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Transportation Economics Simplified

An Introduction to Cost and Benefit Analysis for Transport Planning and Policy Evaluation

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Summary

Transportation is an important but costly activity. It is important to consider all significant impacts in transportation policy and planning analysis. This report provides an introduction to basic transportation evaluation concepts and methods, with examples of their application. It estimates ten costs (subsidies, vehicle ownership and operation, road and parking facilities, traffic congestion, barrier effect, crashes, pollution and resource externalities) for six modes, and discusses other impacts including travel time, social equity, health, and sprawl-related costs. This analysis indicates that automobile travel is more costly than other modes when measured per travel-mile, and since motorists tend to travel more annual miles than people who rely on other modes, their annual costs are many times larger. Many of these costs are external, making them inefficient and unfair. This results in economically-inefficient mobility, vehicle travel in which total costs exceed total benefits. Given better mobility and accessibility options, and more efficient incentives, many travellers would drive less, rely more on other modes, choose to live in more accessible and multimodal neighborhoods, and be better off overall as a result.

Introduction
When purchasing a vehicle or travel service consumers want to know its full costs and benefits, including non-market impacts such as comfort, safety and reliability. Many publications and websites, with various perspectives, provide reviews and advice to help these decisions. For example, the American Automobile Association publishes *Your Driving Costs* reports that estimate typical ownership and operating costs for various vehicles. However, because it is oriented toward relatively affluent motorists, it is based on relatively new vehicles with full insurance coverage, and overestimates depreciation and insurance costs and underestimates repair costs compared with the fleet average. It also ignores residential parking, crash damage and traffic citation costs, and so underestimates the total vehicle costs. It is important that people using this information understand these biases and omissions.

Similarly, policy makers, practitioners (planners, engineers and economists), and the general public need comprehensive information concerning the full impacts that transportation planning decisions have on communities. These decisions can have many impacts, including *market impacts*, that affect goods bought and sold in stores and real estate markets, and *non-market impacts* that affect goods that are not generally bought and sold, such as personal time, health, and environmental quality. Information exists on many of these impacts, but it is often difficult to access, or incomplete and biased. It is important that people using this information understand these factors. Comprehensive analysis is increasingly important as transportation planning considers an expanding range of goals, including affordability, social equity, public health, and environmental protection, plus emerging transportation technologies and services.

This report provides an overview of key concepts and tools for transportation economic evaluation. It describes various estimates of transportation costs benefits, with examples of transportation impact analysis applied to typical planning decisions. This should be of interest to policy makers, practitioners (transport planners, engineers and economists), and the general public that wants to create more efficient and equitable transportation systems.

What is the Planning Goal
The way we think about transportation problems and evaluate solutions is changing (Litman 2013). The old paradigm assumed that the goal was to *maximize mobility*, the amount that people can travel with a given time and money budget. The new paradigm assumes that the goal is to *optimize accessibility*, that is, people's ability to access desired services and activities, considering all impacts and options. Let's consider some examples to illustrate this.

Paving roads makes driving faster, cheaper and more comfortable. The old planning paradigm assumed that road paving is desirable in order to increase mobility. The new paradigm recognizes that road paving is costly and often undesirable. For example, voters often reject local tax increases to pave more roads, and residents on unpaved roads often reject special assessments pave their roads, indicating that they consider the benefits less than the costs. Similarly, motorists often complain about traffic congestion but reject road tolls to finance roadway expansions; they want road expansions, and the increased mobility it would provide, as long as somebody else bears the costs. In these cases, paving and expanding roads would be economically inefficient and unfair, resulting in more mobility than is optimal and imposing costs on non-users. Motorists who use the improved roads would benefit, but everybody would be poorer.

The new paradigm strives to achieve an optimal level of mobility, recognizing that too much mobility is as harmful as too little. To be efficient and fair, a transportation system must reflect these principles:

- *Consumer sovereignty*. This means that, as much as possible, markets should respond to consumer demands. For example, if demand for active travel (walking, bicycling and their variants) increases, an efficient and equitable market responds by improving active travel conditions.
- *Cost-based pricing.* This means that the prices that user pay for a good should reflect its production costs unless a subsidy is specifically justified. For example, as much as possible, users should pay for roads and parking facilities, with higher prices during congested periods.
- *Economic neutrality.* This means that the planning process does not arbitrarily favor one good or group. For example, it means that transportation agencies invest as much to accommodate a walking, bicycling or public transit trip as would be spent to accommodate an automobile trip to access services and activities, and non-drivers receive comparable resources as motorists.

Optimal mobility is the amount and type of travel that people would choose if their transport system reflects these principles. Current systems often violate these principles: road and parking user fees are insufficient to recover their costs or internalize externalities, the planning process favors automobile improvements over other modes, and development policies favor sprawl over compact infill, creating automobile-dependent communities where it is difficult to get around without driving (Shill 2019).

Although individually these distortions may seem modest and justified, their impacts are cumulative and synergistic: their combined impacts are greater than the sum of their individual impacts. According to studies that analyze these impacts, including my report, *Socially Optimal Transport Prices and Markets*, applying efficient and equitable market principles would cause North Americans to reduce their vehicle travel, rely more affordable and resource-efficient modes, choose to live in more compact and walkable communities, and be better off overall: a quarter to half of current vehicle travel results from market distortions (Butner and Noll 2020; Litman 2019; SSTI 2018).

Existing Transportation Economic Analysis

There is extensive literature on transportation impacts. Household expenditure surveys report consumer transport spending, government budgets can be used to calculate public expenditures on transport facilities and services, and numerous studies have quantified, and in some cases monetized congestion, crash, pollution, and various other costs.

Some studies organize this information into frameworks suitable for evaluating various transport modes, projects and policies. For example, the *Australian Transport Assessment and Planning Guidelines* (ATAP 2017), the UK Department for Transport's *Transport Analysis Guidance* (DfT 2018), and New Zealand's *Monetized Benefits and Costs Manual* (NZTA 2020) provide comprehensive frameworks for evaluating and comparing the costs and benefits of various transportation facilities, service and programs. Some studies, such as the European Union's *Handbook on External Costs of Transport* (Ricardo-AEA 2014) and the article, "Estimating Marginal External Costs of Transport in Delhi," (Sen, Tiwari and Upadhyay 2010) attempt to estimate community impacts. My report, *Transportation Cost and Benefit Analysis* (Litman 2021) describes and estimates twenty impacts for eleven travel modes. These studies range in scope and methods, and the most comprehensive tend to be the most difficult to use. The following section summarizes major transportation costs without excessive details.

Cost Categories and Estimates

This section describes various transportation costs and estimates their magnitude.

Subsidies

Some modes receive financial subsidies. About one-third of U.S. public transit expenses are funded by fares and two-thirds by subsidies, but it is not appropriate to assign this cost totally to users. Transit subsidies are provided, in part, for option value for non-users, so the service is available if needed, like a lifeboat on a ship (Geurs, Haaijer and Van Wee 2006). Subsidies are needed largely to maintain service at times and locations with low demand, and to provide special services to people with special needs. In addition, transit travel has low marginal costs and strong scale economies: an additional passenger on an uncrowded bus or train imposes minimal costs and increases efficiency. As transit ridership increases in an area, cost recovery ratios increase to the point that high ridership routes fully recover their costs. This analysis assumes that marginal user subsidies are half of user costs.

Electric vehicles currently receive Corporate Average Fuel Economy (CAFE) credits that currently average $3,000-6,000 per vehicle (for example, during the second quarter of 2020 Tesla sold 90,000 vehicles and received $428 million in credits, averaging $4,700 per vehicle), purchase subsidies averaging about $5,000 per vehicle, public investments in recharging stations that often provide free electricity (commercial stations typically charge $2.50 per recharge), plus road user fuel tax exemptions averaging about $310 per vehicle-year, as summarized below. This indicates that for the foreseeable future, electric vehicle subsidies total about $1,000 per vehicle-year.

