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Our World Accelerated

How 120 Years of Transportation Progress Affects Our Lives and Communities

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Transportation innovations increased our mobility by an order of magnitude, but also imposed significant economic, social and environmental costs, and tend to harm people who don't drive or have low incomes.

Summary

This report critically examines how 120 years of transportation progress affects our lives and communities. Before 1900, automobile and air travel hardly existed; by 2000 they were dominant forms of travel. Mobility became much faster and cheaper per mile of travel. We can now travel about ten times faster and farther than in 1900. Although this provides benefits, it also imposes significant economic, social and environmental costs, including large increases in household expenses, infrastructure costs, and health problems, plus reduced mobility options. These costs offset a major portion of benefits and tend to be inequitable; they harm people who cannot drive or have low incomes. This has important implications for planning future transportation innovations.

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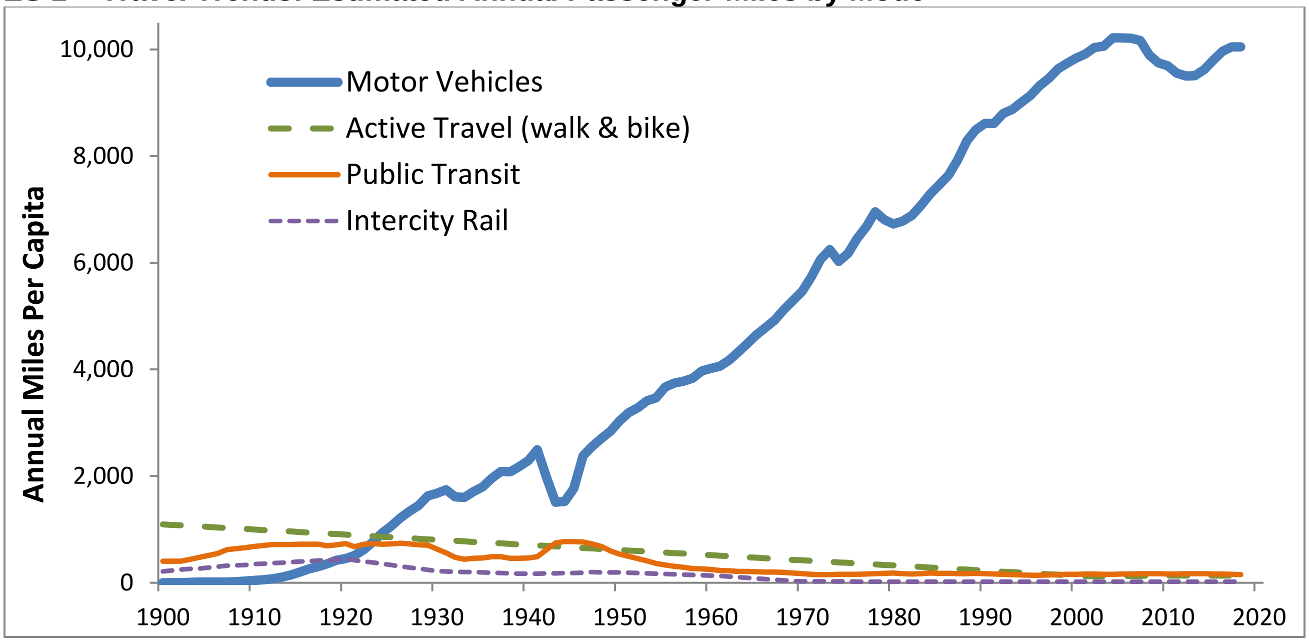
Executive Summary

During the last 120 years, motor vehicles became increasingly reliable, comfortable and affordable, and integrated into our lives and communities. Before 1900, automobiles and aviation hardly existed; by 2000 they were dominant modes. Travel became much faster and cheaper. Our world expanded! We now travel about ten times faster and farther than in 1900, and travel less by active and public transport, as illustrated below.

ES 1 **Travel Trends: Estimated Annual Passenger-Miles by Mode**

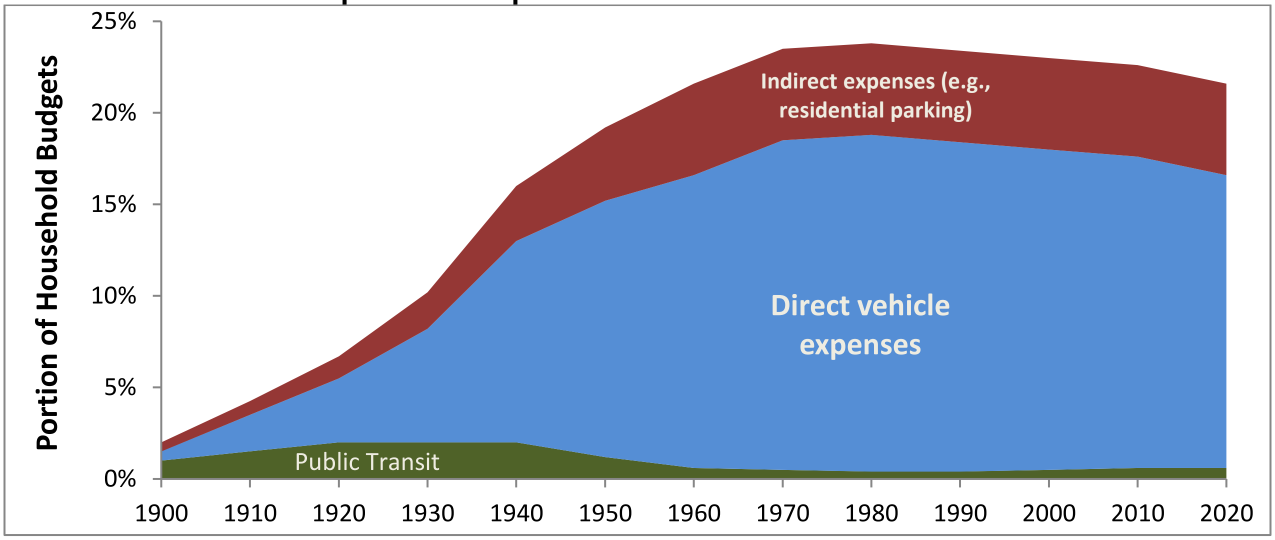


Before 1900 people travelled primarily by walking, with occasional bicycle and rail trips. Motor vehicle travel grew steadily during the Twentieth Century but peaked early in the Twenty First Century.

However, this growth is unlikely to continue. In North America, traffic speeds peaked about 1970 and subsequently declined due to increased congestion, safety and environmental concerns. Similarly, air travel became slower after 2000 due to new security, health and environmental requirements. Per capita vehicle travel peaked early in the Twenty First Century and is likely to decline due to demographic, economic and technical trends that are reducing vehicle travel demands.

Third, although increased mobility provided benefits, it also imposed huge 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 transport. An average automobile commuter spends about 2.5 hours each workday driving or working to pay vehicle expenses. Increased vehicle travel also increased infrastructure costs, accidents, health problems, environmental damages and community degradation. Before 1950, non-auto modes provided relatively convenient and affordable accessibility, but automobile-oriented planning subsequently reduced their efficiency. People who cannot, should not, or prefer not to drive, plus many motorists, are harmed by policies that favor automobile travel over other modes and sprawl over more compact development. Current high levels of automobile travel, and the costs they impose, reduce economic productivity.

