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Evaluating Transportation Diversity

Multimodal Planning for Efficient and Equitable Communities

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Abstract

Transportation diversity refers to the variety of mobility and accessibility options available in a particular situation, including various modes, services and destinations. A transport system must be diverse in order to serve diverse demands, including the needs of people who cannot, should not or prefer not to drive. Multimodal planning that increases transport system diversity tends to increase efficiency, equity and resilience, and achieve various planning goals including congestion reduction, infrastructure savings, affordability, improved mobility for non-drivers, traffic safety, increased public fitness and health, environmental protection and support for strategic development objectives. Conventional planning undervalues many of these benefits, resulting in less diverse, more automobile-dependent communities than optimal. This report examines consumer demands for non-auto travel options, the roles that various modes play in an efficient and equitable transport system, transport diversity benefits, and methods for determining optimal transport system diversity.

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A motorist driving on a rural road stops to ask an old farmer for directions to a nearby town. The farmer ponders the question and replies, "I'm afraid you can't get there from here."

This old joke is amusing because it contradicts what we know about transportation. Given accurate directions and sufficient fuel a motorist can reach nearly any location on a public road. But if the visitor were walking, the situation might not be so funny. Rather than suggesting that the destination is generally inaccessible, it could mean, "*You* can't get there, at least not the way you are traveling." It is tragic rather than comic if some groups of people have inferior transportation options.

"Variety is the Spice of Life"

Introduction

To be efficient and fair, a transportation system must be diverse or *multimodal*, in order to serve diverse demands. This lets travellers choose the best option for each trip: walking and bicycling for local travel, public transit for longer urban trips, and automobiles when they are truly most efficient overall, considering all impacts. A diverse transportation system ensures that everybody, including non-drivers, have viable mobility options and receive their fair share of public investments in transport facilities and services.

Transportation diversity declined during much of the last century due to automobile-oriented planning which invested transportation resources (money and land) primarily in roads and parking facilities, with little support for alternatives. This created automobile-dependent communities that favor driving over other travel modes. This can create problems for both individuals and communities.

Many people cannot, should not or prefer not to drive for most trips. Without suitable options, non-drivers lack independent mobility, which deprives them of economic and social opportunities, and forces motorists to chauffeur non-driving family members and friends. Automobile dependency forces many households to spend more than is affordable on transportation, and exacerbates traffic problems including congestion, risk and pollution. Multimodal planning can reduce these problems.

Of course, it is not feasible to provide every travel option everywhere, but more comprehensive and multimodal planning can create more diverse transportation systems that respond to currently unmet consumer demands, and the results can benefit everybody. Multimodal planning is not anti-car: a multimodal transportation system includes a significant amount of automobile travel, as opposed to "car-free" planning which severely limits driving. Table 1 compares approaches.

Table 1 **Automobile-Dependent, Multimodal and Car-Free Compared**

	Auto-Dependent	Multi-Modal	Car-Free
Planning priority	Motor vehicle mobility: speed and distance	Multimodal mobility and accessibility	Non-auto accessibility.
Mobility Options	Automobile. Other modes are considered inefficient, to be avoided.	Walking, cycling, transit, ridesharing, automobile and mobility substitutes	Walking, cycling, public transit, taxi and mobility substitutes.
Land use development	Dispersed. Development along highways	Most development is compact and mixed.	All development is compact and mixed around transit.
Vehicle parking	Abundant and usually free.	Moderate and often priced.	Very limited.
Vehicle ownership	High. Over 500 vehicles per 1,000 residents.	Moderate. 200-500 vehicles per 1,000 residents.	Low. Less than 200 vehicles per 1,000 residents.
Automobile mode share	More than 80%	20-80%	Less than 20%

Automobile-dependent, multimodal and car-free communities differ in many ways.

Key Terms and Concepts

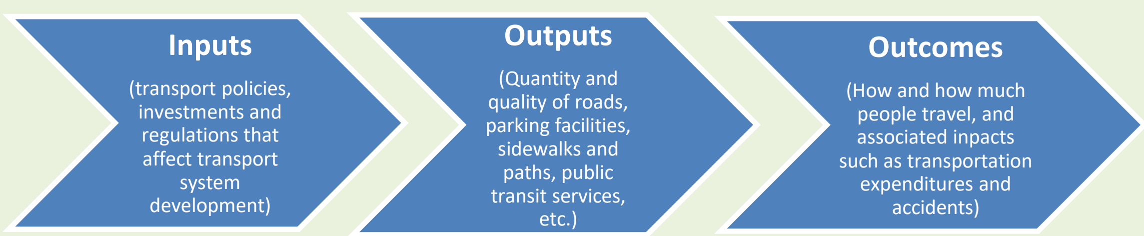
Transportation diversity (also called *multimodalism*, or we say that travellers have *options* or *choices*) refers to the availability of various travel modes and services, which can include walking, cycling, ridesharing (car- and vanpooling), taxi and ridehailing (such as Uber and Lyft) services, various forms of public transportation (bus, train, ferry, commercial air travel), plus mobility substitutes such as telework (telecommunications which substitutes for physical travel, such as telecommuting, Internet shopping and e-medicine) and delivery services (mail, courier, and deliveries by local shops and restaurants). To complement these mobility options communities need compact development and well connected transport networks, so most homes and worksites are located within convenient walking distance of most commonly-used services (shops, restaurants, schools, parks, healthcare, etc.), providing good non-automobile accessibility. As a result, people who live or work in such areas tend to own fewer cars, drive less and rely more on alternative modes. Such communities are called *urban villages*, *Transit-Oriented Development* (TOD), *Smart Growth*, *New Urbanist* or *location-efficient development*, depending on context.

Multimodal planning is the process for creating a diverse transportation system, in contrast to automobile-oriented planning which favors automobile travel to the detriment of other modes, which creates *automobile-dependent* communities. Multimodal planning applies comprehensive analysis of travel demands and impacts, which tends to increase investments in walking, cycling and public transit, and justify Transportation Demand Management programs. Multimodal planning also integrates transportation and land use development policies, and corrects system gaps, such as poor pedestrian and bicyclist access to public transport stops.

Resilience refers to a system's ability to accommodate unpredictable changes, including sudden and extreme conditions. *Option value* refers to the benefits that people may place on having options available for possible future use. Transportation diversity tends to increase resilience which provides option value to people who may want a mode or service in the future.

These factors can be evaluated based on inputs, outputs and outcomes, as illustrated below. For example, multimodal planning tends to increase the amount of money and road space devoted to active modes, which increases the quantity and quality of sidewalks, paths and bikelanes, which often increase walking and bicycling trips, and reduces automobile travel.

Inputs, Outputs and Outcomes



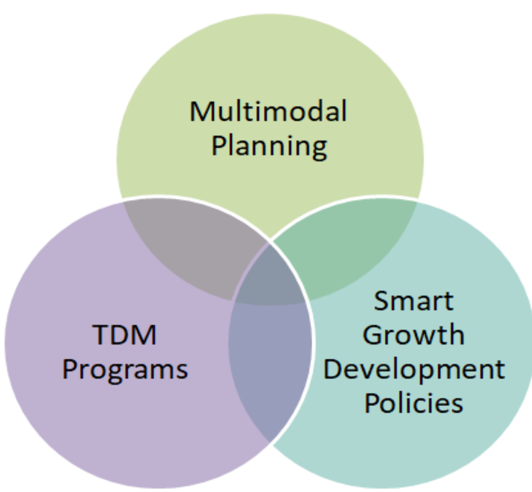
Transportation diversity can be evaluated based on ***input****, such as investments in various modes,* ***output*** *such as the quantity and quality of facilities and services, or* ***outcomes*** *such as how and how much people travel by different modes.*

Automobile-oriented planning evaluates transportation system performance based on vehicle travel speeds, and so favors driving over slower modes in planning decisions such as funding and road space allocation. For example, evaluating transport system performance based on roadway level-of-service, justifies road expansions to reduce congestion delays, but ignores the tendency of wider roads and heavier traffic to degrade walking and cycling conditions, and since most public transit trips include walking links, this reduces transit access. Similarly, conventional planning requires generous parking supply for motorist convenience, although this results in more dispersed development which is difficult to access without a car. More comprehensive analysis tends to justify more diverse transportation investments.

There are many possible ways to evaluate transportation diversity. A narrow perspective only considers the degree that a particular option achieves a particular objective, such as whether a sidewalk improvement solves parking problems or whether a new transit service reduces traffic congestion on a particular corridor. A more comprehensive perspective considers a broader range of impacts, and the potential for network effects, and so considers whether particular sidewalk improvements and public transit service expansions can together help create a more multimodal community where residents own fewer cars, drive less and rely more on alternative modes, and how this can provide multiple economic, social and environmental benefits. More comprehensive analysis reflects current planning practices.

A new paradigm is expanding the range of impacts and options considered in transportation planning, which supports more multimodal planning. The new paradigm recognizes that mobility is not usually an end in itself, rather, the ultimate goal of most transportation is access to desired services and activities (school, work, shopping, healthcare, recreation, etc.), and so recognizes the important roles that walking, cycling and public transit can play in an efficient and equitable transport system, and it expands planning goals to include affordability, safety, mobility for non-drivers, and public fitness and health.

Figure 1 **TDM Strategies**



Multimodal planning is a type of TDM strategy.

Multimodal planning is a type of transportation demand management (TDM) that changes travel behavior to increase transport system efficiency. It supports and is supported by other TDM strategies such as commute trip reduction programs and Smart Growth development policies. These strategies tend to be synergistic: they become more effective if implemented together. For example, since most public transit trips include walking links, pedestrian improvements can help increase transit ridership and associated benefits, and become even more effective if implemented with supportive land use policies such as efficient parking pricing. As a result, multimodal planning should be evaluated as an integrated program rather than as individual components.

More comprehensive and multimodal planning tends to increase investments in walking, cycling, and public transit because they tend to be more space-efficient, energy efficient, affordable, inclusive, healthy, and less polluting than automobile travel. Even motorists who do not use these modes can benefit from reduced traffic and parking congestion, accident risk, chauffeuring burdens and pollution. Current trends are increasing their importance due to:

- A growing number of people who cannot or should not drive due to physical, financial or legal constraints, who need efficient alternatives.
- Concerns about transportation affordability.
- Increasing concerns about sedentary living health problems, and the value of walking and bicycling for fitness and health.
- Traffic safety policies designed to reduce high risk (young, old, impaired and distracted) driving, and the need to provide suitable mobility options for these groups.
- Desires to address specific planning problems, such as traffic and parking congestion, excessive energy consumption and pollution emissions.
- Goals to create more compact, attractive and less polluted communities.

To their credit, many decision-makers support walking, cycling, public transit and Smart Growth polices more than is justified by conventional planning analysis: they realize intuitively that diverse transport systems provide important economic, social and environmental benefits that conventional analysis undervalues. However, more comprehensive evaluation of these impacts can lead to better policy and planning decisions. This report is intended to provide practical guidance for more comprehensive and multimodal transportation planning analysis.

This report explores multimodal planning concepts, investigates travel demands for alternative modes, discusses benefits provided by transportation diversity and practical ways to evaluate these impacts, investigates barriers to increased transport diversity, evaluates criticisms of multimodal planning, and discusses examples. This report should be of interest to policy makers, practitioners (planners, engineers and economists), and multimodal planning advocates.

Multimodal Planning Principles

1. Recognize *all travel demands*, including by people who cannot, should not or prefer not to drive.
2. Count *every trip*. Consider all travel, including short trips, active modes, and recreational travel in travel surveys and data analysis.
3. Recognize the *important roles* that walking, bicycling and public transport play in an efficient and equitable transportation system.
4. Apply *comprehensive analysis* that considers all benefits and costs.
5. Apply *least cost planning*, which invests resources in the most cost effective option, including alternative modes and demand management strategies, considering all impacts.
6. Use *transportation demand management* to encourage use of efficient mobility options.
7. *Integrate transportation and land use planning* to create accessible, multimodal communities.
8. *Reduce or eliminate requirements* and encourage efficient parking management.

The Diversity of Travel Demands

Travel demand refers to the type and amount of travel that people would choose in a particular situation, including latent travel that people would take if additional options were available. For example, some travellers would drive less and rely more on walking, bicycling and public transit if they were more convenient and affordable. Failing to consider latent demand can create self-fulfilling prophecies, in which current high levels of automobile travel justify automobile-oriented transportation planning, which perpetuates automobile dependency (Litman 2021).