Table 1 **Typical Electric Vehicle Subsidies** (www.fueleconomy.gov)

Subsidy	Annual Value
Corporate Average Fuel Economy (CAFE) credits ($4,700 over 15 years)	$313
Purchase subsidy ($5,000 over a 15-year vehicle life)	$333
Electric vehicle recharging stations (50 free annual recharges costing $2.50)	$125
Road user fee exemption (12,500 annual miles, 20 mpg, 50₵ tax per gallon)	$310
Total Annual Subsidy	*$1,081*

Electric vehicles currently receive subsidies that average more than $1,000 per vehicle-year.

Vehicle Ownership

This includes fixed user expenses such as vehicle depreciation, financing, insurance and schedule maintenance. Walking and public transit have no significant fixed costs. Bicycling is estimated to have $100 annual fixed costs, assuming that a new bike costs $1,000 and lasts ten years.

According to the U.S. *Consumer Expenditure Survey* (BLS 2018), in 2018 motorists spent an average of $4,707 per vehicle, although this is probably an underestimate since motorists tend to overlook and underestimate some vehicle expenses, particularly repair, crash damages and traffic violation costs (Andor, et al. 2020). This analysis estimates that an average automobile has $3,000 annual fixed costs. Electric vehicles currently have higher purchase prices than comparable fossil fuel vehicles; this analysis assumes $5,000 annual fixed costs. Some experts predict that declining battery costs will soon make electric vehicles cheaper than fossil fuel vehicles, but motorists tend to use cost reductions to purchase larger battery sets for better performance (speed, capacity and distance) rather than to save money, so electric vehicles will probably stay relatively costly for the for the foreseeable future.

Vehicle Operation
This includes variable expenses that increase with distance travelled, including fuel, tire replacement, repairs, road tolls and parking fees. Since most people own shoes, walking marginal costs reflect additional replacement or repair costs, estimated to total $100 annually for somebody who walks 1,000 annual miles. Bicycling 2,000 annual miles is estimated to have $200 per year additional repair and maintenance costs, although these costs are lower for cyclists who maintain their own bikes. Public transit commuting is estimated to cost $800 annually, reflecting a combination of commuters who purchase monthly passes, and frequent transit users who purchase individual fares.

This analysis assumes that fossil fuel vehicles have $2,000 annual operating costs. Electric vehicles are estimated to have $1,000 annual operating costs, since typical electric vehicle uses 3-12₵ worth of electricity per mile, about half the fuel costs of an equivalent gasoline car, but this many be an underestimate since electric vehicle batteries must be replaced about every 100,000 miles, which currently costs $3,000-15,000 or 3-10₵ per vehicle-mile. Due to their low operating costs, electric cars are assumed to travel about 20% more annual miles than a comparable gasoline car.

Roadway Facilities
In 2018, government roadway expenditures averaged $814 per vehicle, about half of which is funded by user fees, such as fuel taxes and road tolls, and half are funded through general taxes (FHWA 2018, Table HF10). These estimates only reflect current roadway expenditures and do not count the value of the land used for road rights of way, which many economists argue should be considered a roadway costs (Levinson 2018), or the costs of providing traffic services, such as street lighting and traffic law enforcement. Larger vehicles, including buses, impose greater roadway costs per vehicle-mile, but less per passenger-mile. This analysis assumes that roadway costs average $800 per vehicle-year for gasoline cars, of which half is internal, paid through road user fees, and $1,000 per vehicle-year for electric cars due to their greater weight and annual mileage, which are entirely external.

Walking and bicycling have much lower roadway costs, although these are difficult to quantify since these modes sometimes use roadways and sometimes use special facilities. According to the Alliance for Biking & Walking's *Benchmarking Reports* (AWB 2018), state departments of transportation spend on average about $3 annually per capita on active mode (walking and bicycling) facilities, about 0.5% of their budgets. Local transportation budgets probably devote a larger share to sidewalks and paths, but still small amounts. For example, the U.S. Federal Highway Administration's *Nonmotorized Transportation Pilot Program* (FHWA 2014), invested about $100 per capita in pedestrian and cycling improvements in four typical communities over a four-year period, and a detailed engineering study estimated that improving all Albuquerque, New Mexico sidewalks to optimum standards would cost approximately $60 per capita or $6 annual per capita over a decade (Corning-Padilla and Rowangould 2020). This suggests that active transport facility costs range from $25-50 annual per user.

Parking
Surveys indicate that a typical urban community has three to six off-street parking spaces per vehicle, including one residential and two to five non-residential spaces (Chester, et al. 2015; Hoehne, et al. 2019; Scharnhorst 2018). Considering land, construction and operating costs, urban parking facilities annualized costs are typically $500-1,500 for surface spaces and two to four times higher for structured parking (Litman 2021). This suggests that off-street parking costs total $2,000-4,000 per vehicle; cities tend to have fewer but more expensive spaces, while suburbs have more but cheaper spaces. Walking requires no parking. About ten bicycles can park in the area required for one automobile, and bike parking often uses otherwise wasted spaces, so annual parking costs are estimated at $100 for bike, and

$200 for e-bikes that require nearby electric outlets. Some transit users (perhaps 5%) regularly use park-and-ride facilities, so this cost is estimated to average $50 per transit user overall. About a third of parking facilities are residential, and so can be considered internal (users pay for them directly through rents and mortgages) and two thirds are external, financed through taxes and the prices of other goods.

Traffic Congestion
This refers to the delay that a vehicle imposes on other vehicles in traffic. There are many ways to measure these costs (Grant-Muller and Laird 2007). The Texas Transportation Institute's *Urban Mobility Report* (TTI 2019) estimated that in 2017, US congestion costs totaled $179 billion, or about $660 per motor vehicle. This is considered a higher estimate, other congestion cost studies result in lower cost estimates (Litman 2018). This analysis assumes that congestion costs average $400 per vehicle-year, and $500 for electric cars due to their greater annual mileage.

Bicycles and bus travel can cause congestion, but generally much less than automobile travel under the same conditions (Schaefer, Figliozzi and Unnikrishnan 2020). Case studies indicate that shifts to walking and bicycling improvements generally reduce congestion (Rudolph 2017). This analysis assumes that bicyclists and transit passengers impose $50 per year in congestion costs, and pedestrians impose zero congestion delay, although these values could change under alternative assumptions, for example, pedestrians could be assigned a small congestion cost for delaying vehicles when crossing streets.

Barrier Effect
Just as congestion costs reflect the delay that vehicles cause other vehicles, the barrier effect (also called *community severance*) refers to the delay that vehicle traffic causes to walking and bicycling. This includes delays when crossing streets, longer trips to reach safer crossing locations, and shifts from active to motorized modes (Anciaes, Jones and Mindell 2016). For example, as vehicle traffic increases in a neighborhood, parents often limit their children's walking and bicycling activity, and chauffeur them to local destinations. Although generally ignored in North America, some countries have standard methods for calculating barrier effect costs for transportation planning (DfT 2018; NZTA 2018). This analysis assumes that annual barrier effect costs average $50 per bus passenger, $200 for a conventional automobile, and $250 for an electric car, reflecting its higher annual mileage.

Crash Costs
This refers to crash damages, particularly external costs imposed on other road users. There are various ways to calculate these costs. Some estimates only include "economic costs," such as vehicle damage replacement, medical expenses and disability payments, while others also include non-monetary costs, often called "pain and suffering." A widely-cited study U.S. National Highway Traffic Safety Administration study, *Economic and Societal Impact of Motor Vehicle Crashes*, estimated that in 2010, U.S. crash costs totaled $277 billion considering just economic costs, and $871 billion including non-market costs, equivalent to about $1,250-4,000 per motor vehicle in current dollars (Blincoe, et al. 2014). A portion of these costs are compensated by insurance, but a major portion is uncompensated and therefore external.

This analysis assumes that external crash costs average $500 annually for a fossil fuel automobile, and $600 for electric cars due to their higher annual mileage. Bicycling and public transit are assumed to impose $50 annual external costs. Walking is assumed to impose no external crash costs.