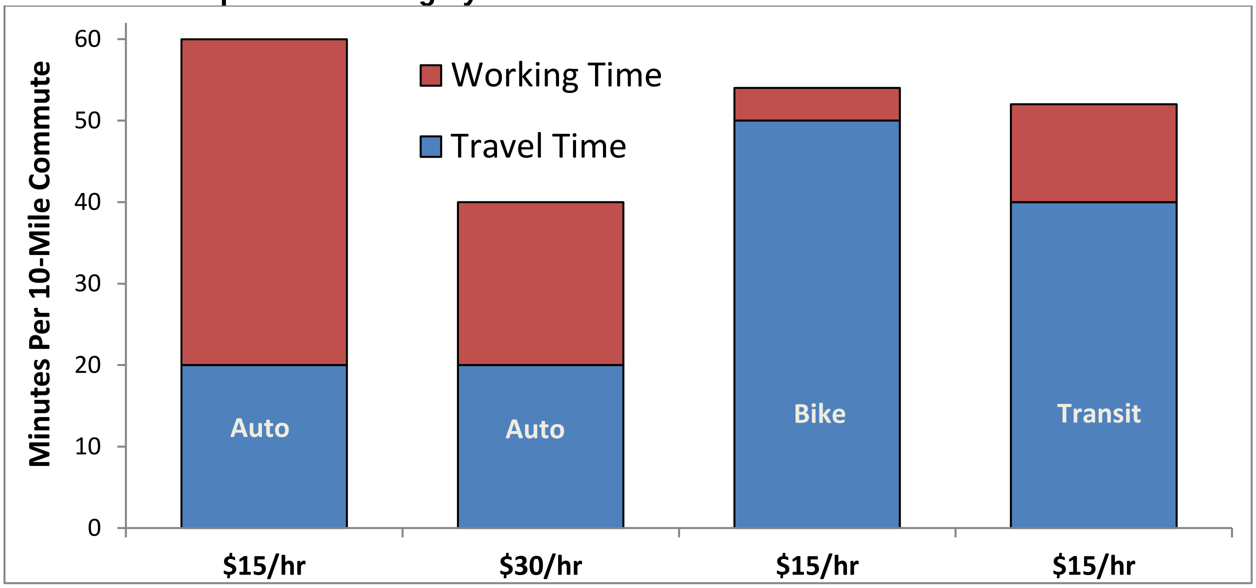
ES 2 Household Transportation Expenditures



Household transportation expenses increased significantly as motor vehicle travel grew.

These high costs offset many of the benefits of increased mobility. Motorists on average travel about five times as many annual miles and spend about five times as much money on transport, compared with people who are car-free. Because of these high costs, automobile travel has relatively low *effective speeds*, which measures time spent travelling plus time spent working for money to pay travel expenses. Effective speeds increase with travel speed and income, and so are regressive. The figure below shows the number of minutes spent travelling and earning money for travel expenses for various modes.

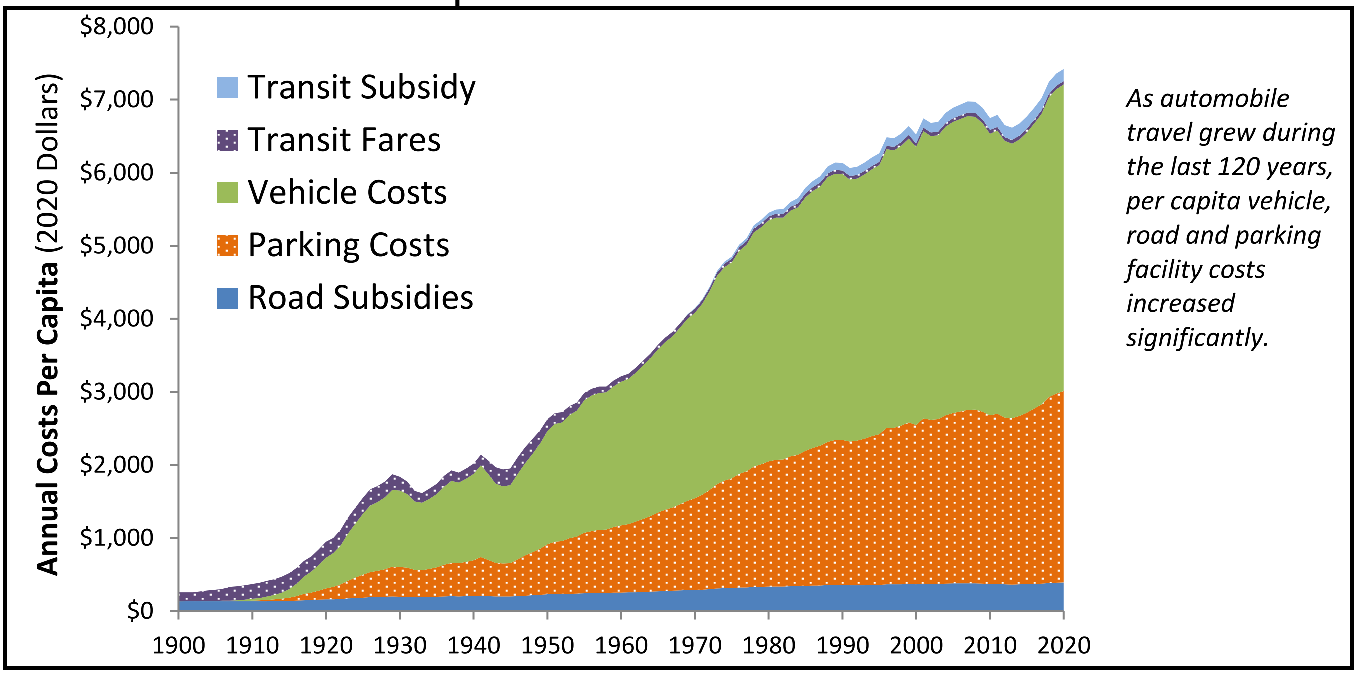
ES-3 Minutes per Commuting by Various Modes



This figure shows effective speed: the time spent travelling and earning money to pay travel expenses, for various types of travel. Many lower-wage motorists spend more time earning money to pay their travel expenses than they spend travelling. Bicycling and transit are often faster than driving overall.

When somebody purchases a vehicle, they expect governments to provide roads and businesses to provide parking facilities for their use. These are expensive and inefficiently priced; only about half of roadway costs and a smaller portion of parking facility costs are paid by users. Most facility 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.

ES-4 **Estimated Per Capita Vehicle and Infrastructure Costs**



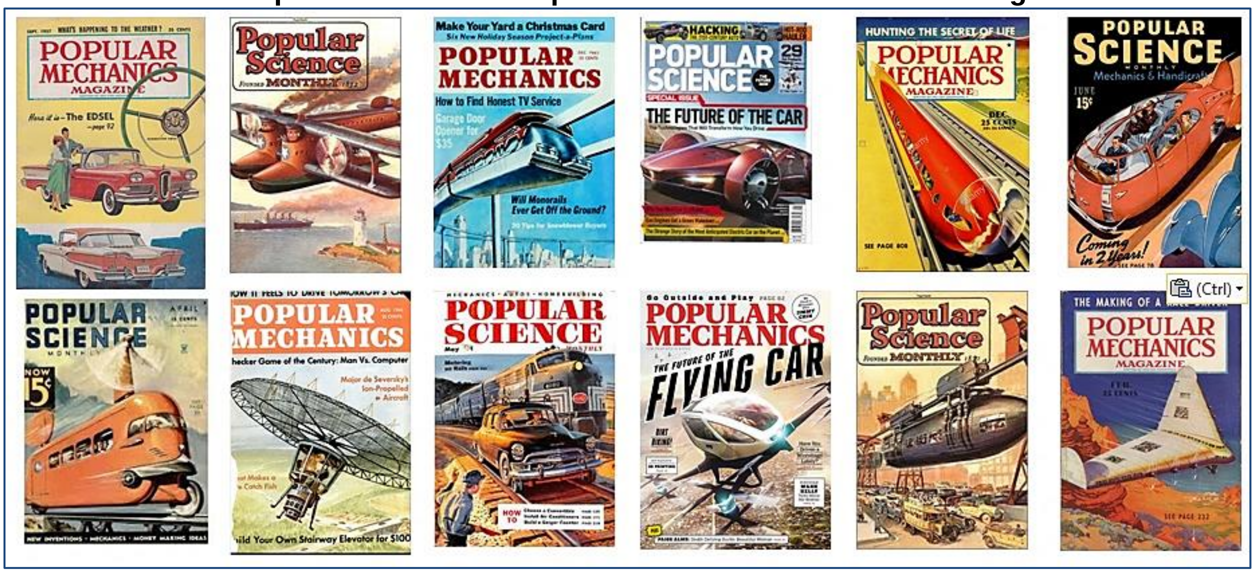
This research indicates that these high levels of mobility do not necessarily reflect consumer preferences. For most of the last century, public policies favored automobile travel over other modes, reducing mobility options. Although few people want to give up driving altogether, surveys indicate that many would prefer to drive less, rely more on non-auto modes, and live in more compact, multi-modal neighborhoods, provided they are convenient, comfortable and affordable to use. Current demographic, economic and technological trends, including aging populations, changing consumer preferences, increased affordability, health and environmental concerns, plus new transportation modes and services, are reducing vehicle travel demands. As a result, rational planning should invest less to support motor vehicle travel, and more to improve affordable, resource-efficient and healthy travel options.