Table 2 identifies various types of non-auto travel demands. This indicates that in a typical community, 20-40% of travellers cannot, should not or prefer not to drive for significant portion of trips, and so will use non-auto modes if they are available and suitable.

Table 2 **Types of Non-Auto Travel Demands** (Brumbaugh 2021; Census 2021; OIA 2020)

Type	Prevalence	Consequences
Seniors who do not or should not drive.	5-10% of residents and increasing.	Experience limited mobility and accessibility, pay high costs for expensive options (such as taxi and delivery services), require chauffeuring, or move to another community with better transport options.
People with mobility impairments.	5-10% of residents	
Youths (12-22 years).	10-20% of residents	
Zero-vehicle household members.	5-15% of households	
Drivers who share vehicles.	5-15% of motorists	
Low-income households who spend more than affordable for vehicles.	20-40% of households	Lack mobility or are burdened by transport costs.
Drivers who temporarily lack vehicles.	Varies	Lack mobility or require chauffeuring.
Tourists and visitors who lack vehicles.	Varies	Lack mobility or visit other areas.
People who walk for religious reasons, such as observant Jews.	0-3% of households	Lack mobility during religious days or move to more walkable areas.
Travellers impaired or distracted by alcohol, drugs or devices.	A small portion of trips, a large portion of drivers.	Drive impaired or distracted, risking citations and crashes.
People who want to walk and bike for health and enjoyment.	40-60% of residents	Have insufficient exercise or must spend time and money exercising at a gym.
Families with pets to walk.	20% of households	May need to drive to dog walking area
Motorists who benefit from better travel options for others.	Most motorists.	Motorists bear more congestion, risk and chauffeuring burdens.

In a typical community, 20-40% of travellers rely on non-auto modes, or will do so if they are convenient, comfortable and affordable.

Of course, many people in these categories— seniors, youths, people with disabilities and low incomes—frequently travel by automobile as drivers or passengers, and seldom rely on walking, bicycling or public transit, but their use of non-auto modes is likely to increase if those modes received more investment.

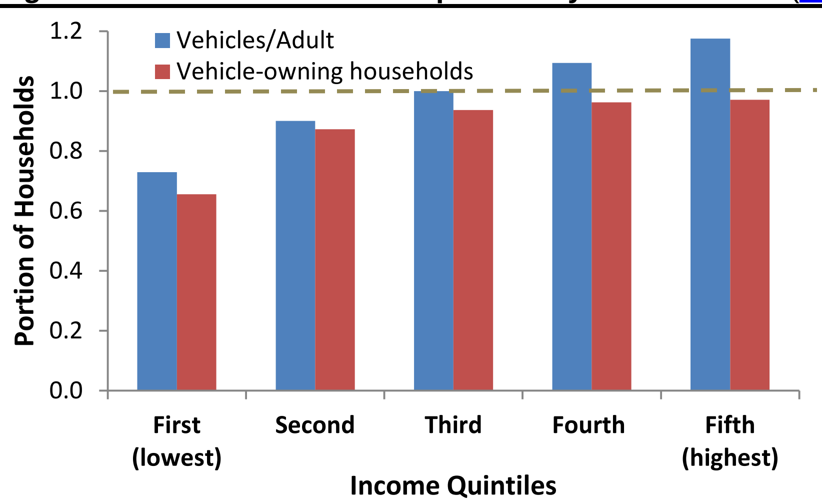
Many of these factors overlap. For example, people with mobility impairments have high poverty rates which increases the importance of affordable and accessible travel options. For example, although affluent wheelchair users can use ramp-equipped automobiles and taxis, despite their high costs, many cannot due to their high costs and so need more affordable options such as a housing in a compact neighborhood where most services and activities are close by with universal designed pedestrian networks and public transit services.

The demand for non-auto travel depends on how the issue is defined. For example, although only a minority of travellers has severe mobility impairments, such as relying on wheelchairs, many people will have a disability sometime in their lives and many families have at least one member with impairment, so demand for universal design is greater than indicated by current use, a concept called *option value*. Similarly, although the portion of total driving impaired by alcohol or drugs is probably small, a significant portion of motorist report that they at least occasionally drive impaired and so could benefit from improved non-auto travel options (TIRF 2019). Middle-income families can benefit from affordable transport options for their children attending college. Motorists also benefit from non-auto improvements that reduce their chauffeuring burdens to family members and friends who cannot drive.

Many of these options can serve multiple users, some of which tend to be overlooked or undervalued in conventional transportation planning. For example, wide and smooth walkways with ramps and curbcuts are often justified to accommodate wheelchair users, who typically represent less than 1% of facility users, but they also serve parents pushing strollers, tourists with wheeled luggage, and people using handcarts to make deliveries who may represent 5-15% of users. Similarly, improving lower-cost modes, such as bicycling and public transit, is important for lower-income travellers, but can also benefit middle- and higher-income travellers.

Physically, economically and socially disadvantaged groups tend to drive less and rely more on non-auto modes than able and affluent travellers (Park, et al. 2022). For example, among the lowest income quintile, 34% of households are car-free and there are only 0.73 vehicles per adult, as illustrated below.

Figure 2 **Vehicle Ownership Rates by Income Class** ([BLS 2011-2020](BLS 2011-2020))

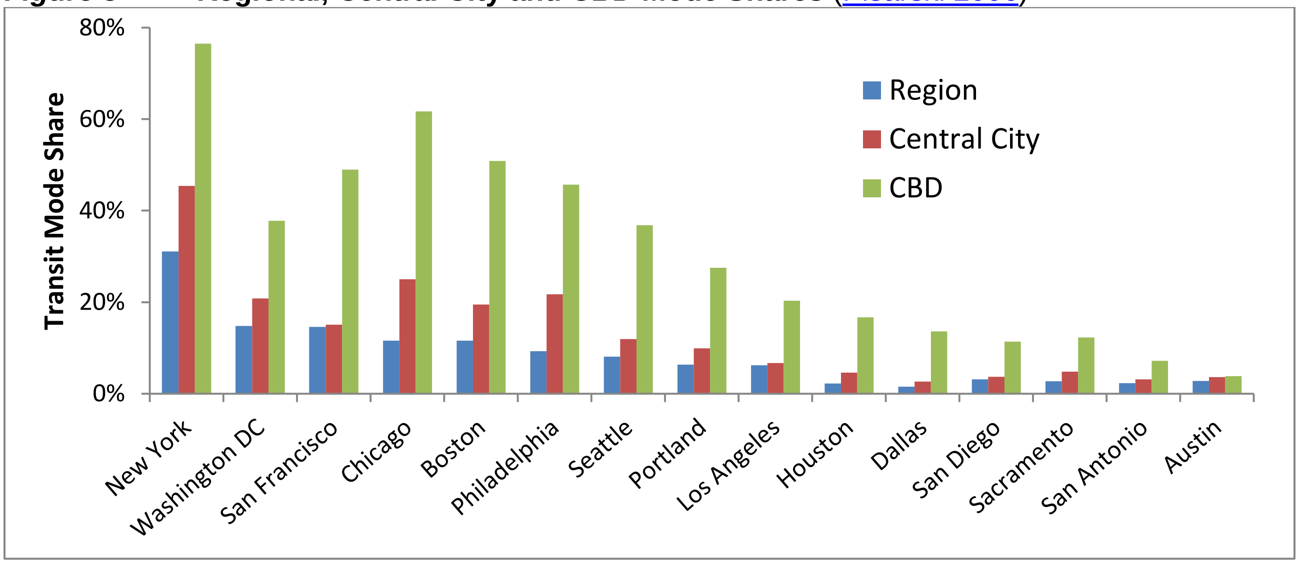


Although about 90% of U.S. households own at least one vehicle and there are about as many vehicles as adults, these rates are much lower in lower-income households. Among the lowest income quintile, 34% of households are car-free and there are only 0.73 vehicles per adult. The second income quintile also has lower than average ownership rates. These shortages are off-set by high vehicle ownership rates in the highest income classes.

Conventional travel statistics tend to exaggerate automobile travel demands and undercount demand for non-auto travel. Although about 90% of North American households own an automobile, and use those vehicles for 75-85% of trips, most people use other modes at least occasionally, or would if they were convenient, comfortable and affordable. The study, *The Multimodal Majority?* (Buehler and Hamre 2015) found that during a typical week about 7% of Americans rely entirely on non-auto modes, 65% use a car plus another mode one to five times, and 25% use a car and another mode seven or more times.

Walking, bicycling and public transit mode shares tend to increase with urban density, as illustrated below, and so tend to be particularly high in areas with the most severe traffic and parking problems. Small increase in regional non-auto mode shares can provide large benefits if concentrated on congested corridors.

Figure 3 **Regional, Central City and CBD Mode Shares** (Pisarski 2006)



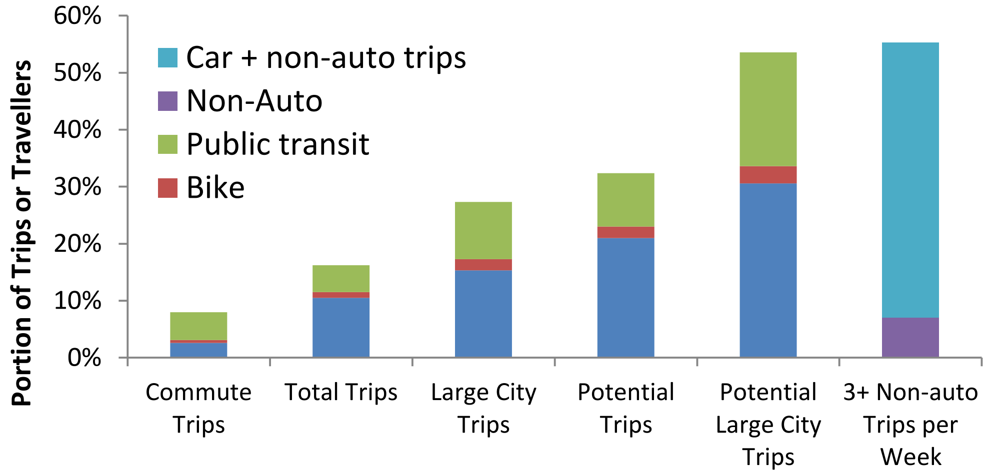
Non-auto mode shares are particularly high in denser urban areas where traffic problems are severe, so small shifts to walking, bicycling or public transit can provide large benefits if concentrated in those areas.

Conventional travel data tends to undercount non-auto travel, which underestimates their demand. Many travel surveys only count peak-period trips between traffic analysis zones (TAZs), which ignores short trips (those within a TAZ), non-commute trips, recreational travel, travel by children and many active mode trips. For example, a *bike-bus-walk* trip is often coded simply as a *bus* trip, and a commuter who parks at the edge of town and walks ten blocks to work is coded as a *driver*, ignoring the walking and bicycling links. More comprehensive surveys indicate that walking and bicycling trips are three to six times more common than conventional surveys indicate (Forsyth, Krizek and Agrawal 2010), so if statistics only indicate that 5% of trips are by walking and bicycling, the actual amount is probably 10-30%. Before-and-after surveys often find significant increases in walking, cycling and public transit travel after their conditions improve, indicating significant latent demand (FHWA 2015).

The figure below illustrates various indicators of U.S. non-auto travel demands. The first column shows the non-auto commute mode share, based on Census data. The second column shows total trips by non-auto modes, based on National Household Travel Survey (NHTS) data. The

third column shows estimated non-auto mode shares in larger cities where traffic problems are most severe. The fourth and fifth columns show estimates of potential non-auto mode shares if communities invested in them to the degree that is cost effective. The sixth column indicates the portion of U.S. residents who use non-auto modes at least three times per week.

Figure 4 **Non-Auto Demand Indicators** (2018 ACS, 2017 NHTS, Buehler and Hamre 2015)



Non-auto modes serve 8% of commute trips, 16% of total personal trips, 27% of personal trips in large cities, and a third to half of potential trips if they are improved. About half of all travellers use non-auto modes at least three times per week.

This indicates that the demand for non-auto travel is greater than indicated by conventional transportation statistics. Of course, people’s needs, abilities and preferences vary and often change over time. This justifies multimodal planning in order to serve these diverse and changing demands, including latent demands for non-auto travel. The next section describes the benefits of serving currently unmet demands.

