, as discussed in the "Social Problems" section, research indicates that smart growth actually tends to reduce total regional poverty and crime by improving passive surveillance (neighbors' ability to watch out for each other) and economic opportunity for at-risk groups.

Cox (2014) argues that relatively high GDP in some lower density U.S. cities demonstrates that sprawl increases economic productivity, but this evidence is anecdotal and fails to account for other factors that affect productivity. When U.S. cities are compared with each other, there are strong positive relationships between smart growth indicators such as density, transit ridership and walkability, and economic productivity (Abel, Dey, and Gabe 2011; Litman 2014a). The low-density, high GDP cities Cox cites tend to either be small cities that attract affluent households, such as Hartford and Bridgeport, or cities benefiting from a resource booms, such as Houston and Abu Dhabi. As discussed in the Economic Development section, more compact development provides agglomeration efficiencies and cost savings that tend to support economic development (Hsieh and Moretti 2014; Melo, Graham and Noland 2009).

CONCLUSIONS AND RECOMMENDATIONS

The world is experiencing rapid urbanization. How this occurs will have immense economic, social and environmental impacts. To help identify optimal urban development policies, this report investigates the costs of sprawl and potential benefits of more compact, "smart growth" development.

This study builds on an extensive body of previous research. In recent years, there has been significant improvement in the data and tools available for evaluating land use impacts, and several sophisticated studies provide important new insights concerning various economic, social and environmental impacts of urban development patterns. As a result, we now have a far better understanding of development pattern impacts than was previously possible.

However, this type of analysis faces several technical challenges. There are various ways to define and measure urban development patterns, various impacts to consider, various ways to measure impacts, and various scales of analysis. If possible, impact analysis should consider several land use factors including development density, mix, centricity, transport network connectivity and design, the quality of transport options (walking, cycling, public transit, automobile, etc.) and pricing, but in practice, sprawl impacts are often evaluated based only on population density, since this information is easiest to obtain and understand. Some impacts overlap, and some are economic transfers (one group benefits at another's expense), so it is important to avoid double-counting. There are also confounding factors to consider, such as the tendency of residents to self-select neighborhoods, which can confuse our understanding of effects. People sometimes confuse density (people per unit of land) with crowding (people per unit of building space), although they are actually very different. All these issues should be considered when researching development impacts.

This analysis starts by identifying basic physical impacts of sprawl, including increases in the amount of land developed per capita, and dispersion of destinations which increases per capita motor vehicle travel. This indicates that compared with smart growth development (typically more than 30 residents per regional hectare), sprawl (typically less than 6 residents per hectare) increases per capita land consumption 60-80%, and motor vehicle travel by 20-60%.

This provides a conceptual basis for understanding various economic costs of sprawl, including displacement of agriculturally and ecologically productive lands, increased infrastructure costs, reduced accessibility for non-drivers, and increases in various transportation costs including facility costs, travel time, consumer expenditures, traffic accidents and pollution emissions. To the degree that sprawl degrades access by affordable modes (walking, cycling and public transit), these impacts tend to be regressive (they impose particularly large burdens on physically, economically and socially disadvantaged people). To the degree that sprawl concentrates poverty in urban neighborhoods, it tends to exacerbate social problems such as crime and dysfunctional families. To the degree that it reduces agglomeration efficiencies, increases infrastructure costs, and increases expenditures on imported goods (particularly vehicles and fuel), it tends to reduce economic productivity. Sprawl also provides benefits, but these are mostly direct internal benefits to sprawled community residents; there is little reason to expect sprawl to provide significant external benefits to non-residents since rational consumers and businesses internalize benefits and externalize costs.

Table 25 summarizes various sprawl impacts and our current knowledge about them.

Table 25
Sprawl Impacts Summary

Impact	Current Quality of Knowledge
Land development (displacement of farmland and other open space)	This impact is easy to measure, but difficult to monetize.
Public infrastructure and service costs	There is good research on this impact and it can be monetized.
Transportation costs	There is good research on this impact and it can be monetized.
Traffic risk	There is good research on this impact and it can be monetized.
Public fitness and health	There is now research on this impact and it can be monetized.
Energy consumption and pollution emissions	There is good research on this impact and it can be monetized.
Social equity (impacts on disadvantaged populations)	There is research on some aspects of this impact, but it is difficult to monetize.
Social problems (poverty and crime)	Some good research, but it is difficult to quantify and monetize.
Affordability	There is research on this impact, but it is difficult to monetize.
Economic development	There is research on this impact, but it is difficult to monetize.
External benefits of sprawl	There is research on this impact.

This table summarizes the current quality of knowledge concerning the various impacts (costs and benefits) of sprawl considered in this study.