Noise and Air Pollution

Various studies have monetized motor vehicle noise and air pollution costs (Litman 2019). The results vary depending on the scope of impacts considered and methods used to measure impacts. For example, a major U.S. National Academy of Sciences study estimated that non-climate change emission costs average about $150 per vehicle-year (NRC 2009), and a major European study estimated that local air pollution costs average 0.0114 Euro and noise costs average 0.009 Euro per vehicle-kilometer, totaling about $400 per vehicle-year (CE Delft 2019). Carbon emission costs are generally estimated at $20-50 per metric ton. This study assumes that pollution costs currently average $500 per vehicle-year. Electric vehicles reduce these costs but electrical production emits various pollutants, and their operation produces particulate pollution and tire noise, which are estimated to average $150 annually (OECD 2020). Electric bikes are assumed to produce $10 per year pollution costs.

Resource Externalities

Resource externalities refers to uncompensated costs that result from the production of vehicle and their fuels, including government subsidies, environmental damages (such as environmental damages caused by oil wells and fracking), human risks from production and distribution (such as oil pipe line and truck explosions) plus macroeconomic costs of imports (ExternE 2015; NRC 2009). This reflects addition costs of consuming non-renewable resources and therefore the benefits of resource conservation, particularly in countries that devote large amounts of their export exchange to petroleum.

This analysis assumes that fossil fuel vehicles have resource external costs averaging $200 annually, electric vehicle and public transit have $50 annual costs, and e-bikes have $5 annual costs.

Cost Summary

Table 2 summarizes the estimated costs per user-year described above. It also indicates the assumed annual miles travelled by a typical full-time user. These costs can, of course, be pro-rated, for example, if people rely on a combination of modes.

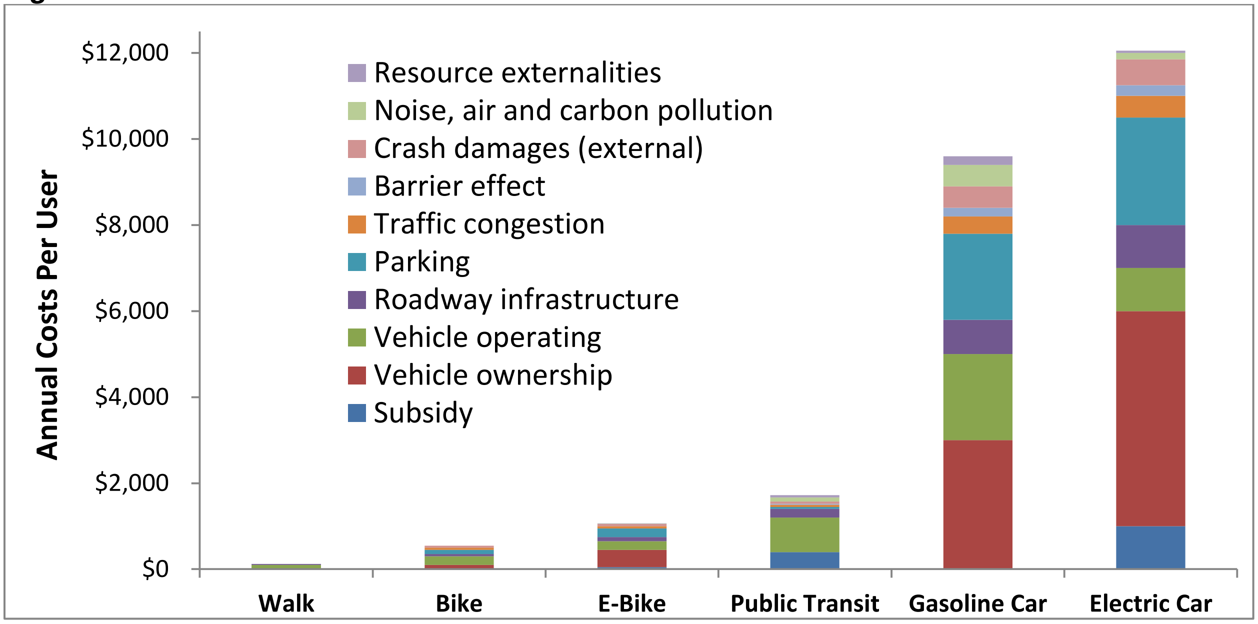
Table 2 **Annual Costs Per Full-Time User**

	Walk	Bike	E-Bike	Public Transit	Gasoline Car	Electric Car
Annual Miles	*1,000*	*2,000*	*3,000*	*4,000*	*10,000*	*12,000*
Subsidy	$0	$0	$50	$400	$0	$1,000
Vehicle ownership	$0	$100	$400	$0	$3,000	$5,000
Vehicle operating	$100	$200	$200	$800	$2,000	$1,000
Roadway infrastructure	$25	$50	$100	$200	$800	$1,000
Parking	$0	$100	$200	$50	$2,000	$2,500
Traffic congestion	$0	$50	$50	$50	$400	$500
Barrier effect	$0	$0	$0	$20	$200	$250
Crash damages (external)	$0	$50	$50	$50	$500	$600
Noise and air pollution	$0	$0	$10	$100	$500	$150
Resource externalities	$0	$0	$5	$50	$200	$50
Internal	*$113*	*$325*	*$650*	*$900*	*$5,400*	*$6,500*
External	*$13*	*$225*	*$415*	*$420*	*$4,200*	*$5,550*
Totals	***$125***	***$550***	***$1,065***	***$1,320***	***$9,600***	***$12,050***

This table summarizes annual costs of various travel modes.

Figure 1 illustrates these costs, measured per full time user-year.

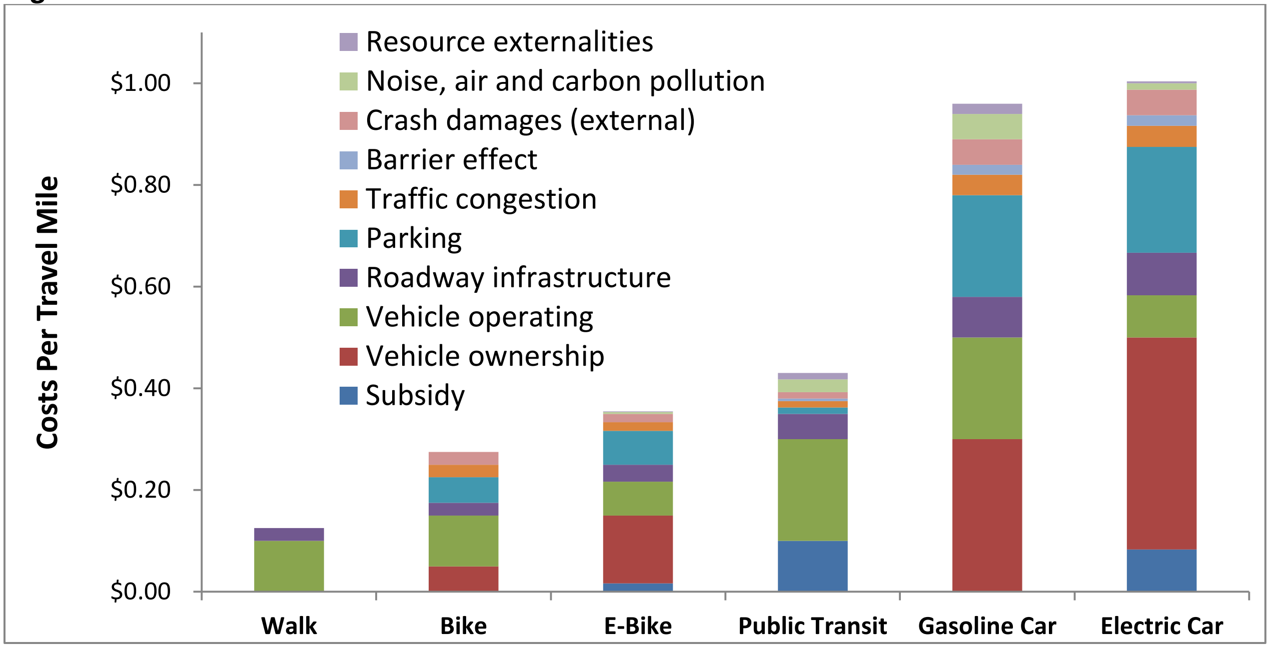
Figure 1 **Annual Costs Per Full-Time User**



This figure compares various costs of six travel modes, measured per year.