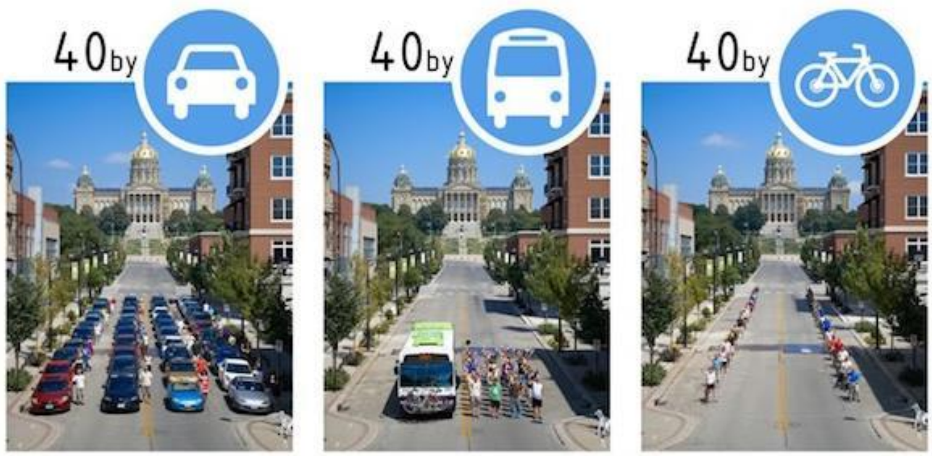
Transportation Diversity Benefits

This section describes various benefits provided by a more diverse, less automobile-dependent transportation system.

Congestion Reductions and Infrastructure Cost Savings

Automobile travel is space intensive. Figure 2 compares road space needs of various modes.

Figure 6 **Space Required to Transport 40 People** (www.tobinbennett.com)

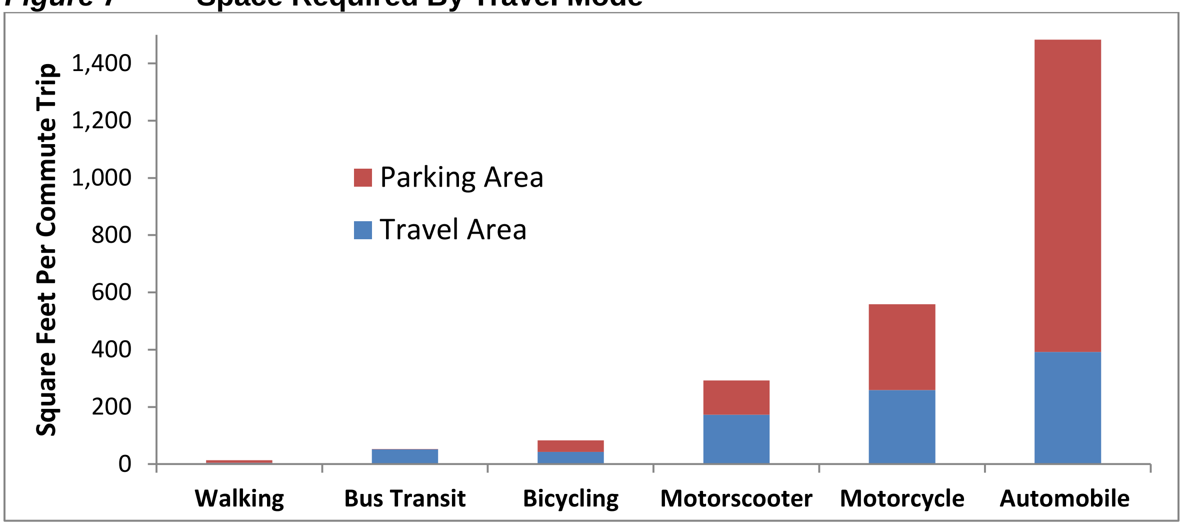


Automobile travel requires far more road space than other modes, and so causes more traffic congestion.

Improving and encouraging space-efficient mode can reduce congestion.

Vehicle travel also requires parking at each destination. Figure 3 compares the road and parking space requirements for commuting by various modes: automobiles require many times more space than walking, cycling and public transit.

Figure 7 **Space Required By Travel Mode**[1]



Automobile travel requires far more space for travel and parking than other modes.

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[1] *Transport Land Requirements Spreadsheet* (www.vtpi.org/Transport_Land.xls), based on Eric Bruun and Vukan Vuchic (1995), "The Time-Area Concept: Development, Meaning and Applications," *Transportation Research Record 1499*, TRB (www.trb.org), pp. 95-104; at https://trid.trb.org/view.aspx?id=452722.

As a result, walking, cycling and public transit help reduce traffic and parking congestion in the short run, and over the long run can help reduce road and parking facility costs. Critics sometimes argue that because transit only carries a small portion of total travel it can do little to reduce congestion, but on the most congested, such as urban highways and downtown arterials, alternative modes can carry a significant portion of peak-period travel and provide significant congestion reductions (Litman 2014a; Nelson\Nygaard 2006).

These impacts can be difficult to measure because congestion maintains a self-limiting equilibrium: it increases until delays cause some travelers to reduce their peak-period vehicle trips. The quality of travel options affects this equilibrium. If alternatives to driving are inefficient or uncomfortable, delays must become severe before travellers shift modes, but if alternative are attractive, less congestion is needed to cause shifts. Congestion does not disappear, but is less severe than would occur without these alternatives.

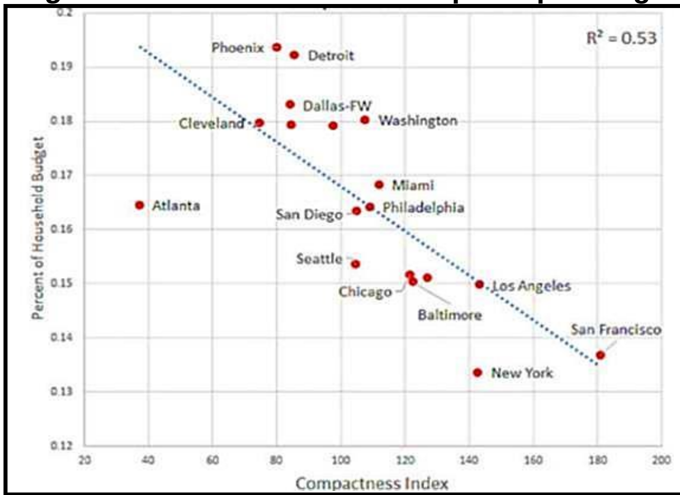
Congestion can be measured in various ways that give very different conclusions about the nature of this cost and the effectiveness of various solutions (Litman 2014a; Wallis and Lupton 2013). Indicators such as roadway Level-of-Service and the Travel Time Index measure congestion *intensity*, the degree that traffic speeds decline during peak periods. Measured this way, alternative modes only reduce congestion if they reduce motorists' delay. More comprehensive indicators, such as *per capita congestion costs* or *commute duration*, also account for the congestion avoided by travellers who choose alternative modes or shorter commutes. For example, compact, multi-modal cities such as New York, Boston and Philadelphia tend to have more *intense* congestion (greater peak-period speed reductions), but lower *congestion costs* (fewer annual hours of delay per capita) due to lower auto mode shares and short trip lengths, which reduces congestion *exposure* (the amount residents drive during peak periods). More dispersed, automobile-oriented cities such as Houston, Atlanta and Detroit tend to have less intense congestion but greater congestion costs.

Empirical evidence indicates that residents of more multimodal communities experience less traffic congestion than in more sprawled, automobile-dependent areas. A major study in Phoenix, Arizona found less intense congestion, and less congestion experienced by residents of more compact, multimodal neighborhoods than in lower-density, automobile-dependent areas (Kuzmyak 2012). Hamilton and Wichman (2016) used a unique fine-grained traffic dataset to measure the Washington DC Capital Bikeshare program's congestion impacts. They found that bikeshare stations reduced congestion by 4% or more compared with what would otherwise occur, with the greatest reductions in the most congested areas. Because transit riders tend to travel on congested urban corridors, they usually have much larger congestion reduction impacts than their mode share. For example, although only 11% of Los Angeles commuters use transit, when a strike halted transit service for five weeks, average highway congestion delay increased 47%, with 11% to 38% increases in regional congestion costs (Anderson 2013).

Consumer Savings and Affordability

Walking, cycling and public transit are much cheaper than automobile travel, providing savings and affordability (savings to lower-income households). Automobiles sometimes impose large unexpected costs for repairs, crashes or traffic citations that can be particularly burdensome to lower-income motorists (Weinstein Agrawal, et al. 2011). Residents of compact, multimodal communities spend much less on transportation than in sprawled, automobile dependent areas (CTOD and CNT 2006; Ewing and Hamidi 2014), as illustrated in figures 8 and 9. Households in transit-oriented neighborhoods often spend less than 10% of their budgets on transportation, compared with more than 20% in sprawled, automobile-dependent areas (Litman 2005).

Figure 8 **Household Transport Spending Versus Compactness** (Grammenos 2016)

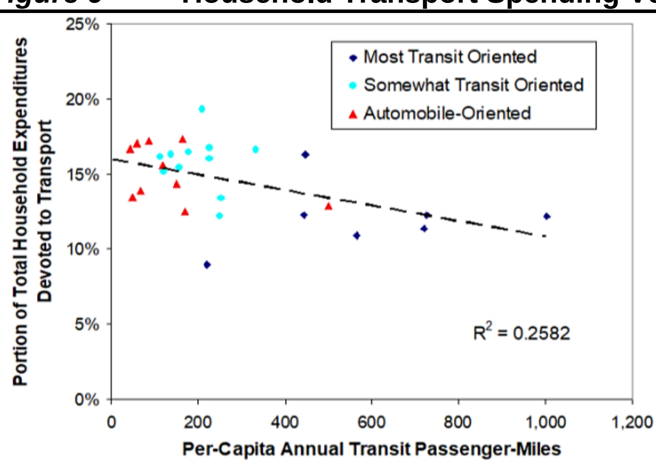


Households in compact, multimodal regions spend a far smaller portion of their budgets on transportation than in sprawled, automobile-dependent regions such as Phoenix and Detroit.

Much greater differences are found when these impacts are evaluated at a finer geographic scale. Residents of compact, multimodal neighborhoods typically spend half as much on transportation as in sprawled, automobile-dependent areas, and have better fallback options when they are unable to drive.

Potential saving are even larger than these surveys indicate since many households spend more on vehicles than necessary, for example, owning expensive vehicles for status sake, or additional vehicles for recreation. Transportation diversity also increases economic resilience by providing savings opportunities for responding to financial stresses such as reduced income or a vehicle failure, an option that is not feasible in automobile-dependent areas. This helps explain why housing foreclosure rates are much lower in more multimodal communities (NRDC 2010).

Figure 9 **Household Transport Spending Versus Transit Use** (Litman 2005)



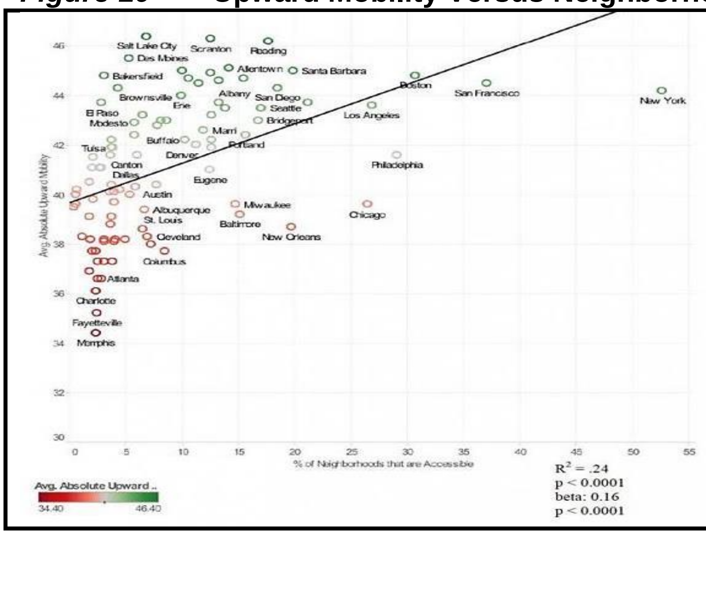
The portion of household budgets devoted to transportation (automobiles and transit) tends to decline with increased transit ridership, and is much lower in transit-oriented than in automobile-dependent urban regions.