After a century of progress we are ten times more mobile, but are we ten times wealthier, healthier or happier? Did faster travel gain us more free time, better social connections or more contentment? On the contrary, our modern transportation system in many ways forces people to travel more, spend more money, work harder, risk more, and have less free time than many want. A ten-fold increase in mobility is an impressive accomplishment. The people who helped this happen should be proud. However, if your income increased ten-fold but you found yourself no wealthier, happier or freer, you should wonder, "How was my wealth squandered?" We can ask the same question from transport progress: "How did we squander the potential benefits of improved mobility?"

Introduction

Transportation innovations have transformed society in the past and will surely do so in the future. In ancient times, travel was mostly by foot, so most people seldom ventured beyond their villages, and imported goods were costly and rare. Over centuries, new technologies and services – wagons, boats, ships, railroads, automobiles and aircraft – expanded where we could go and the products we could use, improving our lives in many ways. These innovations can seem exciting and useful, as illustrated below.

Exhibit 1 **Transportation-Theme Popular Science and Mechanics Magazine Covers**



New transportation technologies often seem exciting and beneficial, as illustrated by these magazine covers. They represent our shared dreams for a better future.

Innovations continue. There are probably more emerging transportation technologies and services being developed now than any time in history. However, it is important to recognize that *new* is not necessarily *better*. Transportation innovations often introduce new costs and problems. It is therefore important to understand their full effects.

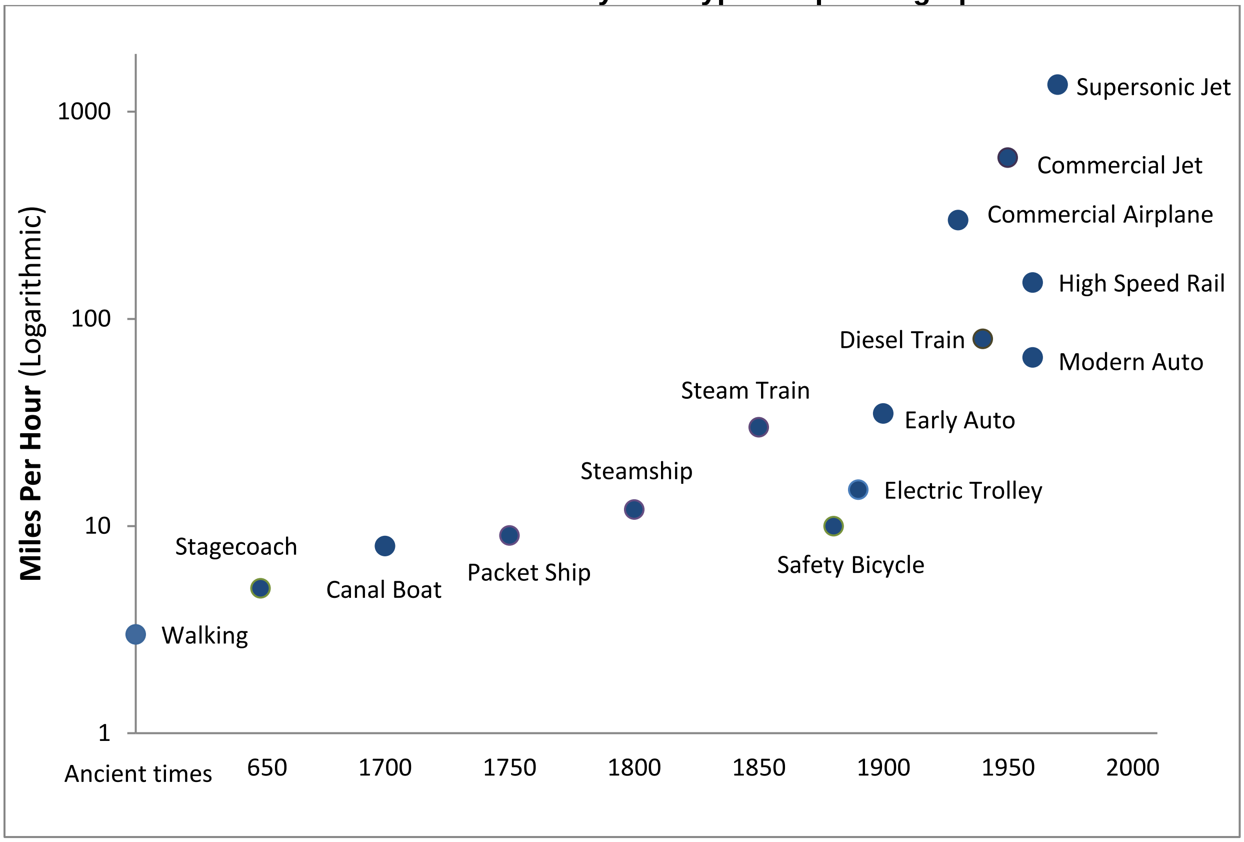
This report critically examines the economic, social and environmental impacts of past transportation innovations so we can put current and future. It focuses on the Twentieth and early Twenty-First centuries, the period during which automobile and aviation developed. It considers changes in personal and commercial travel activity, planning practices, public and household budgets, economic productivity, opportunity and social equity, public health and environmental quality, and community and culture. This is more comprehensive than most previous studies and includes original research.

This report should be of interest to anybody interested in transportation history, and anybody involved in transportation policy and planning who wants to understand the past in order to help prepare for the future. This analysis has important implications for evaluating future transportation innovations. It indicates that previous transportation innovations provided large benefits, but also imposed large costs, including many that are particularly harmful to people who are physically, economically and socially disadvantaged. Many of these costs tended to be overlooked and undervalued in conventional planning, leading to inefficiencies and inequities. This report discusses various insights and implications.

New Modes

Many new modes of transportation have developed during the last few centuries. These modes tended to increase travel speeds and carrying capacity, which tended to reduce costs per passenger- or ton-mile. The figure below indicates when new modes first became widely available and their typical operating speeds.

Exhibit 2 **New Modes' Initial Availability and Typical Operating Speeds**[1]



For most of transportation history, newer modes were faster. Note that speed is indicated on a logarithmic scale so small increases in height indicate large increases in speed.

These changes were particularly large during the last 120 years. Before 1900, automobiles and aviation hardly existed (only kites and balloons); by 2000 they were dominant travel modes. Travel became much faster and cheaper per mile. To understand how these innovations affect travel it is useful to consider two key budgets: time and money. Most people devote 60-80 daily minutes[2] and 16-18% of their household budgets on personal travel. As a result, if travel becomes faster or cheaper we tend to travel more, for example, accepting a longer commute or choosing more distant shopping and holiday destinations. This additional vehicle travel is called *generated traffic* or *induced travel*.[3]

These increases in vehicle travel speed and distance had many economic, social and environmental impacts, some desirable but others not so. Let's see how transportation innovations affected travel activity, our lives and communities, during the last 120 years. An honest accounting of these impacts is useful to help understand some of our current problems and guide future planning.

Travel Changes

This section summarizes changes in various types of travel activity between 1900 and 2020.

Surface Transportation

Before 1900, people travelled primarily by walking, with occasional horse, bicycle, train and boat trips. Over time, these were displaced by newer modes. These changes are discussed below.

Active Travel

Walking is the most basic form of transportation. It, and other forms of active transport (wheelchairs, handcarts, scooters, bicycles, etc.), provide affordable mobility, plus recreation and healthy exercise. In addition, walking facilities (sidewalks and paths) are a major portion of the *public realm* (public spaces were people often interact) and so affect people's community interactions and perceptions. How have active modes changed during the last century? The table below summarizes various factors that affect active travel conditions and how they have changed.

Exhibit 3 **Changes in Active Transport Conditions, 1900 to 2020**[4]

Factor	Changes
Equipment	Shoe, scooter and bicycle technologies improved and generally become more affordable.
Facilities	Facility design has improved in some ways, with universal design features to ensure that facilities accommodate diverse users, including people using wheelchairs, walkers and handcarts. However, the streets in many suburban developments lacked sidewalks. Many communities are starting to implement pedestrian and bicycle improvement plans.
Motor vehicle traffic	Wider roads, and increases in motor vehicle traffic volumes and speeds, and resulting increases in traffic risk, noise and air pollution degraded walking and bicycling conditions in most communities (called the *barrier effect*), often making active travel infeasible, particularly for vulnerable people such as children and people with mobility impairments.[5] Complete streets policies and traffic calming are intended to improve active mode conditions.[6]
Travel distances	Sprawled development increased travel distances, which made many communities too dispersed for convenient access by walking.
Social status	As middle-class people walked and bicycled less, they became stigmatized. Jaywalking laws forced pedestrians off of public streets.