Figure 2 illustrates these costs measured per mile of travel.

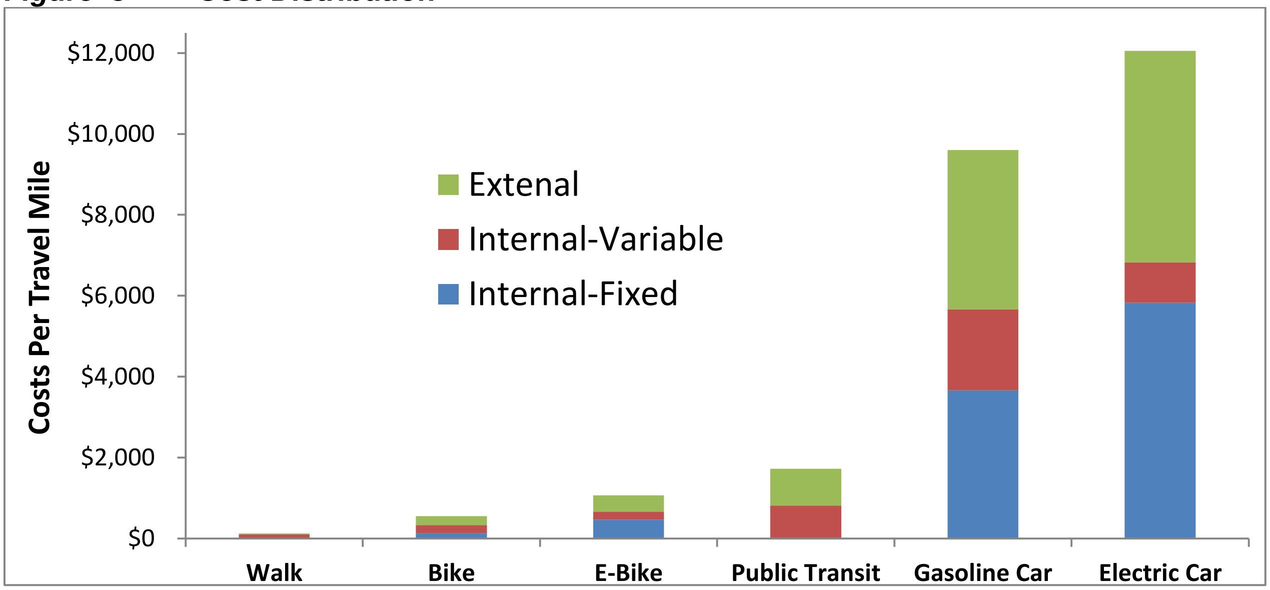
Figure 2 **Annual Costs Per Mile of Travel**



This figure compares various costs of six travel modes, measured per year.

Figure 3 compares distribution of these costs by mode. Internal-variable costs, such as vehicle operation and fares, are roughly proportional to the amount that a person travels, and therefore tend to be most efficient and equitable. Internal-fixed costs, such as vehicle ownership and residential parking, are borne by users, but do not vary by use and so are inefficient since they encourage users to maximize their vehicle travel in order to get their money's worth from those expenditures. External costs are both inefficient and unfair, particularly when expensive modes used by higher-income travellers impose external costs on disadvantaged groups, such as when motorists impose delay, risk or pollution exposure on lower-income walkers, bikers and public transit passengers.

Figure 3 **Cost Distribution**



This figure compares the cost distribution of various modes, assuming that vehicle expenses, plus a third of parking costs, and half of gasoline cars' roadway costs (because they pay fuel taxes) are internal.

Here are some observations from this analysis.

Travel activity imposes numerous costs. It is important to consider all significant impacts when evaluating transportation policies and planning decisions. Conventional analysis tends to overlook many of these impacts. For example, comparisons of urban highway expansion and public transit investments generally consider congestion delay, vehicle operating costs, and sometimes crash and pollution emission changes, but usually ignore vehicle ownership and parking costs, and so underestimate the full savings to users and businesses if transit improvements allow some travellers reduce their vehicle ownership and parking demands. Similarly, ignoring barrier effects understates the costs of expanding roadways and the benefits of improving pedestrian and bicycle conditions.

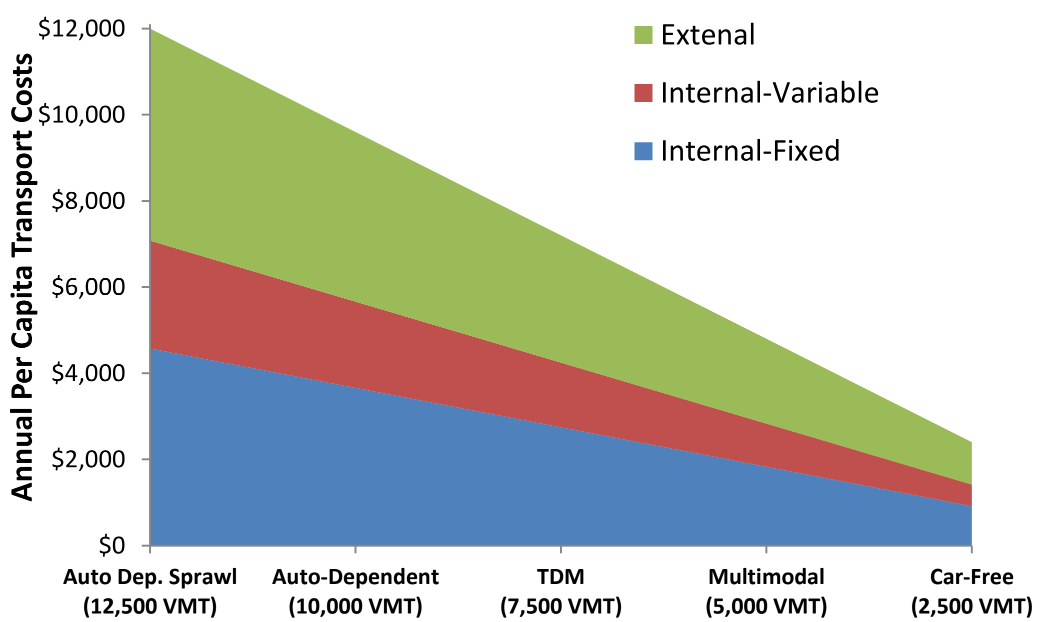
Vehicle expenses and infrastructure (road and parking) costs are generally the largest cost categories. An automobile typically costs more than $5,000 annually to own and operate, and when people purchase a motor vehicle they expect governments and businesses to spend $2,800-3,500 for roads and parking facilities for their use. Although some facility costs are internalized through special fuel taxes, road tolls and parking fees, most are not; their costs are incorporated into general taxes, rents and mortgages, and into the price of other goods, such as the cost of a restaurant meal.

Automobiles impose greater external costs than other modes due to their large infrastructure, congestion, crash and pollution costs. Although electric vehicles reduce pollution and resource external costs, they receive large subsidies, and because their low operating costs induce more vehicle travel, they impose more infrastructure, congestion, and crash costs than a gasoline vehicle.

Walking, bicycling and public transit have much lower total annual costs than automobile travel due to their lower unit costs (per travel mile) and lower annual mileage. A high annual mileage lifestyle is expensive to users and their community. Figure 4 illustrates this. It compares the estimated annual costs of the following transportation "lifestyles" associated with various land use patterns (Salon 2014):

- **Automobile-dependent sprawl**. Most travel is by automobile, and living in sprawled area results in long travel distances, resulting in 12,500 annual vehicle-miles of travel (VMT) per capita. This is typical of exurban locations.
- **Automobile-dependent.** Most travel is by automobile, resulting in 10,000 annual VMT per capita. This is typical of suburban areas.
- **Automobile-oriented with TDM.** Most travel is by automobile, but TDM strategies such as active and public transport improvements, and commute trip reduction programs, encourage shifts to non-auto modes when possible. This results in 7,500 annual VMT per capita. This is the typical target of VMT reduction goals, such as those in California and Washington State (Litman 2014).
- **Multimodal.** Travellers use a combination of modes, including walking and bicycling for local errands, public transit when travelling on busy travel corridors, and automobile travel when cost effective. This results in 5,000 annual VMT per capita. This is typical of transit-oriented neighborhoods.
- **Car-free.** Households do not own personal motor vehicles. Their carsharing, taxi, and share of transit bus travel totals 2,500 annual VMT. This is common in compact, multimodal neighborhoods with features such as good walking and biking conditions, carsharing services and efficient parking pricing.