To quantify the incremental costs of sprawl, this study divided U.S. cities into quintiles (fifths) and, using the "smartest growth" quintile as a baseline, estimated the additional land consumption, infrastructure and public service costs, vehicle costs, and health costs of more sprawled development. For example, the research indicates that sprawl increases annualized infrastructure costs from $502 per capita in the smartest growth quintile cities up to $750 annual per capita in the most sprawled quintile cities. Sprawl has similar effects on other cost categories. In total this analysis indicates that sprawl incremental costs average about $4,556 annual per capita, of which $2,568 is internal (borne directly by sprawl location residents) and $1,988 external (borne by other people). Even using lower-bound assumptions, this analysis indicates that sprawl external costs exceed $400 billion annually. Total costs are probably much higher than this estimate since this analysis considered relatively modest development changes (for example, even in the "smart growth" cities most urban residents would live in single-family housing and rely primarily on automobile travel), and excluded some significant costs such as open space displacement and increased social problems, because they are difficult to monetize.

A key question for this analysis is the degree that sprawl is economically inefficient, that is, the amount caused by policy distortions. This study investigated various planning and market distortions which encourage sprawl, such as development practices that favor dispersed development over compact urban infill, underpricing of public infrastructure and services in sprawled locations and underpricing of motor vehicle travel. For example, surveys indicate that many households want to live in more compact, walkable, mixed-use neighborhoods but cannot because current zoning codes discourage such development. Cost-based pricing of utilities and public services would result in 20-40% lower fees and taxes in smart growth locations. For example, if such fees average $1,000 per month, efficient pricing could result in $850 monthly fees in smart growth locations and $1,150 monthly fees in sprawled locations, reflecting the higher costs of providing public services in dispersed locations. Similarly, by charging users directly for roads and parking, efficient pricing would increase the cost of driving an automobile by several hundred dollars annually, and reduce taxes and rents that currently subsidize roads and parking facilities. Consumer preference research suggests that more optimal planning and pricing would cause many households to choose compact communities, drive less, and rely more on alternative modes than they currently do. This suggests that the high degree of sprawl and automobile dependency that occurs in North American cities is an anomaly, resulting in part from planning and market distortions, so this type of development should not be used as a model for cities that strive to be economically efficient and equitable.

Although sprawl costs may be lower in absolute value in developing countries due to lower wages and property values, they are probably similar relative to incomes and regional economies. As a result, smart growth policies that create more compact communities can provide substantial economic, social and environmental benefits in both developed and developing countries.

This study identified various factors to consider when determining how cities should expand. The results are consistent with the conclusions of Angel (2011) and UN-Habitat (2013) that cities should expand systematically along major utility and transit corridors. To help determine the optimal expansion policies, densities and development policies in specific situations, 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 economically excessive vehicle 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 patterns 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 multi-family 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.

This analysis indicates that very high regional densities (more than 100 residents per hectare) are only justified in highly constrained cities such as Hong Kong and Singapore. Most smart growth benefits can be achieved by shifts from low (under 30 residents per regional hectare) to moderate (50-80 residents per regional hectare, which is typical of affluent European cities). Although higher densities can provide additional benefits, these are likely to be modest in most cities. However, cities such as Singapore and Seoul demonstrate that with good planning, high density neighborhoods can provide high quality livability, and most cities should have a few districts of very high residential densities around their downtowns and other major transit terminals.

Because motor vehicles are very space-intensive (an automobile typically requires more space for roads and parking than the land used for a typical urban resident's house), a key factor for efficient and livable cities is to manage roads and parking for maximum efficiency, and to limit motor vehicle ownership rates to the capacity of available roads and parking facilities. This requires an integrated program of improvements to space-efficient modes (walking, cycling, ridesharing and public transit), incentives for travelers to use the most efficient mode for each trip, and accessible, multi-modal development which minimizes the need to drive. Since a bus lane can carry far more passengers than a general traffic lane, an efficient city provides bus lanes on most urban corridors. Table 26 summarizes optimal urban expansion, densities and development policies in these various types of cities.

Table 26
Optimal Urban Expansion, Densities and Development Policies

Factor	Un-Constrained	Semi-Constrained	Constrained
Growth pattern	Expand as needed	Expand less than population growth	Minimal expansion
Optimal regional density (residents / hectare)	20-60	40-100	80 +
Housing types	A majority can be small-lot single-family and adjacent	Approximately equal portions of small-lot single-family, adjacent, and multi-family.	Mostly multi-family
Optimal vehicle ownership (vehicles per 1,000 residents)	300-400	200-300	< 200
Private auto mode share	20-50%	10-20%	Less than 10%
Portion of land devoted to roads and parking	10-15%	15-20%	20-25%
Examples	Most African and American cities.	Most European and Asian cities.	Singapore, Hong Kong, Male, Vatican City.