Non-Drivers' Independent Mobility and Economic Opportunity

As previously described, 20-40% of residents in typical communities cannot or should not drive due to age, poverty, disability or impairment. Without suitable travel options:

- Non-drivers lack independent mobility. They have fewer opportunities to travel when and where they want, and so may have difficulty accessing basic services and activities. This reduces their economic opportunities, and conversely, the pool of potential employees available to businesses. It also reduces their recreational activities, reducing their physical and mental health.
- Non-drivers receive less than their fair share of transportation investments. Approximately $700 is spent on roads and $1,000-3,000 on parking subsidies annually per capita, compared with $100-200 for transit subsidies and $20-50 for pedestrian and cycling facilities. This is unfair to non-drivers and since driving tends to increase with income, it is regressive, resulting in lower-income households subsidizing the costs of their wealthier neighbors.
- Motorists must chauffeur non-drivers. In automobile-dependent communities this represents a major portion of total travel (Litman 2015). In the U.S., at least 6.9% of total personal trips, 15% of morning peak trips, and 9.4% of afternoon peak trips are for chauffeuring (McGuckin 2009).
- Higher-risk people drive even if they should, and want to, use alternatives. Many traffic safety strategies, such as graduated licenses, senior driving tests, anti-impaired and anti-distracted driving campaigns are intended to reduce high risk driving. Their effectiveness depends, in part, on these groups having viable alternatives to driving.
- More compact, multimodal communities increase economic mobility, the chance that a child who grows up in a lower-income household will be more economically prosperous as an adult (Ewing, et al. 2017; Talen and Koschinsky 2013). More diverse transport options help them access economic opportunities such as school and work (Stanley, et al. 2010).

Figure 10 **Upward Mobility Versus Neighborhood Accessibility** (Ewing, et al. 2016)



Economic mobility (the chance that children born in poverty become economically successful as adults) is greater for households living in more accessible, multimodal communities.

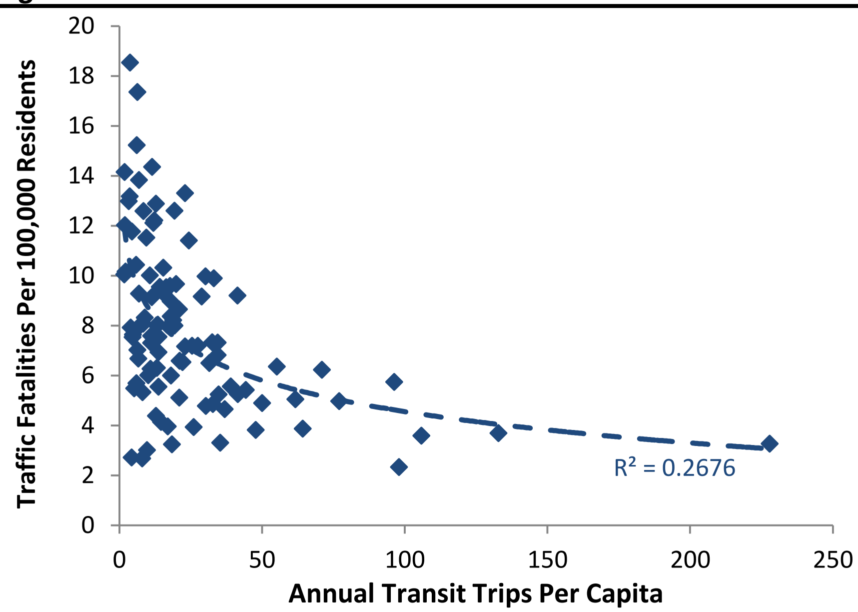
This probably reflects ways that multimodal transportation increases non-drivers' economic opportunities.

Traffic Safety

An extensive body of research using various data sets and methods indicates that traffic casualty rates (deaths and injuries) tend to decline with more compact and multimodal urban development (Duduta, Adriazola-Steil and Hidalgo 2013; Welle, et al. 2015). Per capita traffic crash rates tend to decline with more compact and mixed development, smaller block sizes, increased street connections, narrower streets, better pedestrian and cycling facilities, better crosswalks, roundabouts and more traffic calming (Ewing and Dumbaugh 2009; Garrick and Marshall 2011). Ewing and Hamidi (2014) found that more compact U.S. urban areas had slightly higher crash rates but much lower traffic fatality rates than sprawled areas: each 10% increase in their compact community index is associated with a 0.4% increase in total crashes, and a 13.8% reduction in traffic fatalities.

Traffic fatality rates tend to decline with increased transit ridership (Stimpson, et al. 2014). The figure below illustrates the relationship between transit trips and traffic fatality rates for U.S. cities. Higher-transit-ridership regions (more than 50 annual transit trips per capita) have about half the average traffic fatality rates as low-transit-ridership cities (less than 20 annual trips per capita). This represents a small increase in transit mode share, from about 1.5% up to about 4%, but is associated with large reductions in traffic fatality rates. This suggest that many of the factors that encourage transit travel, such as more compact development, improved walking conditions, and reduced parking supply, also tend to reduce traffic fatality rates.

Figure 11 **Transit Travel Versus Traffic Deaths in U.S. Cities** (Litman 2016)



As transit travel increases, per capita traffic fatality rates tend to decline. Cities where residents average more than 50 annual transit trips have about half the average traffic fatality rates as cities where residents average fewer than 20 annual transit trips.

As active travel (walking and cycling) increases in a community, total per capita traffic casualty rates, and per-mile pedestrian and cyclist crash rates tend to decline, an effect sometimes called safety in numbers (Jacobsen 2003; Myers, et al. 2013). This probably results from a combination of less total vehicle travel, less higher-risk (youth, senior, impaired, etc.) driving, slower traffic speeds, and more caution by drivers in compact, multimodal communities.

Public Fitness and Health

To maintain basic fitness and health, experts recommend that people spend at least 22 daily minutes (150 minutes a week) in moderate physical activity, such as fast walking or cycling (CDC 2008). Although there are many possible ways to exercise, organized sports or fitness training require special time and expenditures, and can be challenging for people who are overweight and sedentary. For many people, particularly those with the greatest risks, neighborhood walking and cycling are among the most practical way to achieve fitness targets.

An extensive body of research indicates that living in a more multimodal community increases the portion of residents who are physically active and fit (Ewing and Hamidi 2014). Controlling for other factors Frank, et al. (2006) found that a 5% increase in a walkability index is associated with a 32.1% increase in active transport, a 0.23 point reduction in body mass index, a 6.5% VMT reduction, and reduced per capita air emissions. Improving walking and cycling conditions, improving public transit services, more connected roadway networks, more compact and mixed development, improved access to parks and recreational facilities, and programs that promote active transport tend to increase public fitness and health (CPSTF 2017).

Most public transit trips include walking links so physical activity tends to increase with transit travel. Lachapelle, et al. (2011) found that transit commuters average 5 to 10 more minutes of moderate-intensity physical activity, and walked more to services and destinations than nonusers. Melbourne, Australia residents who use public transit average 41 daily minutes of walking or cycling for transport, five times more than the 8 minutes averaged by residents who travel only by automobile (BusVic 2010).

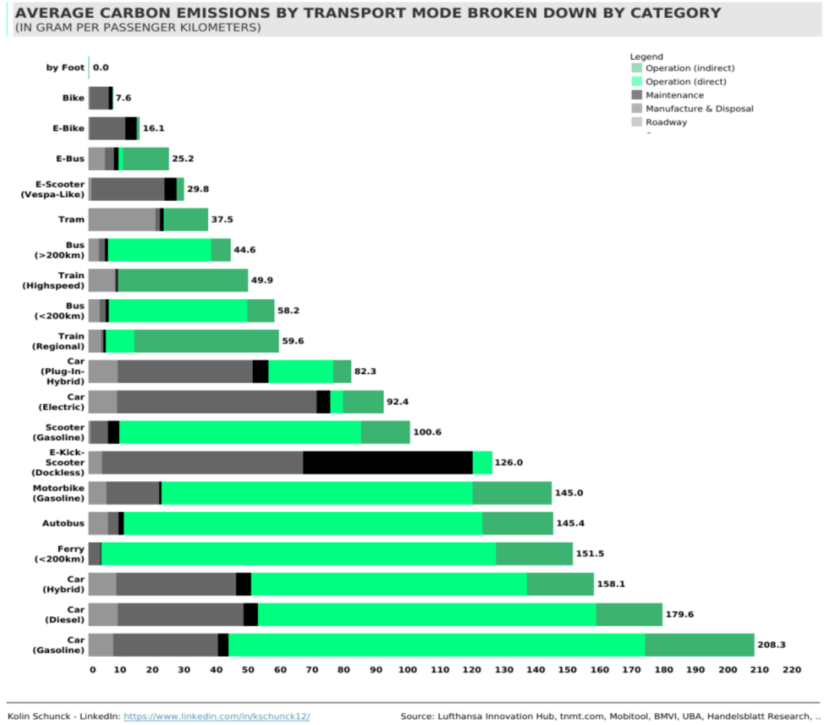
Ewing and Hamidi (2014) found that every doubling in their Compact Community index life expectancy increases about 4%. For the average American with a life expectancy of 78 years, this translates into a three-year difference in life expectancy between people in a less compact versus a more compact county.

Frederick, Riggs and Gilderbloom (2017) analyzed the relationships between commute mode share (the portion of commuters who do not drive an automobile, which ranges from 11% to 36%) as an indicator of transportation system diversity, and twelve public health and quality of life indicators for various mid-size U.S. cities and counties. The results indicate that, after adjusting for various demographic factors, there is significant positive relationship between more modal diversity and positive public health outcomes including healthier behaviors reported in the Gallup/Healthway’s Well-Being Index, more leisure quality reported by Sperling’s Cities Ranked and Rated, more access to exercise reported by the Environmental Systems Research Institute, less sedentary living and obesity reported in the Center for Disease Control’s Diabetes Interactive Atlas, more Years of Potential Life Lost (an indicator of longevity and overall health), and higher birth weights (an indicator of infant health) reported by the National Center for Health Statistics. These relationships are stronger than many other sociological, geographical, and economic indicators including density, latitude, race, education and income, suggesting that living in a more multimodal community provides significant health benefits. Many of the health benefits found to be associated with urban density may actually reflect those areas’ transportation diversity, which suggests that policies that improve walking, cycling and public transit can provide health benefits in cities, suburbs and small towns.

Energy Conservation and Pollution Emission Reductions

Travel modes vary significantly in their energy consumption and pollution emissions. The figure below compares lifecycle greenhouse gas emissions for various modes, taking into vehicle and infrastructure production, maintenance and operation emissions.

Figure 12 **Lifecycle Carbon Intensity by Mode** (TMNT 2021)

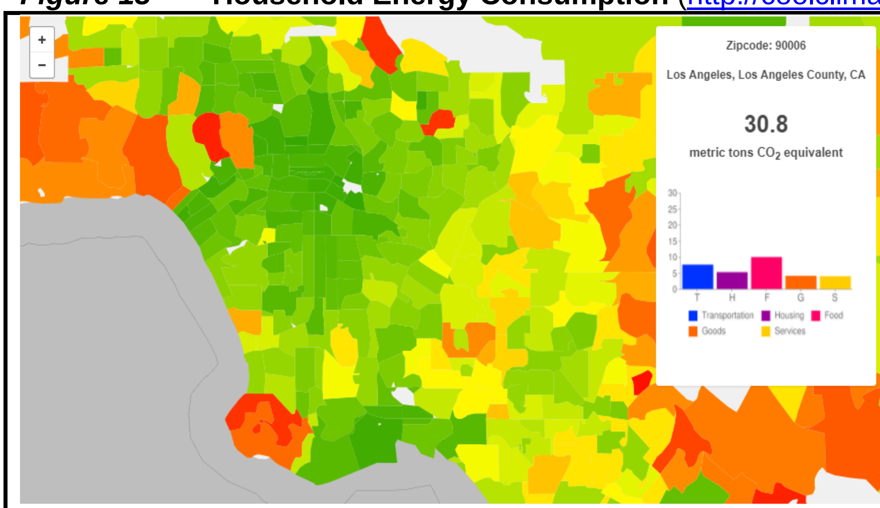


Energy consumption and pollution emissions vary by mode and vehicle type.