Figure 4 **Annual Costs by Transportation Lifestyle**



This figure compares the cost of various transportation lifestyles.

Higher annual vehicle mileage increases both internal (user) and external costs.

Most North American communities are automobile-dependent, making it difficult to access common services and activities without a car. Many people have little experience with successful, multimodal lifestyles, and so assume they are inferior, but that is not necessarily true. Although multimodal living differs from an automobile-oriented lifestyle, it offers many benefits. It relies more on neighborhood services (shops, schools, parks, etc.) and jobs that are easy to access without a car, but these constraints are offset by $5,000 in annual savings, eliminated vehicle ownership responsibilities, and physical activity integrated into daily life which reduces the need to devote special time and money to exercise. Multimodal living tends to increase neighborhood social interactions, mental health and happiness. New transportation technologies and services, such as mobility navigation and payment apps, ridehailing, carsharing and telework, are making a multimodal and car-free lifestyle more feasible and convenient.

Additional Impacts

Some important impacts, described below, are unsuited to measuring per vehicle-mile or -year.

Travel Time

Time, the hours of our lives, is a scarce and valuable resource. Travel time is an important impact to consider, but the methods commonly used to monetize it, typically calculated as 25-50% of average wages is inappropriate for several reasons (ITF 2019). Although some trips are urgent and important, and travellers would pay these amounts to save time, empirical evidence indicates that most travellers' willingness-to-pay for time savings is much lower (Cervero 2011).

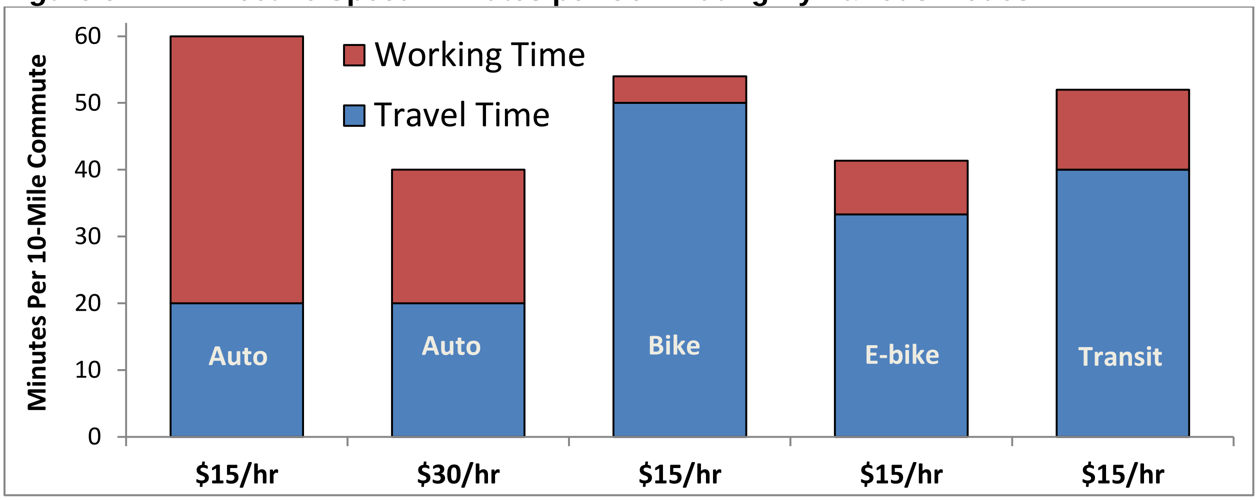
Many transportation projects justified by their travel time savings, such as highway expansions to reduce congestion delays, actually save little or no time over the long run. Extensive research indicates that traffic congestion tends to maintain equilibrium, it increases to the point that some potential peak-period vehicle trips are avoided. If roads are expanded, some of this latent demand fills the added capacity until congestion again discourages some potential trips. People tend to maintain a fixed travel time budget (Ahmed and Stopher 2014), so increases in travel speed result in greater travel distances, and over the long run, more sprawled development that reduces accessibility and increases the amount that people must drive to reach services and activities (Yan 2021). The amount of time people devote to travel does not decline.

Travel time cost values vary significantly depending on conditions and user preferences. For example, unpleasant conditions, such as driving in congestion or travelling in a crowded bus, have relatively high unit travel time costs, while under pleasant conditions, active travel (walking and bicycling) have low or negative travel time costs because travellers enjoy the experience or value the exercise it provides.

According to the National Household Travel Survey (NHTS 2017, Table 27), walking commute trip average 15 minutes, which means that people who walk to work achieve, on average, the 150 weekly minutes of moderate physical activity that experts recommend for health. In this way, active transportation substitutes for additional time and money required for exercise, such as working out at a gym. As a result, with good walking and bicycling conditions, the additional time that some travellers choose to walk or bicycle rather than use motorized modes can be considered a consumer benefit rather than a cost. Note, public transit commutes average 58 minutes, but a significant portion of this probably consists of walking or bicycling to and from transit stops and stations, so the same time cost variation – the low or negative travel time costs applied to self-selected walking and bicycling trips – can reduce the incremental costs of many transit trips.

Travel time costs can be evaluated based on *effective speed*, which measures travel distance divided by time spent traveling plus time spent earning money to pay travel expenses, as illustrated below.

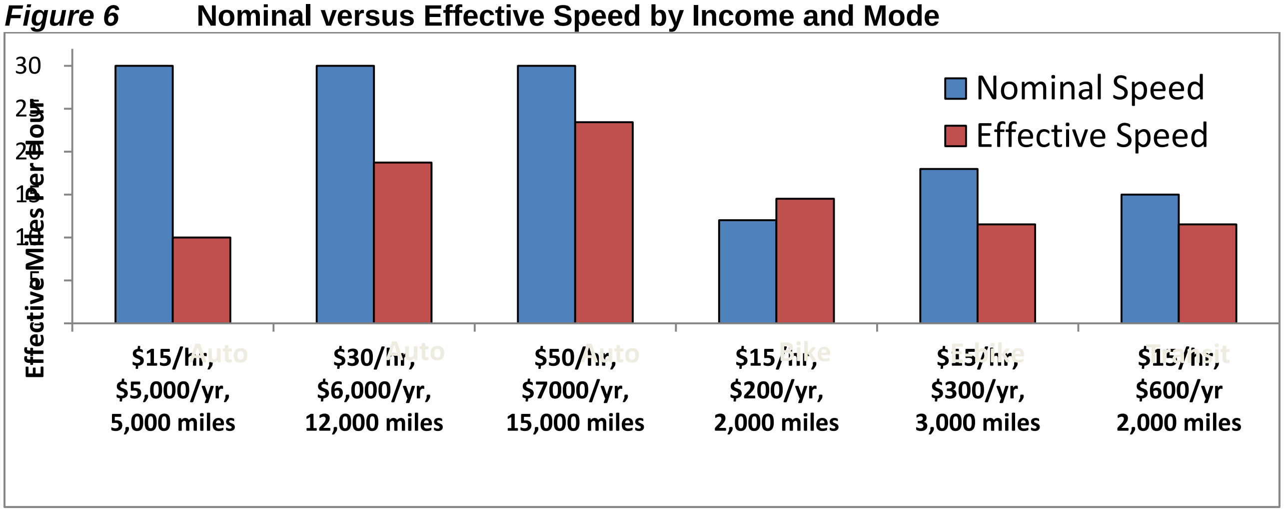
Figure 5 **Effective Speed: Minutes per Commuting By Various Modes**



This figure compares effective speed for various modes and incomes. Many lower-wage motorists spend more time earning money to pay their travel expenses than they spend travelling. Measured this way, bicycling, e-biking and transit are often faster than driving. (Assumes bicycling 12 mph, 10₵/mile; e-bike 18 mph, 20₵/mile; Public Transit 15 mph, 30₵/mile; Auto 25 mph, $5,000 and 5,000 annual miles for $15/hr motorists and $7,000 and 12,000 annual miles for $30/hr motorists.)