During the last century, active transportation conditions improved in some ways but declined in others, including many streets built without sidewalks, plus wider roads with increased vehicle traffic that creates barriers to active travel. Many communities are now implementing walking and bicycling improvement plans.

Although data are limited, available information indicates that active travel conditions and activity declined significantly during the last century. Of course, in 1900 many roads were unpaved and few had sidewalks, and pedestrians and bicyclists encountered horse excrement and dangers from wagons and streetcars,[7] but these did not dissuade walking and bicycling. Until the 1920s, rural roads had minimal traffic risk and pedestrians filled city streets, as shown in contemporary films such as, *A Trip Down Market Street, 1906*[8] and, *A Ride through Barcelona 101 Years Ago*.[9] However, as motor vehicle traffic increased it displaced walking and bicycling.

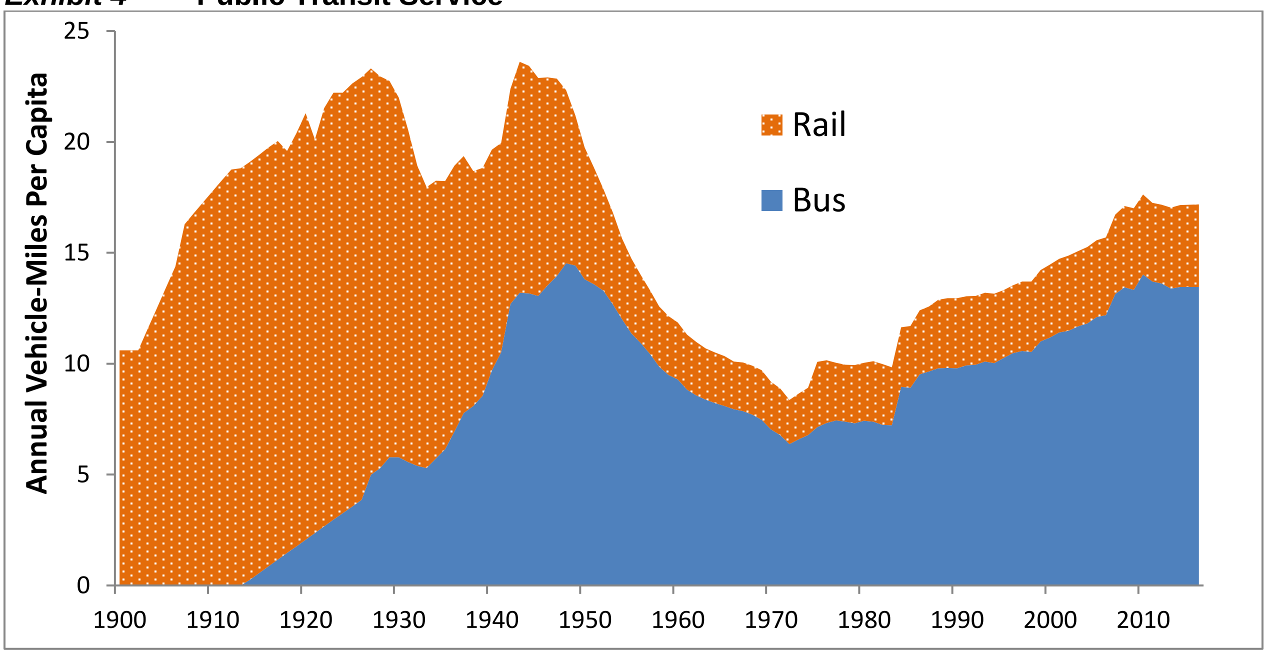
As automobile traffic grew, pedestrians lost their safety, their rights, and their dignity. Early in the century, motorists were expected to drive cautiously for safety sake, but the automobile industry shifted the responsibility to pedestrians through campaigns to ridicule and outlaw "jaywalking" (a pejorative term for unsophisticated behavior), forcing pedestrians to yield to automobiles.[10] As a result, pedestrians are often blamed when injured in traffic accidents.[11]

Since walking was the dominant travel mode in 1900, we can assume that most people walked or bicycled three or four miles a day (60-80 minutes), ten times the 0.37 daily miles of walking and bicycling recorded in 2009.[12] Similarly, we can also assume that in 1900, nearly all students walked or bicycled to school. This declined to 41% in 1969, and down to just 13% in 2001, while the portion of students driven to school increased to 55%.[13] What caused these changes? Do modern children lack shoes? Do they prefer being chauffeured by their parents rather than travelling under their own power? No, these shifts probably resulted from automobile-oriented planning and sprawled development patterns that improved automobile access and degraded walking and bicycling conditions.

Public Transport

Transit service (rail and bus vehicle-miles per capita) and ridership (passenger-miles per capita) grew during the first half of the Twentieth Century, but declined after 1950 as travellers shifted to cars, urban streets became congested, and development sprawled, making transit less convenient and efficient. After 1960, governments subsidized public transit services, but they received a relatively small portion of total transportation investments, and other factors including automobile-oriented planning, parking subsidies and dispersed development patterns made transit travel uncompetitive in most communities.[14] The figure below illustrates transit's decline and partial recovery.

Exhibit 4 **Public Transit Service**[15]

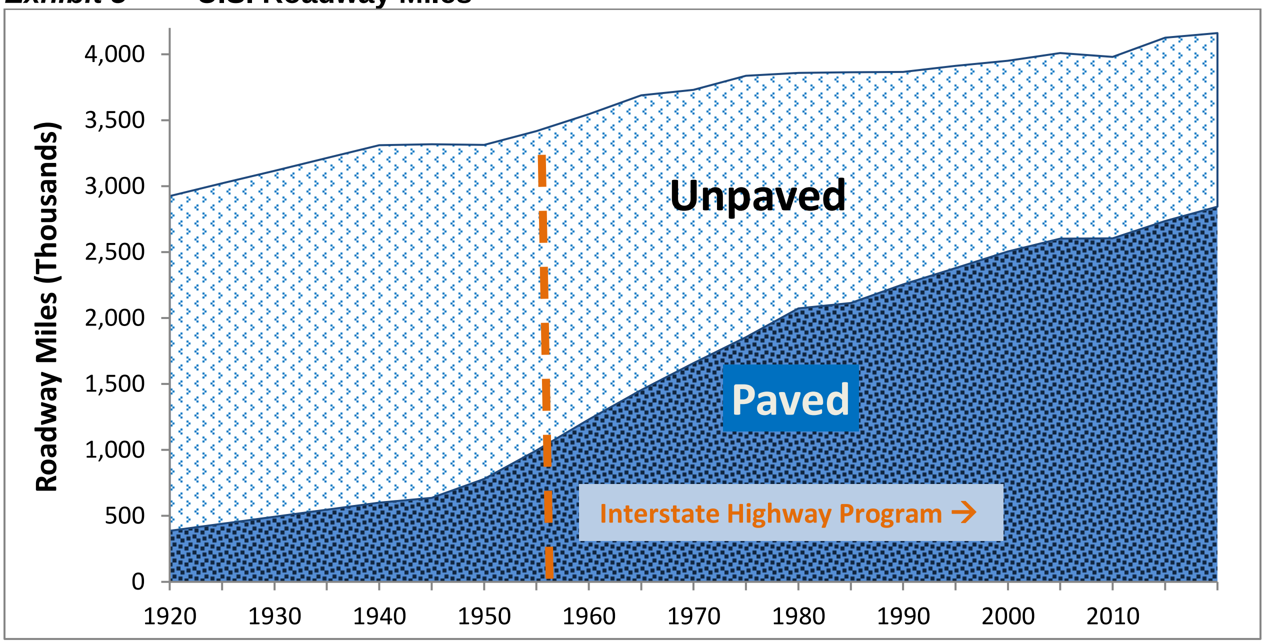


Per capita transit service grew during the first half of the Twentieth Century, subsequently declined as travellers shifted to cars, city streets became congested and development sprawled, but partly recovered due to public subsidies.