Walking and bicycling emissions are tiny. Local transit services have low to moderate emission rates but can leverage large reductions in per capita emissions by creating more compact, multimodal communities (ICF 2010). Electric automobiles reduce emissions 40-80% compared with comparable fossil fuel vehicles, depending on type and electric power source.

More compact, multimodal development reduces per capita energy consumption and pollution emissions by reducing vehicle travel and building energy use (Decker, et al. 2017; Litman 2011; Meyer 2013). The figure below illustrates these impacts.

Figure 13 **Household Energy Consumption** (http://coolclimate.berkeley.edu/maps)



This map produced by the Cool Climate Calculator illustrates average annual household carbon footprint by zip code in the Los Angeles region. More central locations tend to have lower emissions (dark green) due largely to less driving and more use of alternative modes.

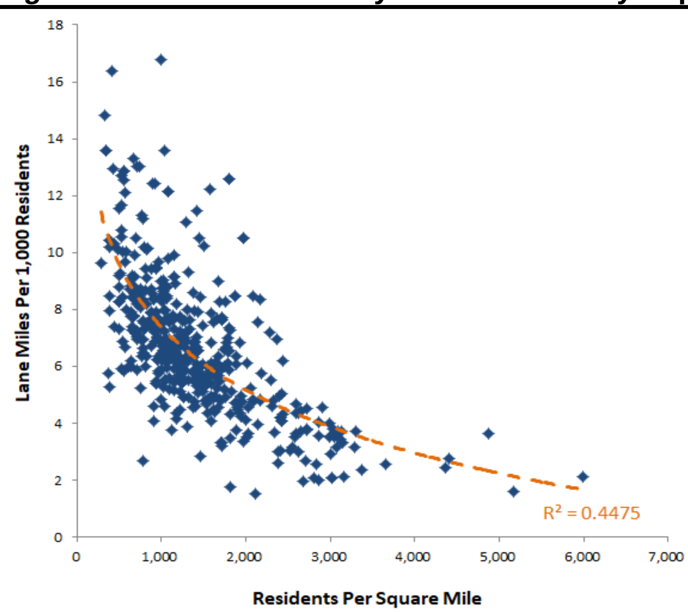
Strategic Development Goals

Many communities have strategic goals to create more compact communities in order to reduce land consumption and therefore preserve openspace, reduce public infrastructure and service costs, and to create more accessible, less automobile-dependent communities (Ewing and Hamidi 2014; Litman 2017). These are sometimes called *livability objectives.*

Openspace includes farmlands and undeveloped lands such as forests, shorelines, parks and wilderness areas, which provide various economic, social and environmental benefits including agricultural production, tourism, recreation, cultural activities, water and air quality, wildlife habitat and beauty (Jacob and Lopez 2009; Tagliafierro, et al. 2013).

More compact development reduces the costs of providing public infrastructure and services such as roads, parking facilities, utilities, emergency services and school transportation. Burchell and Mukherji (2003) found that modest increases in development density can reduce road lane-miles about 10%, public service costs 10%, housing development costs 8%, providing capital cost saving that average of $13,000 per dwelling unit or $550 annually. A study for West Des Moines, Iowa calculates that, to accommodate 9,275 new housing units, compact development designed to maximize neighborhood walkability would generate $11.2 million ($417 annual per capita) net fiscal gains (incremental tax revenue minus incremental costs), about 50% more than the $7.5 million ($243 annual per capita) generated by the lowest density scenario (SGA and RCLCO 2015). The figure below shows how density reduces per capita lane-miles, and therefore roadway and stormwater management costs, and environmental impacts.

Figure 14 **Urban Density Versus Roadway Supply** (FHWA 2012, Table HM72)



As urban densities increase, roadway supply declines. U.S. cities with less than 1,000 residents per square mile (approximately 1.6 residents per acre) have nearly three times as much land devoted to roads than denser cities with more than 4,000 residents per square mile (approximately 6 residents per hectare). This reduces per capita road construction and operating costs, hydrologic and stormwater management costs, and environmental impacts.

(Each dot represents a U.S. urban region.)

Multimodal transportation planning both supports and is supported by compact development, particularly strategies such as more efficient parking management, improving space-efficient modes (walking, cycling, public transit, etc.), and transit-oriented development.

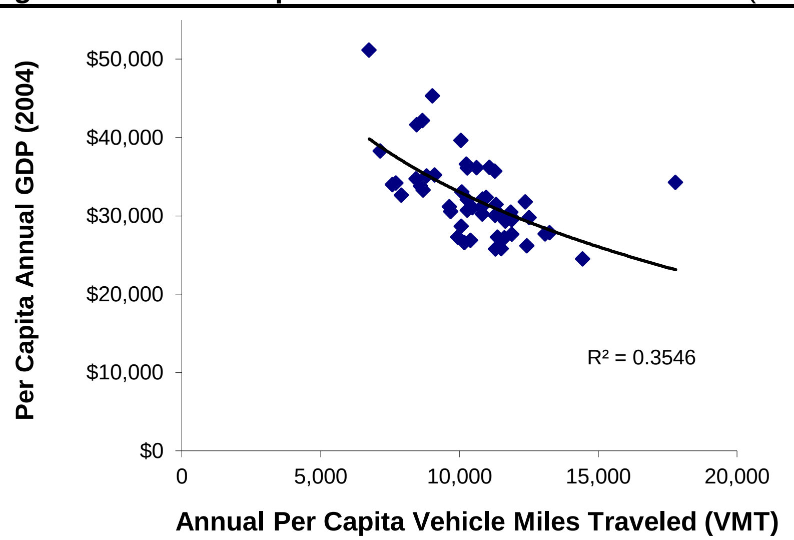
Local Economic Development

More multimodal transportation can support local economic development in several ways (Angel and Blei 2015; Decker, et al. 2017):

- It expands the pool of lower-wage workers available to employers, many of whom are limited in their ability to drive and so must rely on alternative modes, at least occasionally.
- It increases agglomeration efficiencies, which tend to increase productivity and incomes (Melo, Graham and Noland 2009). Hsieh and Moretti (2015) estimate that allowing more infill development in productive U.S. cities could increase national economic output by 13%.
- It reduces the costs of providing public infrastructure and services, parking subsidy costs to businesses, and various economic costs such as productivity from disabilities caused by traffic accidents and illnesses caused by sedentary living.
- It reduces the amount of money that residents spend on vehicles and fuel, expenditures that provide relatively little local economic productivity and employment per dollar. As a result, reducing vehicle expenditures tends to increase local economic activity.
- It lets households build long-term wealth by shifting spending from vehicles to housing. For example, a multimodal household that spends $20,000 annually on a mortgage and $5,000 on vehicles after a decade typically accrues $100,000 more equity than an auto-dependent household that spends $15,000 on a mortgage and $10,000 on vehicles (Litman 2017).
- It supports industries including tourism, recreation and retail which are stimulated by more walkable, bikeable and attractive communities.

At both state and regional scales, per capita GDP tends to decline with vehicle-miles traveled (VMT) and increases with per capita transit ridership (Kooshian and Winkelman 2011). The figure below illustrates the negative relationship between per capita vehicle travel and economic productivity. This reflects the efficiencies of reduced transportation costs and more compact development.

Figure 15 **Per Capita GDP and VMT for U.S. States** (BTS 2006 and BEA 2006)



Per capita economic productivity increases as vehicle travel declines. (Each dot is a U.S. state.)

Summary
Compared with automobile travel, other modes can provide various savings and benefits, as summarized in Table 4. Depending on the audience, walking, cycling and public transit can be called space-efficient, affordable, inclusive, healthy, green or sustainable modes. Not every non-auto mode improvement provides all of these benefits, but most provide several.

Table 4 **Multimodal Transportation Benefits**

Typical Impacts of Non-Auto Modes	Benefits
Space-efficient. Non-auto modes require less space per passenger-mile.	Less traffic and parking congestion, and therefore lower road and parking costs.
Non-auto modes cost less than driving.	Increases affordability and economic resilience.
Inclusive. Non-auto modes serve people who lack a vehicle or driver's license.	Improves mobility options for people who cannot drive. Reduces chauffeuring burdens.
Increases safety. Public transit has very low crash casualty rates. Walking and cycling impose minimal risk on other road users.	Reduces traffic casualty (injuries and deaths) rates, including risks to motorists.
Non-auto modes are healthy and enjoyable to use.	Improves public fitness and health, provides enjoyment, and supports industries such as tourism.
Non-auto modes are energy efficient and low polluting	Reduces energy consumption and resulting economic and environmental costs.
Multimodal planning supports strategic planning goals such as more compact development.	Reduces per capita land consumption, public infrastructure costs, and improves overall accessibility.
Non-auto modes reduce fuel imports, expand worker pools, provide agglomeration efficiencies, reduce infrastructure costs and support industries.	Increases local economic development (employment, productivity, tax revenues)

Compared with automobile travel, walking, cycling and public transport can provide many benefits.

Even people who do not currently walk, bicycle or use public transit can benefit from living in a community that accommodates these modes if they reduce traffic and parking congestion, accident risk, chauffeuring burdens, and pollution emissions, and non-users might need these modes in the future, called *option value* (DfT 2003; ITF 2017). This is not to suggest that walking, cycling and public transit can serve all trips and driving should be eliminated, but it does suggest that everybody can benefit from multimodal planning which allows each mode to serve the trips for which they are best suited.

Multimodal Performance Indicators

This section describes methods that can be used to evaluate the degree that a transportation system is multimodal and the benefits of improving transport diversity.

Performance indicators are metrics suitable for evaluating conditions and measuring progress (or the lack thereof) toward goals. Most commonly-used transportation performance indicators, such as roadway Level-of-Service (LOS) ratings and distance-based traffic accident rates (traffic crashes per 100 million vehicle miles), evaluate transportation system performance based on automobile travel conditions, with little consideration of other modes. This favors automobile-oriented improvements and undervalues improvements to other modes. In recent years, professional organizations have developed multimodal performance indicators suitable for multimodal planning (Brozen, et al. 2014; De Oña, et al. 2016; FDOT 2012; NYDOT 2012).

Indicators by Mode

Walkability

Walkability refers to the overall quality of the pedestrian environment. Dowling and Associates (2008-2010) describe walking Level-of-Service (LOS) indicators. Semler, et al. (2016) describe how to choose and implement such indicators. Seiff and Weissman (2016) describe the process for collecting these data in typical communities. The *Walkability Level of Service Website* (www.levelofservice.com) provides information on methods for evaluating pedestrian LOS.

Performance indicators include:

- Portion of roads with suitable sidewalks, crosswalks and paths.
- Conditions of sidewalks, crosswalks and paths (pedestrian LOS).
- Roadway widths and traffic volumes (and therefore the ease of crossing roads).
- Pedestrian amenities such as benches, trees and awnings.
- Pedestrian information including wayfinding signage.

Universal Design

Universal Design (also called *barrier-free design*) refers to facilities that accommodate people with diverse abilities and needs, including wheelchairs users, people who walk with difficulty or have visual disabilities, and pedestrians pushing strollers or handcarts. The term *Universal Design* is preferred to *handicapped access* because these design requirements can benefit many users, not just those with disabilities.

Several planning and professional organizations publish Universal Design guidelines and standards, including the U.S. *Access Board* (www.access-board.gov) and *Access Exchange International* (www.globalride-sf.org).

Performance indicators include:

- Portion of roads with suitable sidewalks, crosswalks and paths, and the portion of those facilities that meet universal design standards.
- Portion of transportation services that meet universal design standards.
- Enforcement of universal design standards.

Bicycling

Dowling and Associates (2008-2010) describe bicycling Level-of-Service indicators. Semler, et al. (2016) and Seiff and Weissman (2016) describe how to choose and implement such indicators.

Performance indicators include:

- Portion of roads with suitable bike lanes and paths.
- Conditions of roads, bikelanes and paths (bicycling LOS).
- Roadway traffic volumes (and therefore the ease of riding on or crossing).
- Amenities such as bicycle parking.
- Enforcement of traffic laws that protect cyclists.
- Cycling information including wayfinding signage.

Public Transit

Public transit includes various vehicles and services (demand response, bus, train, ferries, etc.) that provide motorized transport to the general public. This includes local services within a community, and interregional services that connect distant communities. Various publications provide guidelines for evaluating transit service quality (Kittelson & Associates 2017). The *Local Index of Transit Availability* (LITA) rates transit service availability within urban areas, taking into account demographic and geographic factors (Rood 1999). Transit service can be assessed with respect to specific mobility needs, such as welfare-to-work (Tomer, et al. 2011).