Figure 6 compares nominal and effective speeds. This indicates that automobile travel tends to be regressive; lower-income workers spend more total time to travel a given distance than higher-income workers. Bicycling, e-biking and public transit are often faster than driving for lower-income workers.

Figure 6 **Nominal versus Effective Speed by Income and Mode**



Effective speeds are inversely related to income. As a result, policies that favor faster but expensive modes, such as automobile travel, are regressive. To address this, transportation system performance should be evaluated based on effective rather than nominal speeds.

Public Fitness and Health
To maintain fitness and health, experts recommend that people engage in at least 150 minutes a week of moderate physical activity, and more if possible (CDC 2018). Although there are many possible ways to exercise, most, such as working out at a gym or participating in competitive sports, require special time and expenditures. For many people, walking and bicycling for transportation and recreation are the most practical way to maintain fitness. Some studies, including the World Health Organizations' *Health Economic Assessment Tool*, monetize those impacts, assigning a dollar value to each additional mile walked or biked (WHO 2014). The resulting values are often large. For example, Mulley, et al. (2013) estimate that in Australia physical activity health benefits average AU$1.68 per km (range $1.23–$2.50) per kilometer walked and AU$1.12 (range $0.82–$1.67) per km bicycled.

Social Equity
Transportation equity analysis considers ways that transportation planning decisions support or contradict various social equity goals, including providing independent mobility for non-drivers, increasing affordability, and reducing external transportation costs, particularly costs by advantaged groups imposed on disadvantaged groups, such as negative impacts that automobile travel imposes on walking, bicycling and public transit travellers, and on lower-income neighborhoods.

Most communities are to various degrees automobile-dependent, meaning that most common services and activities are easy to access by automobile, but often difficult and dangerous to access by other modes. In a typical community, 20-40% of residents cannot, should not, or prefer not to drive, due to disabilities, financial constraints or preference. As a result, transportation planning which favors automobile travel to the detriment of other modes is unfair, and since many physically and economically disadvantaged people are constrained in their driving ability, this tends to be regressive.

Although all travel imposes external costs, motorists impose much larger external costs per year because motor vehicles are resource-intensive. This form of travel require far more space, more costly infrastructure, and more energy than other modes measured per mile of travel, and motorists travel far more annual miles than people who depend on other modes. This is unfair (horizontal inequity), and because automobile travel tends to increase with income, it tends to be regressive (vertical inequity), it results in wealthier travellers imposing costs on lower-income travellers.

Affordability
Transportation affordability refers to costs relative to incomes, and low-income households' ability to afford access to basic services and activities such as healthcare, shopping, education, employment and some social and recreational activities. Many experts define affordability as households being able to spend less than 45% of their budgets on transportation and housing combined (CNT 2018). Since most households spend more than 35% of their income on housing, this indicates that affordability requires that households can spend less than 10% of their budgets on transportation, with higher amounts for households with low housing costs (for example, those that pay little or no rent or mortgage), and less for those with high housing expenses.

Table 3 shows average household expenditures by income quintile (fifth of households). The first and second income quintiles currently spend 13% and 16% of their budgets on motor vehicle expenses respectively, but some of these households own no vehicles. Of vehicle-owning households, the first quintile devotes 20% of its budget, and second quintile devotes 18% of its budget to motor vehicles. This is far more than is considered affordable.

Table 3 **Average Expenditures per Household** (BLS 2018)

	Income Quintiles				
	First	Second	Third	Fourth	Fifth
Mean Expenditures (household budget)	$26,399	$39,968	$51,729	$69,131	$118,781
Affordable Transportation Limit (10%)	$2,640	$3,997	$5,173	$6,913	$11,878
Vehicles per Household	1.0	1.6	1.9	2.3	2.7
Portion that own at least one vehicle	66%	89%	94%	95%	97%
Reported vehicle expenditures per household	$3,464	$6,322	$8,087	$10,418	$16,411
Portion of budget: all HHs	*13%*	*16%*	*16%*	*15%*	*14%*
Portion of budget: vehicle-owning HHs	***20%***	***18%***	***17%***	***16%***	***14%***

Most vehicle-owning households spend more on vehicles than is considered affordable.

These high levels of vehicle expenditures may be affordable to some lower-income households, such as those with a low rents or paid-off mortgage, but are excessive and harmful to many lower-income households, particularly when they experience large unexpected costs due to mechanical failures, crashes and traffic violations. When households have difficulty paying healthcare or housing costs, or purchasing healthy food, the reason is often high vehicle expenses. This indicates that affordability should be considered an important planning objective that justifies policies and programs that improve affordable modes (walking, bicycling, e-bikes and public transit) and create more compact, multimodal neighborhoods where it is easy to get around without a car.

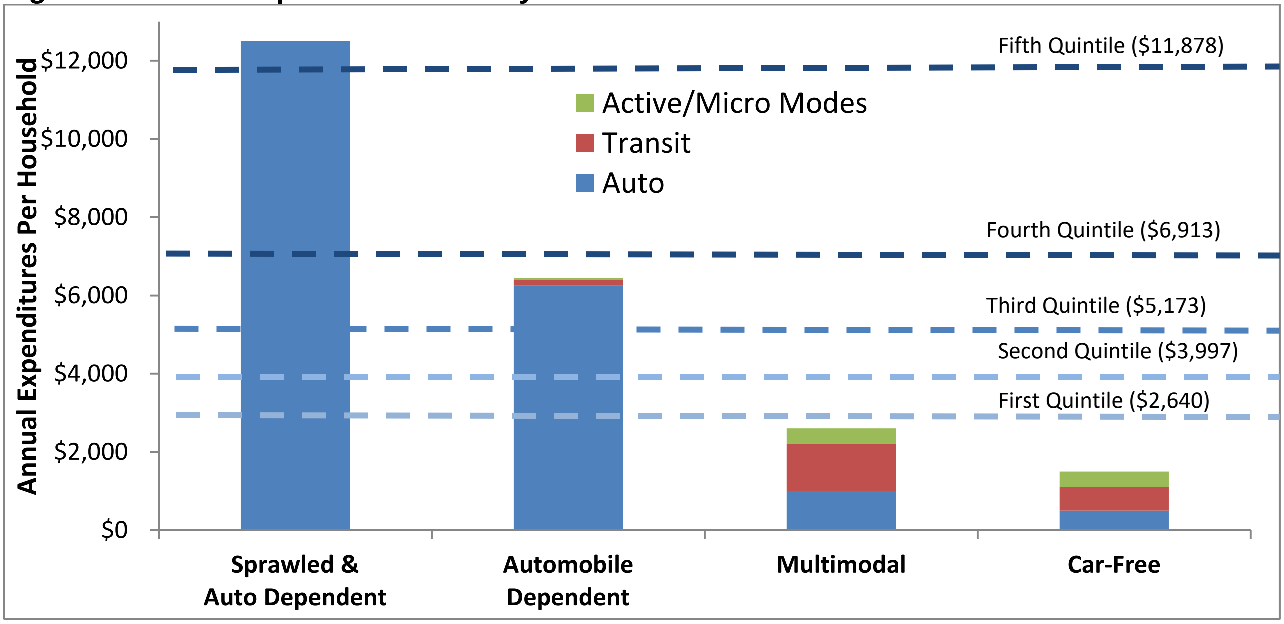
Sprawl-Related Costs

Transportation and community development patterns interact in ways that can have various economic, social and environmental impacts (Salon 2014). For example, automobiles require more space for roads and parking, and impose more noise and air pollution which encourages sprawl. This increases travel distances between destinations and reduces accessibility, and increases per capita impervious surface, which displaces habitat, increases stormwater management costs, and increases heat island effects.