Automobile Travel

During the first half of the Twentieth Century, automobiles became faster, more reliable, comfortable and affordable. The Ford Model T, the first mass-produced car, had a 45 mph top speed. Priced at $850 when initially sold in 1908, by the 1920s the price had declined below $300, equivalent to a reduction from $22,000 to $5,000 in current dollars.[16] The Model A, produced from 1927 through 1931, had a 65 mph top speed, with prices starting at $385. Over time automobiles improved with features such as automatic transmissions, quieter operation, air conditioning, sound systems, sophisticated information networks, and even heated and cooled cupholders. Although new vehicle prices increased, there were plenty of inexpensive used cars. Roadways also improved, with more pavement and higher design speeds, as indicated below. This further increased traffic speeds and reduced vehicle operating costs.

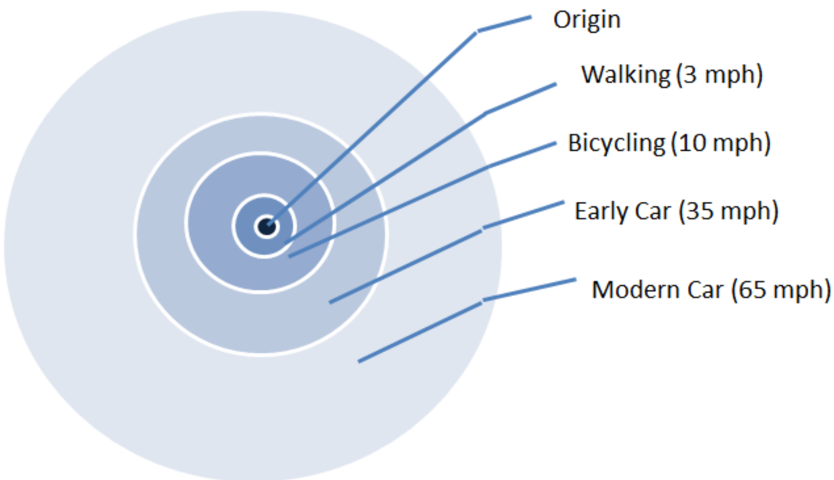
Exhibit 5 **U.S. Roadway Miles**[17]



During the last century most roads were paved. Starting in 1956, the U.S. Interstate Highway program developed a network of high-speed highways that significantly increased vehicle travel speeds.

These improvements significantly increased the distance that motorists could travel within their time and money budgets, and therefore the activities and destinations they could access. In a theoretical world, with unconstrained travel and evenly distributed destinations, accessibility can be measured as the area of a circle, using the formula πR^2. For example, assuming a 20-minute maximum one-way commute, a 3 mile per hour (mph) walker can access jobs in a 3.14 square mile area, a 10 mph bicyclist can access 314 square miles, a motorist driving at 35 mph can access 3,848 square miles, and a 65 mph motorist can access 13,273 square miles of jobs, as illustrated below.

Exhibit 6 **Theoretical Area Accessible by Various Modes**

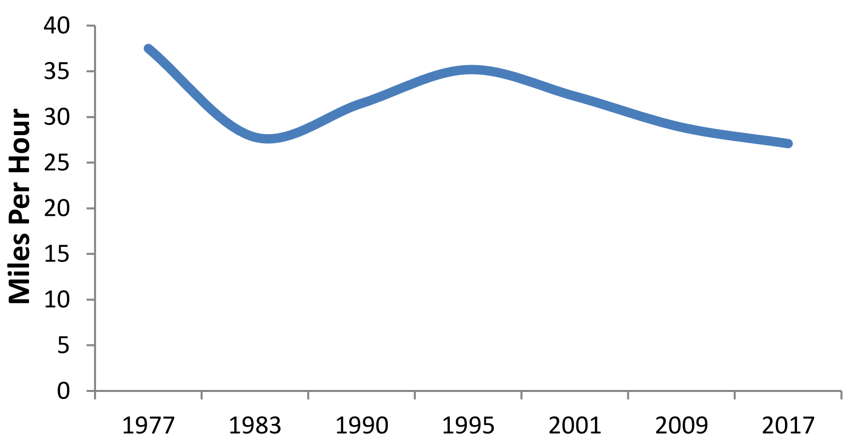


Faster travel can significantly increase the area that can be reached in a given time period, although in real world conditions, faster modes are often constrained by congestion and the need to find parking.

Of course, in real conditions, vehicles are limited to specified routes, jobs tend to cluster in certain commercial districts, and motorists must spend time searching for parking. As a result, having a car *capable* of 65 mph does not really provide access to 4,227 times as many jobs as walking.

Factors that increased vehicle travel speeds eventually reached their practical limits. Higher speeds increased infrastructure costs, crash risks and environmental impacts. Growing vehicle traffic caused congestion to increase, first in cities and eventually in suburban areas. Although highway programs expanded roadway capacity in the 1950 and 1960s, funding and public support were inadequate to meet the growing demand. Starting in the 1970s, many communities experienced highway "revolts" which stopped planned highway expansions.[18] Some communities established vehicle travel reduction targets, and many apply multi-modal planning and demand management solutions instead of roadway expansions.[19] Complete Streets policies,[20] road diets,[21] and even highway removals[22] are increasingly common. As a result, traffic speeds peaked in the 1970s, and subsequently declined as illustrated below.

Exhibit 7 **Average Automobile Commute Speed**[23]

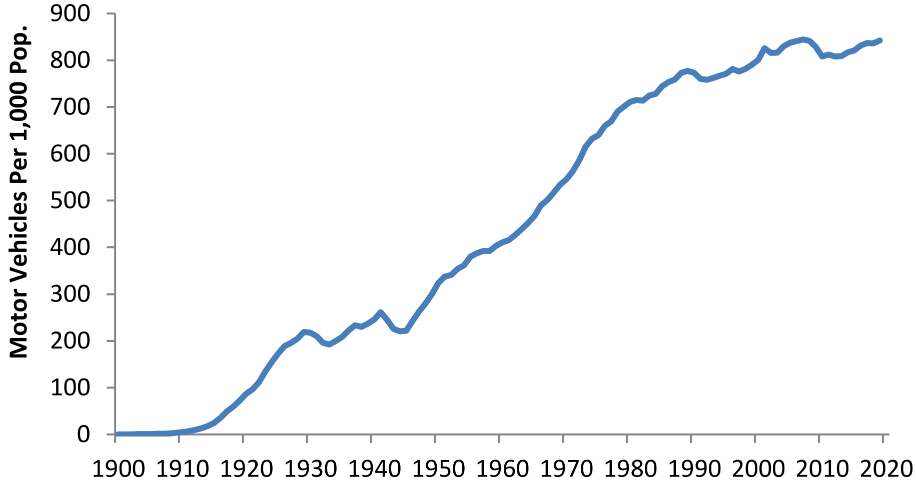


According to the U.S. National Household Travel Survey, average automobile commute speeds declined about 30% between 1970 and 2017.

Summary of Travel Changes

The figures below show changes in per-capita travel miles during the last 120 years. In the U.S., per capita motor vehicle ownership grew during the Twentieth Century but peaked at 0.79 vehicles per capita in 2007. This is significantly higher than most peer countries.

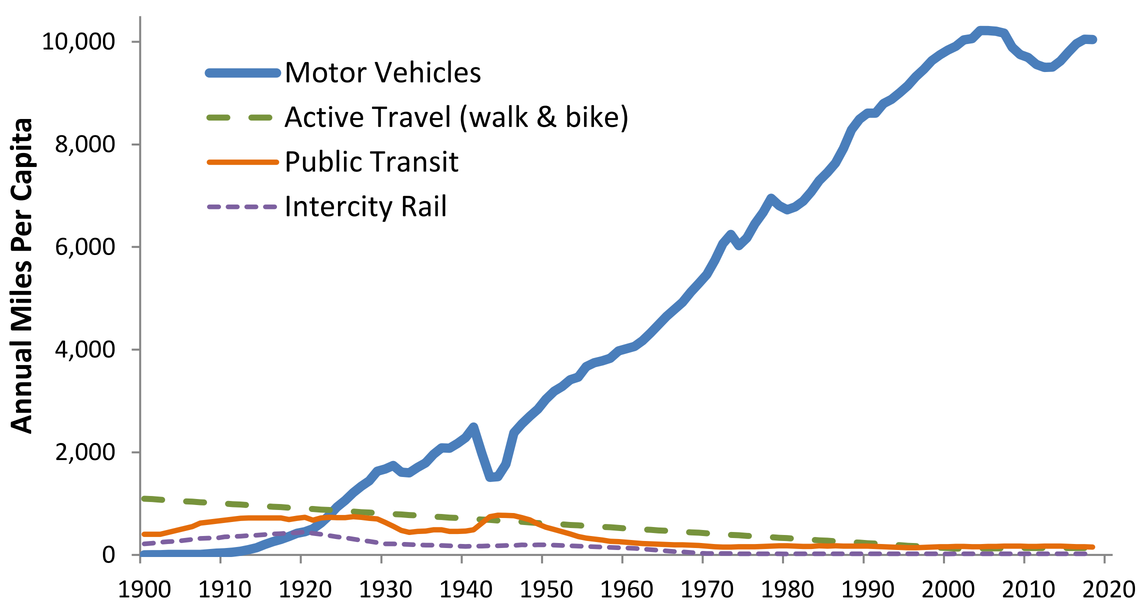
Exhibit 8 **US. Vehicle Ownership Growth**[24]



Per capita vehicle ownership grew during most of the Twentieth Century but peaked early in the Twenty First Century and is unlikely to increase.