Performance indicators include:

- Service availability (portion of homes, worksites and services located within a ten-minute walk of transit services).
- Service hours.
- Service frequency (number of transit vehicles per hour).
- Service reliability (on schedule performance).
- Comfort (e.g., crowding and cleanliness of shelters and vehicles).
- Service speeds compared with driving.
- Personal security while walking, waiting and riding on transit.
- Quality of pedestrian access to transit stops and stations.
- Fares relative to users' income.

Taxi

Taxi services provide chauffeured automobile travel to the general public. Ridehailing services such as Uber and Lyft are a variation. Taxi services are often regulated, in part to maintain service quality (Linton 2016).

Performance indicators include:

- Average response time for various conditions and locations.
- Number of taxis per capita, or per non-driver in an area.
- Ridehailing services availability.
- Price for an average trip relative to users' income.
- Comfort, safety, reliability, and courtesy of service.
- Number of taxis able to carry people with disabilities (i.e., wheelchair users).
- Number of problems reported by users.

Automobile
Automobile travel provides mobility for people who have a driver's license and a vehicle, and can afford the expenses, although it can be delayed by congestion. Automobile travel can include ridesharing (passengers on a vehicle trip that would occur anyway) and chauffeuring (special vehicle travel to transport a passenger). Vehicle rental and carsharing services provide occasional automobile use. The *Highway Capacity Manual* (TRB 2010) describes roadway Level-of-Service ratings.

Performance indicators include:
- Portion of population licensed to drive.
- Portion of population that owns a personal automobile.
- Roadway conditions.
- Traffic and parking congestion.
- Availability of rideshare services (car- and vanpooling).
- Availability of vehicle rental and carsharing services.

Telework
Electronic communications (telephones, Internet, and other communications services) can substitute for some physical trips, including telecommuting (working offsite to avoid travel), telelearning, Internet shopping and e-government services.

Performance indicators include:
- Portion of households with telephone and Internet access.
- Portion of employers who allow telecommuting.
- Portion of public services (banks, government agencies, libraries, etc.) that can be accessed by telephone or Internet.

Delivery Services
Delivery services include postal systems, private couriers, and local delivery services for goods such as groceries. Such services can provide basic access and substitute for vehicle trips.

Performance indicators include:
- Quality of mail and courier services.
- Portion of businesses (such as grocery stores) that offer home delivery.
- Portion of households with telephone and Internet access.

Proximity (Compact and Mixed Communities)
More compact and mixed development increases reduces the distances that must be traveled to reach common destinations, which increases the portion of trips that can be made by non-auto modes. The National Association of Realtors' *National Community Preference Survey* (NAR 2020) indicates that about half of households place a high value on living in within an easy walk of other places and things in a community. López, Annema and van Wee (2022) found that people value having various services and amenities nearby.

Aggregate Multimodal Indicators

Aggregate multimodal performance indicators evaluate the overall diversity of transport options in an area, and therefore whether planning is multimodal.

Performance indicators include:

- Consideration of non-automobile modes in transport planning and funding processes.
- Consideration of affordability, mobility for non-drivers, health and environmental goals in transport planning process.
- Multimodal accessibility indicators and maps (Litman 2013).
- Mode share (a smaller automobile mode share indicates more diversity).
- Per capita motor vehicle ownership and annual mileage (smaller values indicate more diversity).

Accessibility Mapping Tools

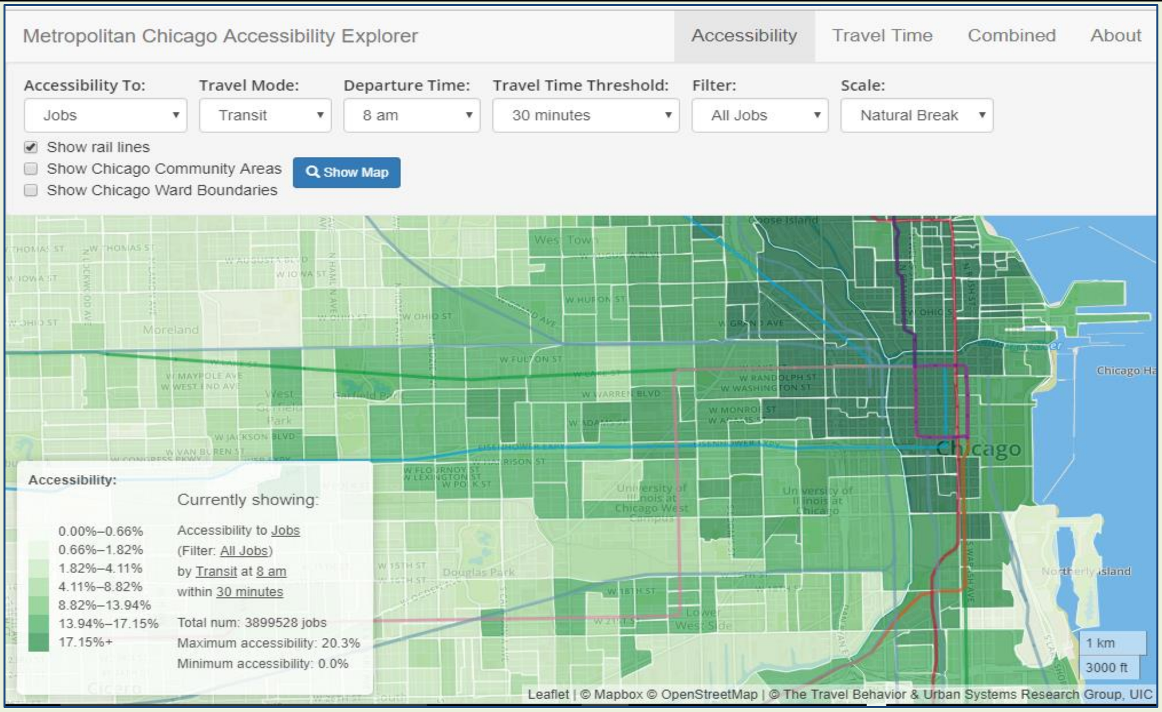
Access Scores (http://bit.ly/2p2ueHY)
Access Scoring uses GIS mapping tools to measure people's mobility demands, their ability to access work and common non-work activities by various modes and at various times and locations, and indicates how specific transportation system changes will affect that accessibility.

Accessibility Observatory (http://ao.umn.edu)
This is a leading resource for the research and application of accessibility-based transportation system evaluation.

Opportunity Score (https://labs.redfin.com/opportunity-score)
This program ranks locations in 350 U.S. cities based on the number of jobs that can be accessed within a 30-minute walk or transit ride.

Sugar Access (www.citilabs.com/software/sugar/sugar-access)
Sugar Access is an integrated Geographic Information Systems (GIS) software program that quantifies the time and financial costs of accessing various types of services and activities (healthcare, shops, schools, jobs, parks, etc.) by various travel modes in a particular area.

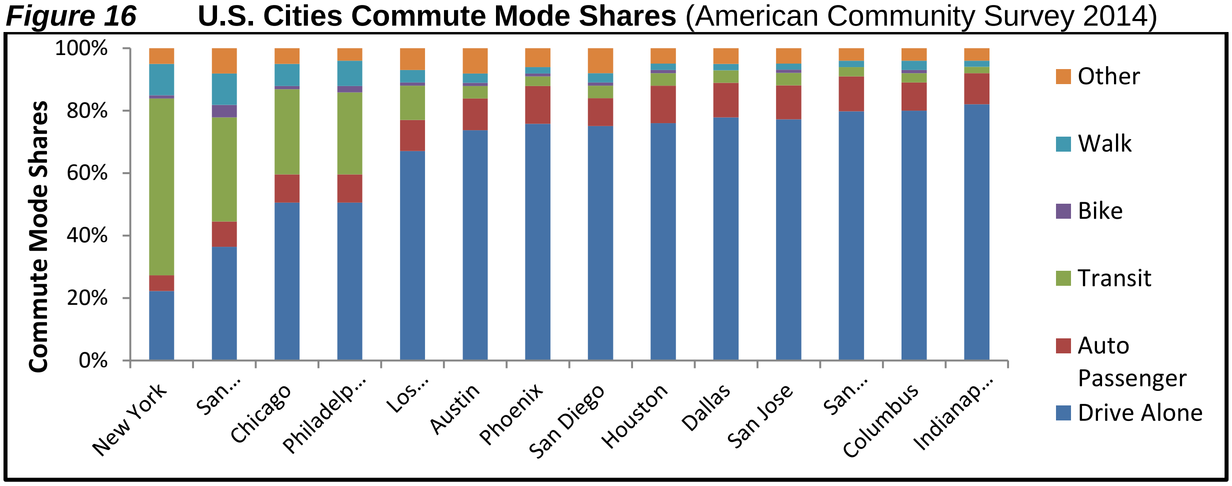
Urban Accessibility Explorer (http://urbanaccessibility.com)
The Metropolitan Chicago *Accessibility Explorer* is an easy-to-use mapping system that measures the number of activities, including various types of jobs, schools, parks, stores and libraries, that Chicago region neighborhood residents can reach within a given travel time, by a particular mode and time of day. The results are displayed on maps which can be adjusted by scale and area.



This Accessibility Explorer map shows the number of jobs that can be accessed within 30-minutes by public transit at 8:00 am. It can be changed to indicate other modes, destinations and time periods.

Mode share, vehicle ownership and vehicle travel data are available from various sources including Census, the American Community Survey, and local travel surveys. The figure below illustrates commute mode share for various U.S. cities. Although commuting represents only about 20% of personal travel, commute mode share can be a useful indicator of transportation diversity: areas with high automobile mode shares tend to be automobile-dependent, with high rates of per capita vehicle ownership and use, and low rates of active transport.

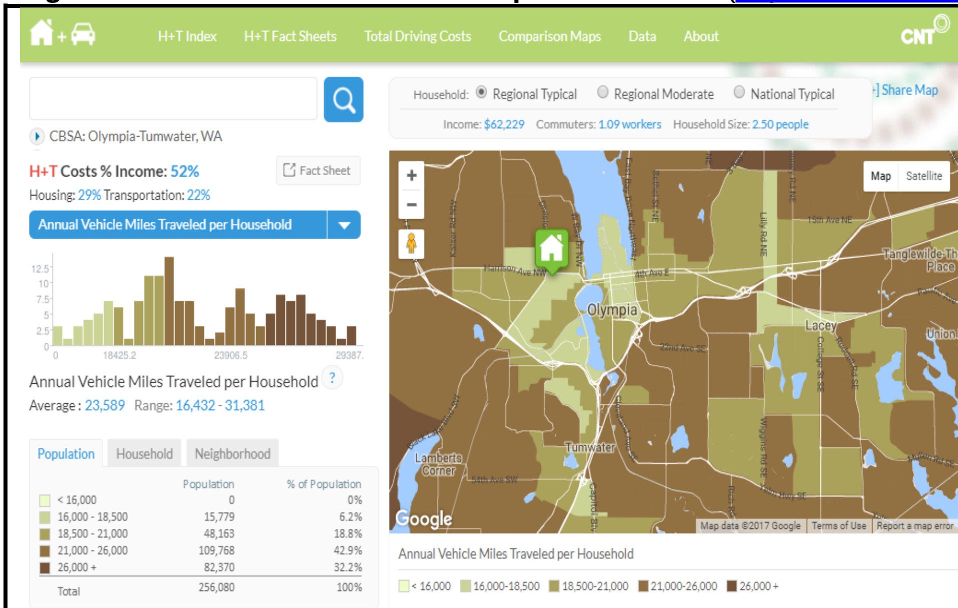
Figure 16 **U.S. Cities Commute Mode Shares** (American Community Survey 2014)



Automobile commute mode shares (driver and passenger) range from 27% in New York City to 92% in Indianapolis. Similar ranges are often found between multimodal and auto dependent areas within a region.

The figure below illustrates average annual vehicle-miles driven per household for neighborhoods in Olympia, Washington. This ranges from 16,432 in central, multimodal areas up to 31,381 in more automobile-oriented areas.

Figure 17 **Annual Vehicle Miles per Household** (http://htaindex.cnt.org)



The H+T Affordability Index website produces maps indicating average annual vehicle-miles per household by U.S. census tract based on travel survey data. This information is used to calculate average transportation costs and affordability.