Sprawl increases the mobility required to access services and activities and reduces affordable travel options (Levinson, Marshall and Axhausen 2018). Figure 7 illustrates total transportation costs for a typical two-adult household in various types of communities: automobile-dependent sprawl where every adult requires an automobile that is driven 12,500 annual miles; a compact, automobile dependent area where two adults share a car driven 12,500 annual miles; a multimodal community where the household travels by automobile (mostly carsharing) 2,000 miles, rides transit 4,000 miles and uses active and micro modes 2,000 annual miles; and a car-free community where the household drives 1,000 miles (by carsharing or taxi), uses transit 2,000 miles, and active modes 4,000 annual miles.

The dashed lines indicate affordable transportation spending by income quintile, assuming that households can spend up to 10% of their total budgets on transport. This makes an important point: automobile dependency and sprawl, which require every adult to drive more than 10,000 miles per year, is costly and therefore unaffordable to most low- and moderate-income households. Of course, many lower-income households do own vehicles and live automobile-dependent lifestyles, but this often leaves insufficient money for other essential goods including medicine, healthy food, and comfortable housing, which explains why many responsible, hard-working families experience financial crises.

Figure 7 **Transportation Costs by Location**



Household transportation costs vary significantly by location. Residents in sprawled, automobile-dependent areas must drive high annual miles and bear high vehicle costs which are unaffordable to most households. Only a multimodal or car-free neighborhood is truly affordable to most lower- and moderate-income households.

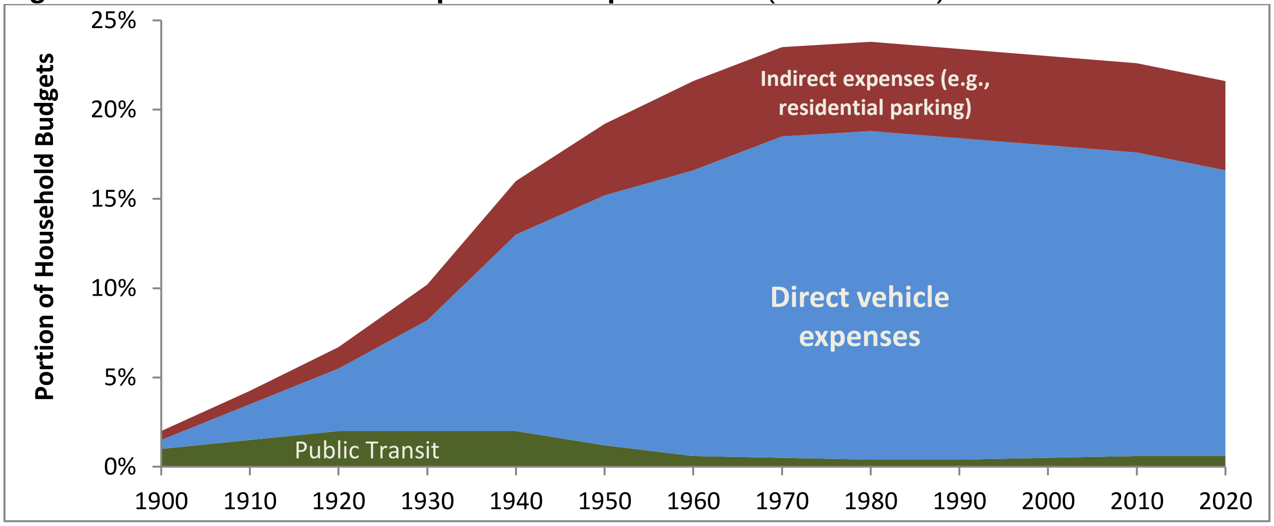
As a result, improving affordable modes (walking, bicycling and public transit) and affordable housing in a multimodal community provides economic opportunity and resilience to low- and moderate-income households.

Historical Trends

It is interesting to consider how transportation costs have changed over time. My report, *Our World Accelerated* (Litman 2020), examines the economic impacts resulting from the development of motorized transportation during the last 120 years affects.

Before 1900, automobiles hardly existed, by 2000 they were dominant transportation mode. Travel became much faster and cheaper. We now travel about ten times faster and farther than in 1900, and rely much less on walking, bicycling and public transit. Although this increased mobility provided benefits, it also imposed large economic, social and environmental costs, and was particularly harmful to physically and economically disadvantaged people. In 1900 a typical working-class family had negligible transportation expenses, by the end of the Century most vehicle-owning households devoted about 20% of their budgets to vehicles and residential parking, as illustrated in Figure 8. As a result, an average automobile commuter spends about 2.5 hours each workday driving or working to pay vehicle expenses.

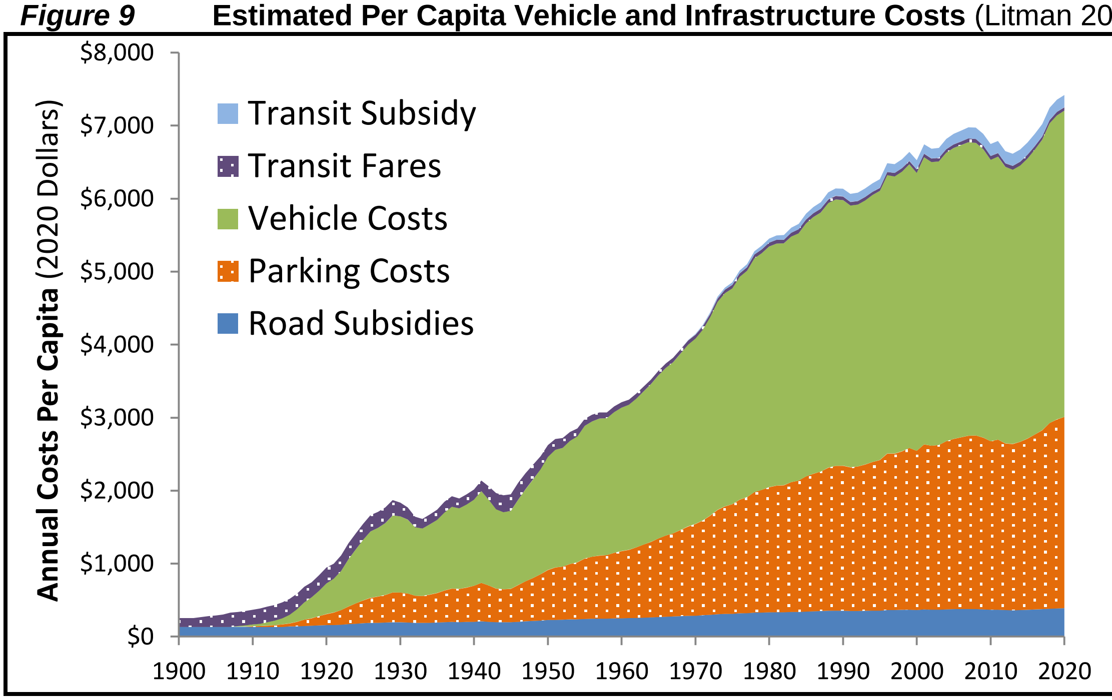
Figure 8 **Household Transportation Expenditures** (Litman 2020)



Household transportation expenses increased significantly as motor vehicle travel grew.

Increased vehicle travel also increased public infrastructure costs, including the costs of providing roads and government-mandated parking facilities, as illustrated below. Most of these costs are paid indirectly through general taxes, rents and higher prices for other goods. The following figure illustrates total estimated vehicle and infrastructure costs. In addition, motor vehicle travel imposes large health and environmental costs, and contradicts social equity goals.