In the pre-automobile period, people relied primarily on active travel, and so walked and biked three to four miles per day.[25] Rail and public transit passenger-miles peaked around 1920. Motor vehicle ownership and travel increased steadily, from virtually zero in 1900 to approximately 10,000 annual miles per capita in 2000, increasing personal mobility by an order of magnitude. However, vehicle travel peaked in most developed countries early in the Twenty First Century and is likely to decline in the future due to demographic, economic and technical trends.[26, 27]

Exhibit 9 **Travel Trends: Estimated Annual Passenger-Miles by Mode**[28]



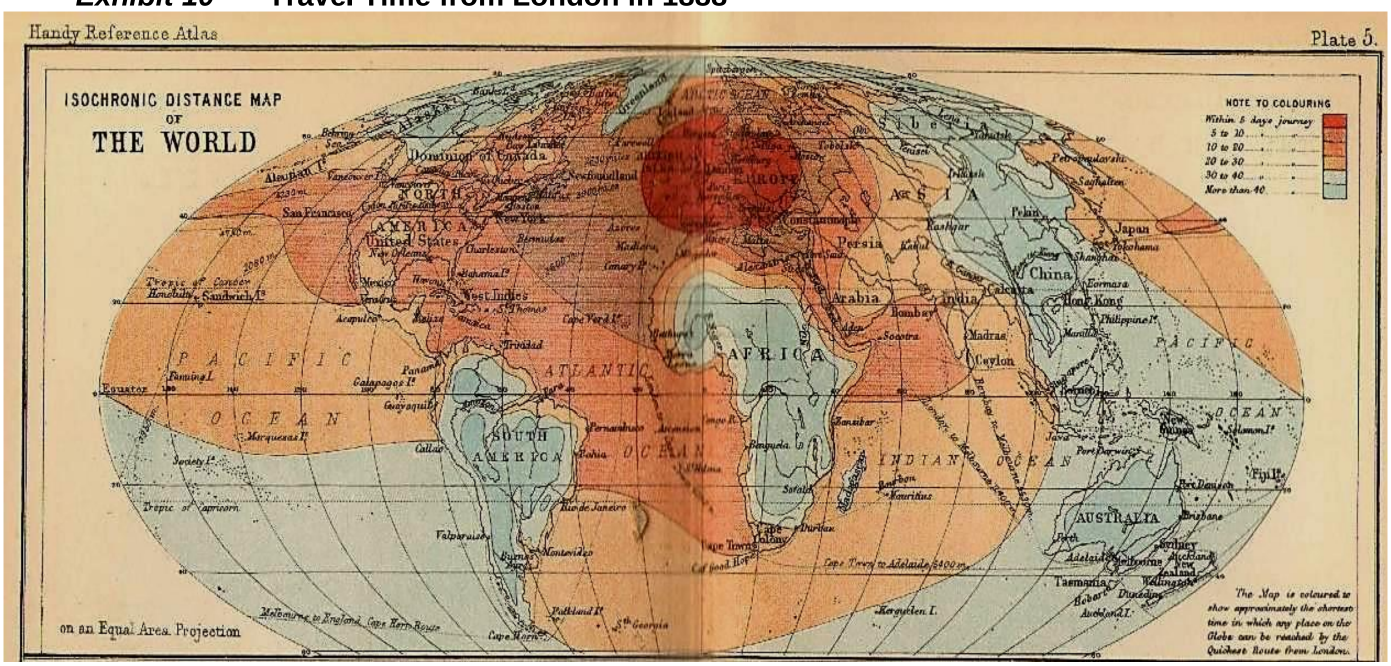
Before 1900 people travelled primarily by walking, with occasional bicycle and rail trips. Per capita motor vehicle travel grew steadily but peaked early in the Twenty First Century.

Long-Distance Travel

During the last two centuries there were also tremendous increases in long-distance travel speed and affordability.[29] Let's put this into perspective by examining an old map.

I collect old world atlases. Below is one of my favorite maps, from an 1888 *Atlas of the World*. The colors indicate the time required to travel from London to destinations around the world, measured in days. For example, at that time it was possible to reach most of Western Europe within five days, New York in five to ten days, and the west coast of North America and Africa, within 10-20 days, but to reach central Africa, Australia and much of Asia required 40 or more travel days. It is now surprisingly accurate if the units are changed from days to hours. For example, travel from London to New York now requires five to ten hours, and to isolated areas in Africa or Australia often takes 20-40 hours including time required to reach airports, clear security and customs, make connections, and travel overland to destinations. This indicates that international travel speeds have increased about *24 times*.

Exhibit 10 **Travel Time from London in 1888**[30]

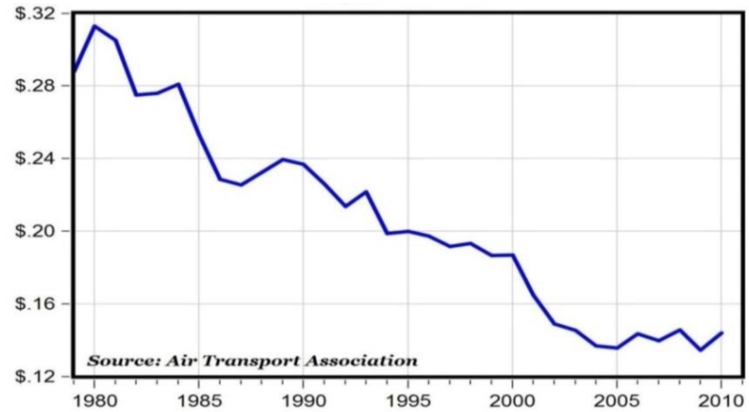


This 1888 map shows travel times from London to destinations around the world. Although originally measured in days, it is now approximately correct if measured in hours, indicating that travel speeds increased about 24 times.

Financial costs also declined significantly. At the start of the Twentieth Century, a trip between London and New York cost about $100, equivalent to about $2,500 in current dollars.[31] In the 1920s, a New York to Los Angeles train trip cost about $120, equivalent to about $2,000 in current dollars.[32] Since then, air travel has significantly reduced long-distance travel time and financial costs.

The first airplane flew in 1903, and by the 1920s, scheduled airmail services were established. Starting in the 1930s, airlines carried passenger between major cities. In the 1940's, flying across the United States cost the current equivalent of $4,500 and took more than 15 hours.[33] air travel subsequently became much faster, cheaper and safer. Airfares declined 50% between 1979 and 2011, as illustrated below.

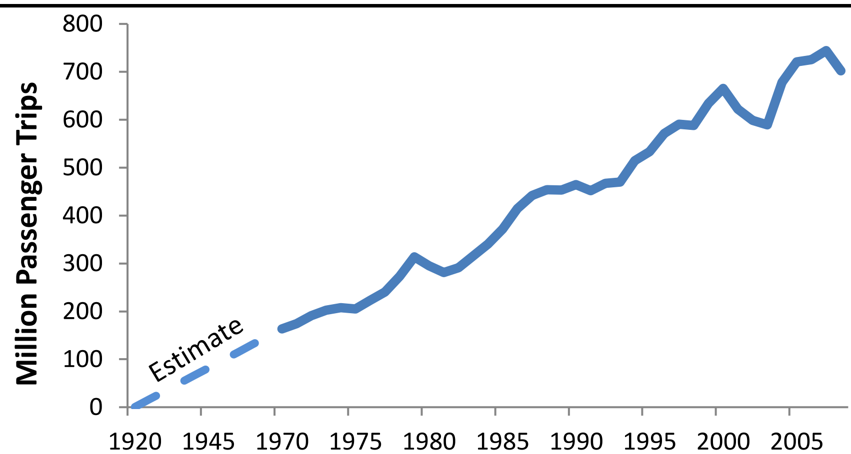
Exhibit 11 **Air Travel: Real Cost Per Mile 1979 to 2011**[34]



Technological innovations and increased competition reduced airfare prices.