Transportation for Everyone Ratings

Because travel demands are diverse, no single travel option can serve all needs. To provide a high level of accessibility, a community requires diverse and integrated mobility options with complementary land use development patterns. The *Transportation for Everyone* rating system, Table 5, is a simplified method for measuring these options in an area (a neighborhood, city or region), and therefore overall accessibility for diverse users, including non-drivers.

Table 5 **Transportation for Everyone Rating**

Accessibility Factors	Rating (0-10)
1. All-weather (paved) roads, and reliable motor vehicle fuel and repair services.	
2. Compact, mixed urban development, which creates *Transit-Oriented Development* (if located around transit stations) or *Urban Villages* (if pedestrian oriented), where most common services (shops, restaurants, schools, parks, transit stops, etc.) can be reached within a 5-10 minute walk or bicycle ride of most homes and worksites.	
3. Good walking and cycling conditions, including adequate sidewalks, crosswalks, paths, bike lanes, bike parking, and vehicle traffic speed control.	
4. High quality public transit services, with good coverage, frequency, comfort, safety and affordability for both local and interregional (between city) services.	
5. Good connectivity, including dense walking and road networks, and intermodal connections such as walking and cycling access, and taxi services at transit stations.	
6. Convenient and affordable carsharing and bikesharing, taxi and ride-hailing services (e.g., Uber and Lyft).	
7. Universal design (the ability of transportation systems to accommodate people with diverse needs and abilities, including those with disabilities, babies and heavy loads).	
8. Good telework options, such as on-line shopping, banking and municipal services, and efficient delivery services ((mail, courier and local shops).	
9. Convenient user information concerning transportation options.	
10. Social marketing that promotes non-automobile modes to enhance their status.	

Each factor can be rated from 0 (worst) to 10 (best).

Transportation for Everyone Score
70–100 Multimodal – A car is unnecessary for most daily travel. Many households are car-free.
50–69 Mixed – It is possible but often difficult to rely on non-auto modes. Most households have at least one car.
0–49 Automobile Dependent – It is difficult to live without a car. Most households have one car per driver.

A higher rating is particularly important for people whose ability to drive is constrained, including youths, people with disabilities or low incomes, and people who are frequently impaired or distracted, plus drivers who want to avoid chauffeuring household members with such constraints, or who may value having non-automobile options for current or future use.

Optimal Transportation Diversity

This section describes various ways to determine the optimal amount of transportation diversity.

Method 1: Market Principles

Economists identify three basic requirements for efficient and fair markets (in this case, transportation systems can be considered markets):

- *Consumer sovereignty* (markets provide the goods and services that users demand).
- *Economic neutrality* (public policies do not arbitrarily favor one good or group over others).
- *Cost based pricing* (the price user pay for goods reflects their marginal production costs).

According to this approach, optimal transportation diversity is what travellers would choose if the transport system reflected these principles, for example, if the planning process delivered facilities and services that travellers demanded; if funding allocation reflected least-cost principles so alternative modes and demand management programs whenever they are more cost effective than other solutions; and if motorists were required to pay directly for using roads and parking facilities, plus efficient pricing of congestion, accident risk and pollution emissions.

Such reforms could significantly change planning decisions and travel activity (DeRobertis, et al. 2014; Litman 2014c). There is evidence of significant latent demand for non-auto modes, indicated by increases in walking, cycling and public transit travel that often occurs after these modes are improved (FHWA 2014; Schmidt 2018), so consumer sovereignty would improve these modes. More efficient pricing would significantly increase vehicle user charges and reduce automobile travel (cost-based parking pricing alone typically reduces affected automobile travel by 20%, and distance-based insurance and registration fees could reduce vehicle travel another 10%). This suggests that optimal transportation diversity involves less automobile travel and more use of alternative modes than what currently exists in North America.

Transportation market distortions result in economically inefficient automobile travel, that is, lower-value vehicle travel that motorists would forego if they had better options or more efficient pricing. If an employee drives to work when their parking is free but uses another mode if they must pay directly, the additional vehicle travel stimulated by free parking is economically inefficient; the marginal value is worth less than the parking space costs.

By leveraging additional vehicle travel, these distortions have large total costs. For example, free parking not only increases parking demand and therefore parking facility costs by about 20% by stimulating more driving, it also increases traffic congestion, traffic accident risk and pollution emissions by about 20%. Described more positively, parking policy reforms that require motorists to pay directly for parking not only reduces parking costs, it is also an effective way to reduce congestion, accident and pollution costs. Similarly, policies that underprice road use and fuel, under-investments in non-auto modes, and policies that favor sprawl over more compact development, all lead to economically excessive vehicle travel and associated costs.

If market reforms are infeasible, blunter policies may be justified on second-best grounds. For example, if efficient road and parking pricing are politically unacceptable, regulations that limit driving, and public transit subsidies may be efficient.

Method 2: Comprehensive Planning

A second approach to determining optimal transportation diversity is to consider how more comprehensive analysis could justify more multimodal planning. Conventional planning is reductionist: individual problems are assigned to agencies with narrowly-defined responsibilities. Such planning can result in those agencies rationally implementing solution to their problems within their scope that exacerbate other problems facing society, and tend to undervalue strategies that provide more modest but multiple benefits. More comprehensive planning, which considers the following goals, tends to support more diverse transportation:

- Reduce *traffic and parking congestion* by improving and encouraging space-efficient modes (walking, cycling, ridesharing and public transit). The optimal automobile mode share is the amount that roads and parking facilities can efficiently accommodate, which is often much less than what currently occurs.
- Ensure that people who cannot or should not drive have *affordable basic mobility* (they can access essential services and activities) improving inclusive and affordable modes (walking, cycling and public transit). The optimal level of transportation diversity is the quality of non-auto travel options which ensures that non-drivers have convenient and comfortable transportation options, and households can spend less than 15% of their budget on transport or less than 40% on housing and transport combined (which recognizes that households often make trade-offs between housing and transport costs). In many communities this requires a significant improvement in non-auto modes.
- Improve *traffic safety* by reducing total vehicle travel and improving the travel options used by higher-risk (young, old, disabled, impaired and distracted) drivers. Optimal transportation therefore includes incentives to reduce driving, particularly for higher risk groups, and improved travel options to meet their mobility needs. This can justify significant policy changes in automobile-dependent communities with high traffic fatality rates (more than 5 deaths per 100,000 residents annually).
- Achieve *public fitness and health* objectives by increasing use of active modes (walking and cycling). Optimal transportation ensures that communities have good walking and cycling conditions, and incentives to use these modes, so most people can achieve physical activity targets (150 weekly minutes of exercise) through neighborhood walking and cycling.
- *Reduce energy consumption and pollution emissions* by favoring resource-efficient modes and minimizing motor vehicle travel. Optimal transportation includes transportation demand management strategies to reduce vehicle travel and favor resource-efficient modes.
- Achieve *strategic development objectives* to create more efficient and livable communities by favoring space-efficient and low-polluting modes (walking, cycling and public transit). Optimal transport diversity

This suggests that more comprehensive planning recognizes additional benefits from a more diverse transportation system, and so would justify more support for non-auto modes and transportation demand management programs. To the degree that current planning overlooks or undervalues these goals, it is likely to result in more automobile dependent, less diverse transportation systems than is optimal for society.

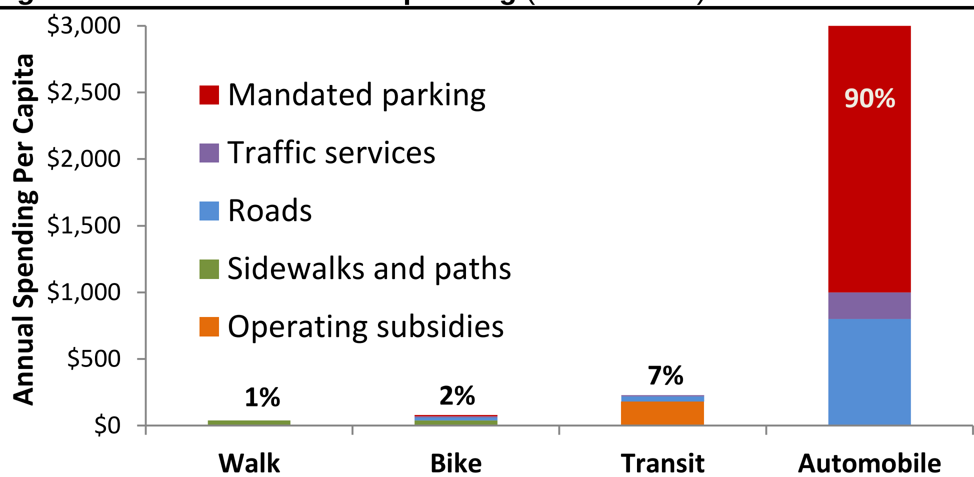
Method 3: Equity – A Fair Share for Non-drivers

As previously discussed, many people cannot, should not, or prefer not to drive, and so need other travel options, so fairness justifies devoting a portion of transportation resources (money and road space) to non-auto modes. There are various possible ways to determine the fair allocation of such resources.

Horizontal equity, which requires that everybody be treated about equally, suggests that non-auto mode investments should at least equal non-drivers' portion of the population, and more to account for benefits to motorists. For example, if 30% of local trips would be made by walking and bicycling, if their travel conditions were improved, it would be fair to invest up to 30% of transportation resources (money and road space) to support those modes, and more to make up for a century of underinvestment.

Currently, only about 3% of total transportation dollars are spent on sidewalks and paths, and about 7% on public transit; the majority of these resources are devoted to automobile-oriented roads, traffic services and government-mandated parking facilities. Of course, walkers and bicyclists use roads, but their costs are minimal due to their small size and weight. The figure below compares estimated infrastructure spending by mode.

Figure 18 **Infrastructure Spending** (Litman 2021)



This graph compares infrastructure spending by mode. Automobiles receive the most by far.

Vertical equity, which requires that public policies favor disadvantaged groups, suggests that transportation resources should be allocated to ensure that physically, economically and socially disadvantaged groups can access basic services. For example, transportation facilities and services must accommodate people with disabilities, and lower-income residents deserve affordable transport options that require spending less than 15% of their household budgets to access healthcare, shopping, school and jobs (Pereira, Schwanen and Banister 2016).

Equity can also justify policies that favor space-efficient modes (bus and HOV lanes) so users of these modes are not delayed by congestion caused by automobile traffic. To the degree that automobile travel imposes delay, risk and pollution on pedestrians and bicyclists, it would be fair for motorists to bear the costs of facilities that protect active travellers from these harms. To the degree that pedestrians, cyclists, rideshare and public transit travellers are less advantaged than motorists, these policies can be justified for both vertical as well as horizontal equity.

Such comparisons can be complicated because there are many ways to categorize travellers and calculate costs. Some analysis of non-drivers focus on relatively small groups such as zero-vehicle household occupants, transit commuters, or people with disabilities. A broader definition also includes adolescents, lower-income households, motorists with unreliable vehicles, people who prefer non-auto modes for exercise and enjoyment, and motorist who benefit from reduced chauffeuring burdens for non-drivers in their households.

Modal cost comparisons are also affected by which costs are considered. About half of roadway expenses are financed through special road user charges, such as additional fuel taxes (beyond general sales taxes) and vehicle registration fees, and so need not be considered subsidies. On the other hand, most zoning codes require a generous number of parking spaces in most developments, resulting in 2-6 subsidized off-street parking spaces per vehicle, each with $500-2,000 typical annualized costs (Litman 2009; Shoup 2005). Although privately owned, they are government mandated and so can be considered a public subsidy of driving.

This suggest that fairness can often justify increased non-auto mode investments, including walking and cycling facility improvements, and public transit services that provide basic mobility to disadvantaged groups. Fairness can also justify policy reforms, such as parking cash out (non-drivers receive cash benefits equivalent to parking subsidies given to motorists).

From Maximizing LOS to Minimizing VMT (CGOPR 2016)

The primary objective of conventional transportation planning is to maximize vehicle traffic speeds and minimize delay, measured using roadway Level-of-Service (LOS). This approach has been criticized for being automobile oriented (LOS recognizes the benefits that wider roads provide motorists but ignores the disbenefits they cause users of other modes) and for discouraging infill development, and therefore more accessible urban development.