Figure 9 **Estimated Per Capita Vehicle and Infrastructure Costs** (Litman 2020)

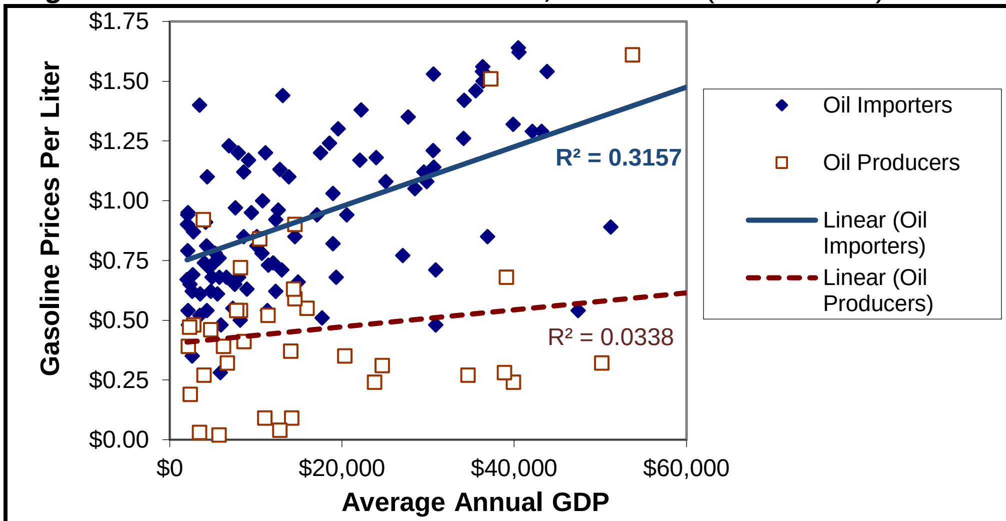


As automobile travel grew during the last 120 years, per capita vehicle, road and parking facility costs increased significantly.

Macro-Economic Impacts

People often assume that since automobile ownership tend to increase with income, it support economic development. This is often used to justify automobile-oriented policies such as highway expansions, low fuel taxes, and parking subsidies (Litman 2014). It is true that some vehicle travel supports productivity by improving delivery of goods and services, and expanding labor pools, but evidence suggests that transport underpricing (prices below production costs) and the additional vehicle travel it causes are economically harmful. As Figure 10 shows, productivity tends to increase with fuel prices, probably because higher fuel prices encourage transportation system efficiency.

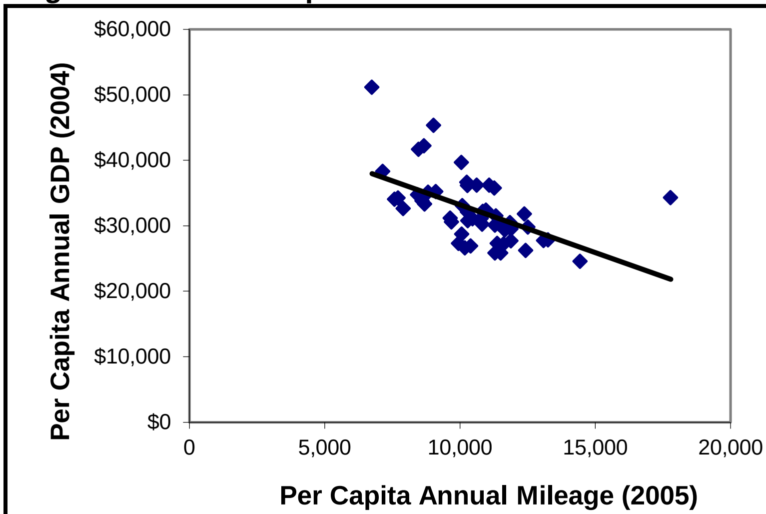
Figure 10 **GDP versus Fuel Prices, Countries** (Litman 2014)



Economic productivity tends to increase with higher fuel prices, indicating that substantial increases in vehicle fees can be achieved without reducing overall economic productivity.

The figure below shows a negative relationship between per capita vehicle travel and per capita GDP, indicating that factors that encourage transportation efficiency, such as urbanization and multimodal transportation systems, tend to support economic productivity.

Figure 11 **Per Capita GDP and VMT for U.S. States** (2009)



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

Demand

Demand refers to the type of travel that people would choose under specific circumstances, and the factors that affect those decisions. Current transportation planning tends to measure motor vehicle travel demands, using surveys and models that predict the number of vehicle trips that people would make under various conditions. However, it does a poor job of accounting for other modes and factors, and for identifying latent demands for non-auto and emerging modes such as e-bikes and ridehailing.

Although few motorists want to give up driving altogether, surveys indicate that many would prefer to drive less, rely more on other modes, and live in walkable urban neighborhoods, provided that they are convenient, comfortable and affordable (NAR 2017). More multimodal planning and more efficient transportation pricing are likely to further increase use of affordable and resource-efficient modes. Multimodal demand analysis identifies latent demand for non-auto modes, and ways to serve that demand, for example, by improving public transit service quality, the connections between non-auto modes, and appropriate housing options in multimodal neighborhoods.

Conclusions

Transportation is an important but costly activity. It is important that transport policy and planning analysis consider all significant benefits and costs. Conventional planning often overlooks or undervalues important impacts. More comprehensive analysis is increasingly important to consider emerging planning issues and new transportation technologies and services.

This report provides estimates of ten major costs of six modes, plus some difficult-to-measure impacts including travel time values, social equity, health and sprawl-related costs. Motor vehicle travel is generally much more expensive than other modes. An automobile typically costs more than $5,000 annually to own and operate, requires $2,800-3,500 worth of road and parking infrastructure, and imposes significant congestion, risk and pollution damage costs. Automobile travel costs are higher than for walking, bicycling and public transit travel measured per travel-mile, and since motorists tend to travel more annual miles than people who rely on other modes, their annual costs are many times larger. Many of these costs are external, making them inefficient and unfair. This results in economically-inefficient mobility; vehicle travel in which total costs exceed total benefits.

Walking and bicycling generally have the lowest total costs. E-bike costs are somewhat higher, but still relatively inexpensive. Public transit costs vary depending on conditions; on high demand urban corridors, transit service is efficient and requires minimal subsidy, but unit costs and subsidies are much higher at times and places with low demand. Although electric vehicles reduce pollution and resource externalities, they receive large financial subsidies, and by increasing annual vehicle travel, tend to increase infrastructure, congestion and crash costs.

Community development patterns and transportation policies significantly affect per capita transportation costs. The automobile-dependent transportation systems common in North America increase total transportation costs by many thousands of dollars annually, including many external costs that motor vehicle travel imposes on communities. These external costs tend to be economically inefficient, resulting in more vehicle travel than is optimal. They are also unfair and regressive, causing motorists to impose costs on disadvantaged people who rely on other modes.

The Twentieth Century was the period of automobile ascendency during which automobiles grew from virtually nothing into the dominant travel mode in most countries. This increased average travel speeds and annual mileage by an order of magnitude, but increased costs by similar amounts. Average households now spend about 20% of their budget on vehicles and their facilities, with a higher portion for lower-income households. Because automobiles are costly and sometimes imposes large and unexpected expenses, automobile dependency is unaffordable to most moderate and low-income households, often leading to economic stresses and sometimes financial crises. Measured based on effective speed, which considers travel time plus time spent earning money to pay vehicle expenses, bicycling, e-biking and public transit are often faster than driving. Affordability, resilience, health and safety, and environmental protection all justify more multimodal transportation planning.

Although automobile travel tends to increase with economic growth, and some vehicle travel contributes to economic productivity, beyond an optimal level increases in per capita vehicle travel are economically harmful. Policies that encourage more efficient travel, such as efficient pricing and HOV priority policies, support economic development more than policies that increase vehicle travel.

Current planning tends to undercount and overlook non-auto travel demands, which results in under-investment in walking, bicycling and public transit. Given better mobility and accessibility options, and more efficient incentives, many travellers would drive less, rely more on other modes, choose to live in more accessible and multimodal neighborhoods, and be better off overall as a result. This is not to suggest that automobile travel is bad and should be foregone altogether, but it is costly, and automobile dependency is unaffordable to many households.

Transportation systems can be far more efficient, affordable and equitable than what currently exists in most communities. This requires compact, multimodal neighborhoods, where it is easy to reach most commonly-used services and activities within a 15-minute walk or a shorter bike ride, with convenient and comfortable public transit connecting neighborhoods. These policies allow households to get around without driving, and so allow households to minimize their vehicle ownership. This is the only type of transportation system that is truly affordable to most low- and moderate-income households, and provides other economic, social and environmental benefits.

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