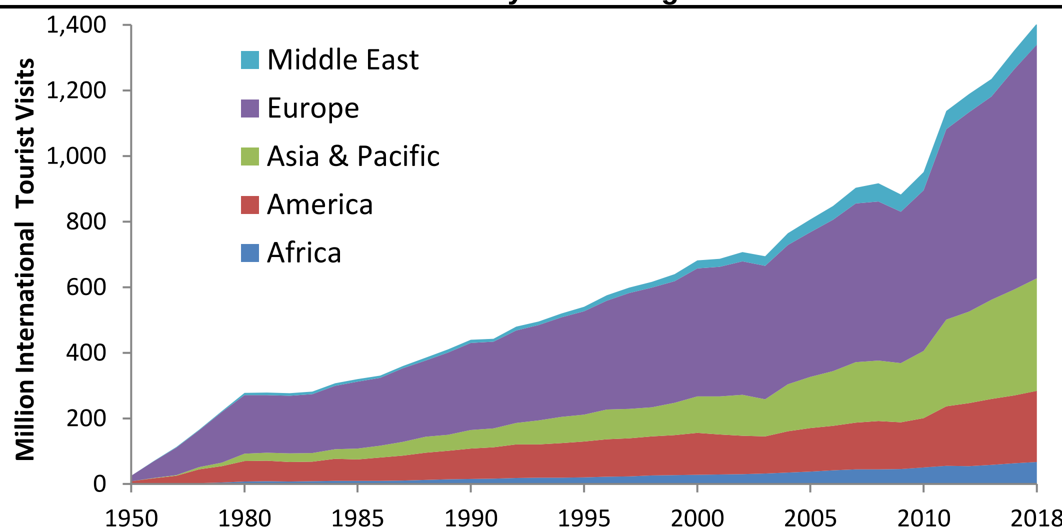
Faster and cheaper travel stimulated air travel and tourism, as illustrated below.

Exhibit 12 **US Air Travel**[35]



Air travel grew steadily during the last half-century due to increased speed and lower fares. However, these growth trends will not necessarily continue due to new security, health and environmental concerns. Although long-distance travel may increase with global economic growth, the growth rate may decline due to countervailing forces

Exhibit 13 **International Tourism by World Region**[36]



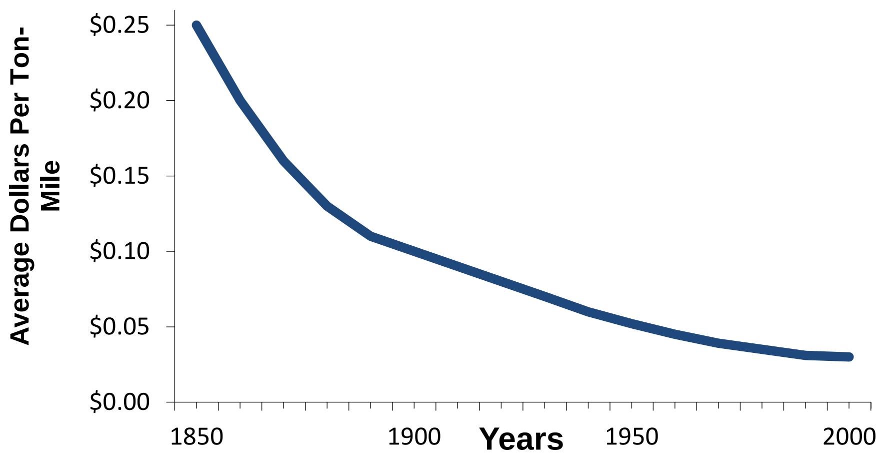
Lower airfares caused huge increases in international tourism.

However, such rapid growth rates will not necessarily continue. Air travel speeds have not increased since the 1960s, and economy-class air travel became less convenient and comfortable to reduce costs and accommodate new security, health and environmental requirements. Maximum commercial aviation speeds declined after Concorde supersonic jet service ended in 2003. Although long-distance travel will probably increase with global population and economic growth, the rate of growth may decline due to these forces.

Freight Transport

Transportation innovations significantly improved freight transport speed, affordability and reliability. At the start of the Twentieth Century, horse-drawn wagons, railroads and steam ships transported freight. Improved railroads, steamships, automobiles, trucks and airplanes, plus logistical improvements such as containerization, significantly reduced shipping costs, as illustrated below.

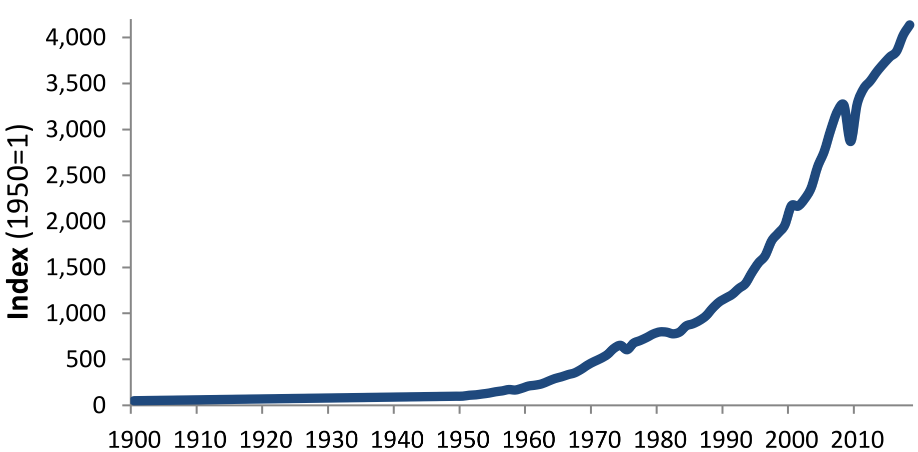
Exhibit 14 **Railroad Freight Costs**[37]



Shipping costs per ton-mile declined significantly during the last 150 years.

As a result of declining costs and increasing demand, freight volumes grew immensely during the last century, as shown below.[38] Freight transport represents about 10% of vehicle travel and more than a third of transport fuel consumption and emissions.[39]

Exhibit 15 **International Freight Volumes**[40]



World trade volumes increased about 100 times during the last 120 years.

Impacts on Accessibility

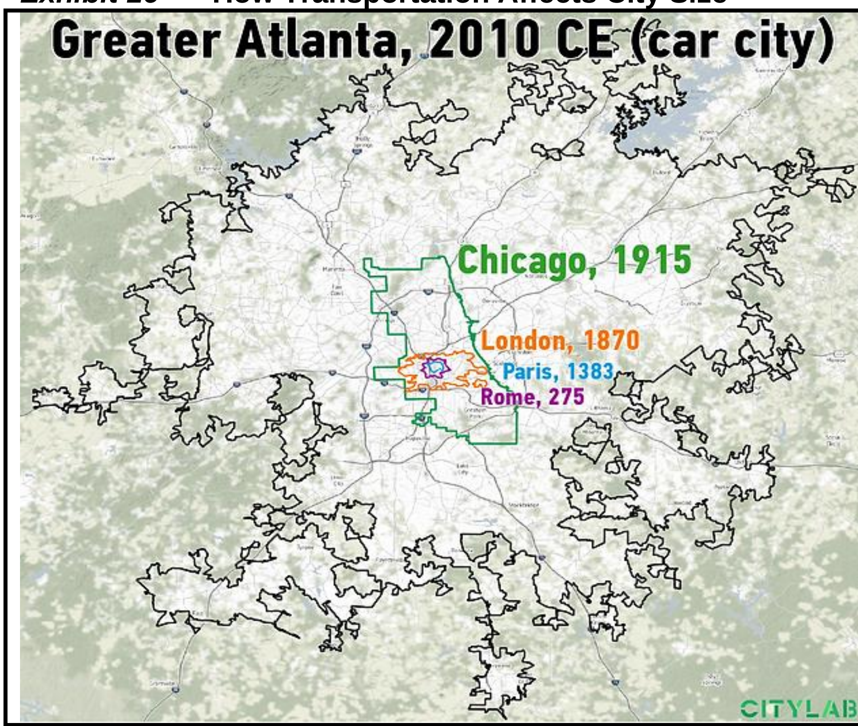
Accessibility (or *access*) refers to people's overall ability to reach desired services and activities.[41] Several factors can affect this accessibility:[42]

- *Mobility.* The ease of physical movement, and therefore the quality (availability, frequency, speed, comfort, etc.) of travel modes (walking, bicycling, taxies, public transport, air travel, etc.).
- *Proximity*. The distances between destinations, and therefore land use development factors such as development density and mix, which affect these distances.
- *Transportation system connectivity*. This includes the density of sidewalk, road and public transit networks, and the quality of connections between modes, such as transit connections to airports.
- *Affordability.* This refers to the financial costs of travel relative to users' income.
- *Convenience*. The ease of obtaining travel information, paying fares and carrying luggage.
- *Social acceptability.* The ability to use a mode sometimes depends on its social status.