In response, many jurisdictions are fundamentally changing their transportation planning objectives from maximizing LOS to minimizing Vehicle Miles Traveled (VMT), based on the assumption that more multimodal and integrated planning can increase accessibility in ways that reduce vehicle travel and associated costs. California legislation (SB 743) established this concept in law, and transportation agencies have worked to develop appropriate planning practices and performance indicators for implementation. Other jurisdictions are making similar changes.

Method 4: Equity – Optimal Urban Design

Another approach to determining optimal vehicle ownership and mode shares is based on urban design factors. Taking into account various planning objectives including reducing infrastructure costs, consumer costs, accidents, and pollution emissions, maximizing transportation system efficiency, and categorizing cities according to their ability to expand geographically, it recommends design features summarized in Table 6.

Table 6 **Optimal Urban Design** (Litman 2014a)

Factor	Unconstrained	Semi-constrained	Constrained
Growth pattern	Expand as needed	Expand less than res. growth	Minimal expansion
Gross (regional) density (residents/ha)	20-60	40-80	80 +
Net (parcel) density (residents/ ha)	40-120	80-160	160 +
Housing types	A majority can be small-lot single-family or adjacent	Approximately equal portions small-lot single-family, adjacent, and multi-family	Mostly multi-family
Automobiles per 1,000 res.	300-400	200-300	< 200
Private auto mode share	20-50%	10-20%	Less than 10%
Intersections per sq. km.	40+	60+	80+
Land in road ROW	10-15%	15-20%	20-25%
Roadway design	All streets have good sidewalks and crosswalks, and safely accommodate cycling.		
Recreational facilities	Most households are located within a ten-minute walk of local parks and recreational facilities, and 20% or more of urban land is devoted to public parks		
Creativity space	Affordable studios and workshops, located in mixed-use arts districts		
Examples	Most African and American cities	Most European and Asian cities	Singapore, Hong Kong, Male

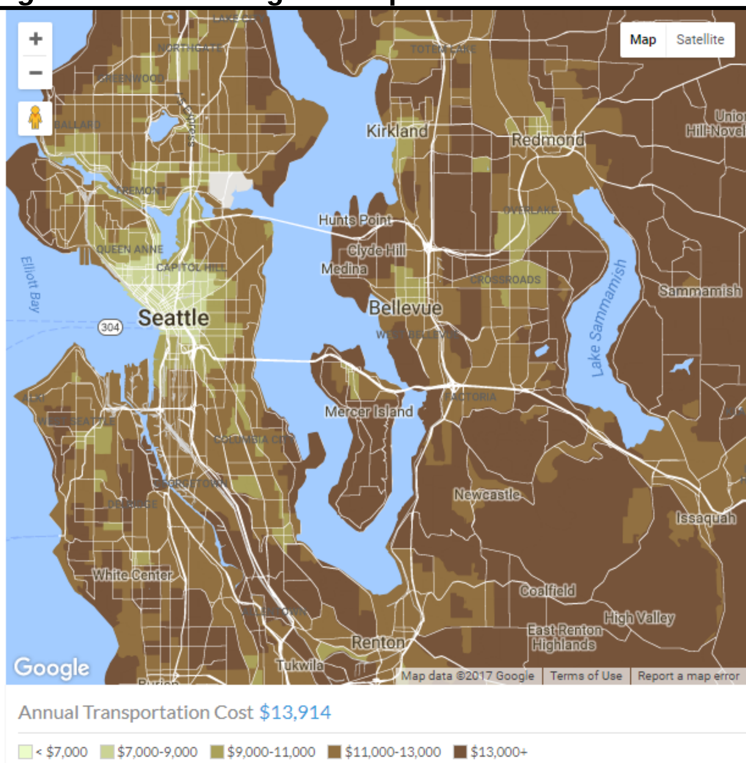
This table summarizes key design parameters for efficient and equitable cities, including vehicle ownership and automobile mode share ranges.

This indicates that optimal vehicle ownership rates range from 300-400 per 1,000 residents in unconstrained cities down to less than 200 vehicles per 1,000 residents in highly constrained cities, and considering personal travel, private automobile modes shares can range from 20-50% in unconstrained cities to less than 10% in highly constrained cities. These parameters can help set optimal transportation diversity targets, and therefore help prioritize transportation planning and investment decisions. It suggests that cities which exceed optimal automobile ownership or mode share targets should improve alternative modes and apply demand management strategies, such as road space reallocation and pricing reforms to limit automobile ownership and use.

Method 5: Accessibility Indicators and Targets

Households can use various accessibility indicators, such as, the *Transportation for Everyone* ratings (Table 5), the *Urban Accessibility Explorer* (http://urbanaccessibility.com), or the average annual vehicle mileage maps from the *H+T Affordability Index* (http://htaindex.cnt.org) to select home locations that provide an adequate level of mobility and accessibility options (Zhao, et al. 2013). For example, a household might limit home locations to neighborhoods that meet certain accessibility targets, such as locations where more than 10,000 jobs are available within 30 minutes by non-automobile modes, or where households spend less than $9,000 annually on average on transportation (Figure 15). This is particularly important for households with one or more members who cannot or should not drive, for lower-income households that want to minimize vehicle expenses, and households that want to minimize their accident risk and environmental impacts, or maximize walking and cycling for fitness and enjoyment.

Figure 19 **Average Transportation Costs Per Household** (http://htaindex.cnt.org)



This map H+T Index map illustrates average household transportation expenditures by location in the Seattle region. A household that wants to minimize these costs can choose homes in the green areas (less than $9,000) and avoid dark brown (more than $13,000).

Community planners can also use these indicators and targets to identify accessibility gaps, such as inadequate walking or cycling conditions, poor public transit services, or a lack of vehicle sharing opportunities, and to set targets for improving overall community accessibility, and to identify where to encourage development that maximizes transportation diversity benefits.

Note that these indicators have various constraints: most only consider a limited set of modes or costs, for example, some only indicate time costs, ignoring monetary costs, accident risk and health impacts. Some of these indicators only consider automobile and public transit, and fail to account for neighborhood walkability. Comprehensive analysis should account for the greatest number of mode, accessibility factors and impacts.

Reforms for More Multimodal Planning

This section identifies common planning practices that are biased in favor of automobile travel, and reforms to support more multimodal planning.

Scope of Impacts

Current bias: Conventional planning considers a relatively limited set of impacts (benefits and costs), as summarized in Table 7. Alternative modes, demand management strategies and Smart Growth development policies tend to provide often-overlooked benefits such as parking cost savings, consumer savings and affordability, and improved mobility for non-drivers.

Reforms: Apply comprehensive impact evaluation.

Table 7 **Impacts Considered and Overlooked**

Usually Considered	Often Overlooked
	Generated traffic and induced travel impacts
	Impacts on non-motorized travel (barrier effects)
	Parking costs
	User costs (including vehicle ownership costs) and affordability.
	Project construction traffic delays
	Indirect environmental impacts
Financial costs to governments	Strategic land use impacts (Smart Growth versus sprawl)
Vehicle operating costs (fuel, tolls, tire wear)	Mobility for non-drivers, and social equity impacts
Travel time (congestion delays)	Per-capita crash risk
Per-mile crash risk	Public fitness and health impacts
Pollution emission rates	Latent demand for alternative modes (e.g., walking and cycling)

Conventional transportation planning tends to focus on a limited set of impacts. Other impacts are often overlooked or undervalued.

Analysis of Demand

Current bias: Travel surveys and other transportation statistics often undercount short trips (within a transportation analysis zone), non-commute travel, off-peak trips, travel by children, recreational travel, and active trips for access to motorized modes (such as walking between parked vehicles and destinations, or walking and cycling to public transit stops). Few travel surveys analyze latent demand for alternative modes.

Reforms: Develop more comprehensive travel surveys and statistics, including non-drivers' travel demands. Investigate latent demand and factors that affect travel decisions, such as the additional walking, cycling and public transit that would occur if these travel options were improved, and obstacles to the use of those modes.

Accessibility-Based Analysis

Current bias: conventional transportation planning tends to evaluate *mobility* (physical movement) rather than *accessibility* (people's ability to reach services and activities) and so overlooks many factors that affect accessibility such as the quality of alternative modes, land use density and mix, transport system connectivity, user information, affordability, and mobility substitutes.

Reforms: Develop and apply accessibility-based evaluation tools, such as mapping which measures the time and money needed to access common services and activities by various modes. Use this to evaluate the quality of accessibility for non-drivers.

Transportation Performance Evaluation

Current bias: Commonly-used transport system performance indicators, such as roadway Level-of-Service (LOS), Travel Time Index (TTI, which measures traffic congestion delay), and distance-based crash rates, all reflect automobile travel conditions, and so recognize the benefits to motorists of expanding roads, but ignore the dis-benefits that wider roads and increased traffic speeds have on walking and cycling, and since most public transit trips include walking links, the reduction in public transit access. These indicators tend to overlook and undervalue improvements to other modes, such as improving walking and cycling conditions and transit service quality, which are only valued to the degree that they improve driving conditions.

Reforms: Apply multimodal performance evaluation which recognizes the harms that wider roads and increased vehicle travel can have on other modes, and acknowledges the direct benefits of improving alternative modes. Develop and apply tools for evaluating accessibility factors such as walkability and bikability, transit service quality, transport network connectivity, and accessibility for non-drivers.

Funding Practices

Current bias: Conventional planning dedicates a major portion of transportation funding to roads and parking facilities, which cannot be used for alternative modes or demand management programs.

Reforms: Apply *least cost planning*, which allocates funds to the most cost-effective transportation improvements, considering all impacts.

Development Policies

Current bias: Most jurisdictions have policies that limit development density and mix, and require large amounts of parking, creating dispersed and automobile-oriented communities.

Reforms: Where there is demand for compact, multimodal neighborhoods allow more density and mix, and reduced parking requirements. Integrate transportation and land use planning in order to create accessible, multimodal neighborhoods, particularly around rapid transit stations. Support affordable infill development so every household can find suitable housing in a walkable urban neighborhood.

Conclusions

Transportation diversity refers to the quantity and quality of mobility and accessibility options available in an area or to a group. This includes various modes and services, and is affected by factors such as land use density and mix, user information and affordability.

Travel demands and abilities are diverse so no single option can serve all needs. Every community contains people who cannot, should not, or prefer not to drive, and many trips are most efficiently made by non-auto modes, such as walking and cycling for local trips, and ridesharing and public transit for travel on major urban corridors. As a result, an efficient and equitable transportation system requires diverse and connected mobility options, with complementary development patterns.

For much of the last century planning was automobile-oriented. It assumed that the primary goal was to maximize travel speeds, and so favored automobile travel to the detriment of other modes. This created automobile dependent communities were driving is convenient but other modes are inefficient, which creates several problems including traffic and parking congestion, high infrastructure and consumer costs, inadequate mobility for non-drivers, high crash rates, reduced public fitness and health, increased air pollution, and various economic and social costs of sprawl. More multimodal planning can help increase efficiency and equity.

Current demographic and economic trends are increasing the importance of multimodal planning: aging population, unaffordability problems, increasing urbanization, changing consumer preferences, increasing health and environmental concerns are all increasing the value of more resource-efficient, affordable, healthy and enjoyable travel modes.

Various tools can be used to evaluate a particular mode's performance, and a transportation system's overall diversity. They can help identify gaps and guide decisions to create more diverse, and therefore more efficient and equitable, transport systems. The *Transportation for Everyone* rating system is a simplified method for evaluating the quality of accessibility in an area (a neighborhood, city or region), and therefore people's ability to satisfy diverse transport demands, including non-auto travel.

There are several possible ways to determine the optimal level of transportation diversity and therefore, multimodal planning objectives. One approach applies market principles including consumer sovereignty, neutral planning and cost-based pricing. A second approach applies comprehensive analysis which considers all benefits of alternative modes. A third approach considers how more diverse transportation can achieve equity goals. Horizontal equity, for example, suggests that non-drivers should receive a proportionate share of transportation resources (money and road space) based on population or trips, or compared with the costs imposed by automobile travel under the same conditions, while vertical equity suggests that resource allocation should favor disadvantaged groups and ensure access to essential services and activities. A fourth approach sets targets for improving non-automobile accessibility measured using indices and mapping tools.

This report describes reforms for more multimodal planning, including more comprehensive travel surveys and statistics, more comprehensive analysis and more multimodal funding.

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