Different types of cities may have different growth patterns, densities and transport patterns.

An important challenge facing growing cities is to provide affordable housing that responds to low-income residents' needs. Lower-priced housing should be diverse, including some larger units for large, extended families, and flexible lofts for households that need workspace for artistic or business activities. 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 sale or lease, on which owners build their houses. In most growing cities, a major portion of affordable housing should consist of mid-rise (2-6 story), wood-framed apartments and townhouses, generally built by private developers with government support. In highly constrained cities, affordable housing may require government subsidy of high-rise apartments.

In all types of cities it is important to ensure that compact urban neighborhoods are very livable and cohesive by designing urban streets to be attractive and multi-functional (including sidewalks, shops, cafes, and attractive landscaping), building public parks and trails, providing high quality public services (policing, schools and utilities), and supporting activities that encourage positive interactions among residents such as local festivals, outdoor markets, recreation and cultural centers, etc.

Some previous sprawl cost studies have been criticized for various reasons. Critics argue that sprawl cost estimates are exaggerated, that such costs are offset by benefits of equal magnitude, or that more compact, smart growth development patterns impose equal external costs. However, much of this criticism reflects inaccurate or outdated research (for example, old studies which suggested that smart growth does not save energy or reduce public infrastructure costs). Although sprawl does provide benefits, these are largely direct, internal benefits to sprawl community residents and there is little evidence of significant external benefits which offset concerns about external costs. Probably the most legitimate criticism of smart growth is that it can reduce single-family housing affordability, but smart growth policies that allow more compact, infill development increase housing and transport affordability, and so are particularly beneficial to low-income households. This criticism therefore depends on whether single-family housing affordability is more important than compact housing affordability, and whether house purchase affordability is more important than infrastructure and transport affordability. To the degree that smart growth reduces total resource costs (public infrastructure and service costs, traffic accident, pollution damages, etc.) it can benefit all residents.

Much of the research in this report is based on North American conditions because that is where the best data are available. However, the basic relationships should be transferable: more dispersed and automobile-oriented development imposes various costs, including external costs, which can be reduced with smart growth policies. These can benefit most overall by improving their housing and transport options and providing new opportunities to save money to households that choose smart growth locations. Smart growth benefits tend to be particularly large:

- In rapidly growing urban areas.
- In urban areas making significant infrastructure investments.
- In cities where urban fringe land has high social or environmental values.
- Where infrastructure and vehicle fuel are costly to produce or import, for example, if a low-income country must import equipment and energy.
- If communities have goals to improve mobility options for disadvantaged populations, improve public fitness and health, or support environmental objectives.

Below are specific smart growth policies that can be implemented by different levels of government.

Municipal and Regional Governments
- Reform zoning codes to allow higher densities and encourage more mixed, multi-modal development within existing urban areas.
- Significantly reduce or eliminate minimum parking requirements in zoning codes, and implement more efficient parking management practices, such as pricing on-street parking, and efficiently enforcing parking regulations.
- Devote special care to planning central business districts and other major activity centers so they are attractive and multi-modal.
- Use regulations or pricing to manage road space to favor higher value trips and more space efficient modes over lower value trips and space intensive modes.
- Apply complete streets policies which insure that urban roads are designed and managed to accommodate diverse users and uses, including pedestrians (including those with disabilities and special needs), cyclists, public transit travelers, businesses, customers, tourists, delivery vehicles and residents.
- Ensure that any new "greenfield" development is well planned, creating complete communities (housing, shops, schools, parks, etc.) with good walking, cycling and public transit access.
- Structure development fees, utility rates and taxes to reflect the higher costs of providing public services in more dispersed locations.
- Support professional development programs for planners, engineers, developers and public officials to introduce smart growth concepts.

National Economic and Finance Ministries
- Reduce and eventually eliminate motor vehicle fuel subsidies, and implement regularly scheduled fuel tax increases.
- Apply comprehensive and multi-modal urban transportation planning. Ensure that all urban roadway projects reflect "complete streets" principles which accommodate diverse users and uses.
- Provide diverse and stable urban transportation funding options, including optional regional fuel taxes, road tolls, special property taxes (for land value capture), vehicle fees, employee levies, emission fees, and parking taxes.
- Establish national transportation and land use data programs to collect standardize GIS and transportation statistics.
- Provide a regional planning framework that encourages municipal governments to cooperate on transportation and land use planning.

Of course, these issues are complex. Urban planning decisions involve numerous trade-offs between various planning objectives, so many different factors must be considered when evaluating policies and projects. More research is needed to better understand the full benefits and costs of specific policy and planning decisions and determine the best policies to implement in a particular situation.

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