In 1900, most people lived in small towns or city neighborhoods where business districts were easily accessible by walking and bicycling, often connected by rail transit. Large employers, such as mills, mines and factories, often provided worker housing. In agricultural areas, a standard township is six miles square, so most farms were within three miles of a town. As a result, most workers could access jobs, most customers could access services, and most children could access schools by foot, bicycle or horse.

As new, faster modes developed, cities expanded, as illustrated below.

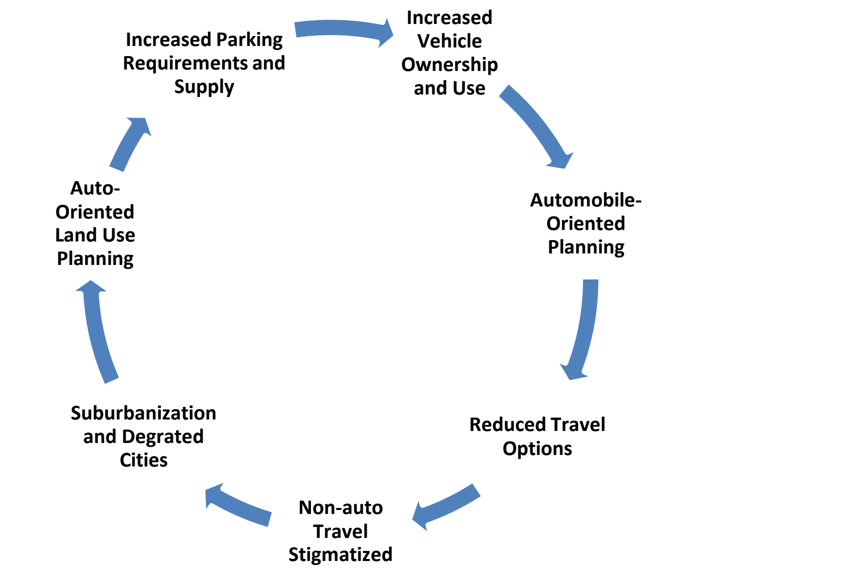
Exhibit 16 **How Transportation Affects City Size**[43]



Ancient Rome and Paris were compact walking cities. London and Chicago expanded along rail lines, with walkable, transit-oriented neighborhoods. Greater Atlanta is a sprawled, automobile dependent city where it is difficult to live without a car.

A cycle of automobile dependency and sprawl developed during the Twentieth Century, as illustrated below. *Automobile dependency* refers to situations in which automobiles are the dominant travel mode and it is difficult to get around without a personal vehicle.[44] *Sprawl* refers to dispersed, automobile-oriented development patterns.[45] This forced people to drive more than they would choose if given better mobility options and more accessible development patterns.

Exhibit 17 Cycle of Automobile Dependency



Many common planning practices contributed to a cycle of automobile dependency and sprawl, which created communities where it is difficult to get around without a personal automobile.

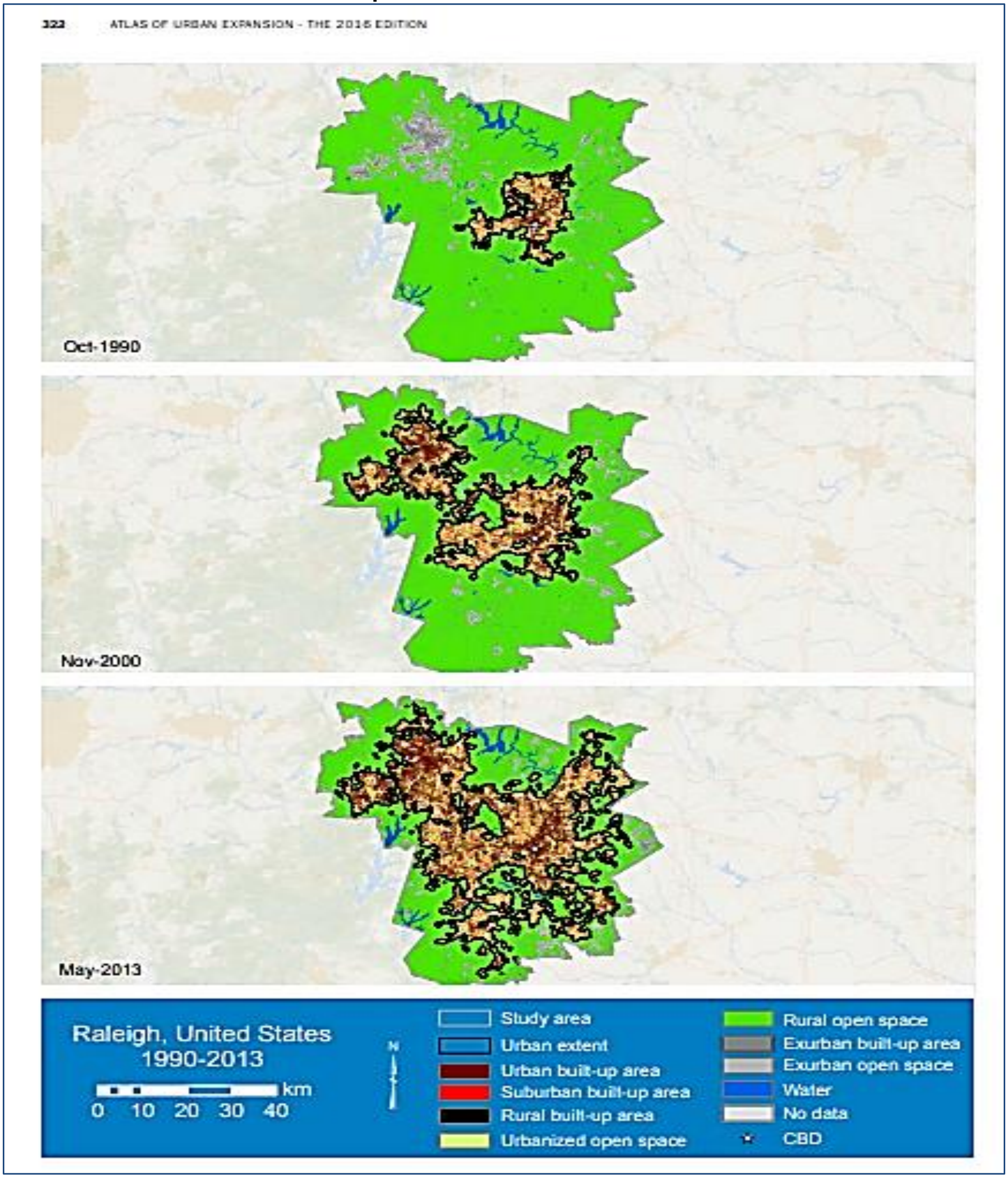
In a traditional community, most common services and activities – shops, schools, restaurants, parks and public transit services[46] – are located within walking distance, creating *15-minute neighborhoods*.[47] Most communities built before 1950 planning reflected these features, providing a high level of accessibility to non-drivers. Many communities built after 1950 are automobile-dependent and sprawled. The table below contrasts these development patterns. This trend was compounded by "white flight," which caused many households to move to automobile-dependent suburbs for the sake of status and perceived security, despite reduced accessibility and higher transportation costs.[48] This greatly reduce non-drivers' accessibility and freedom, and impose chauffeuring burdens on motorists.[49]

Exhibit 18 Traditional versus Automobile-Dependent Community Design

Traditional Communities	Automobile-Dependent Communities
• Compact development	• Sprawled, low-density development
• Mixed residential and commercial	• Residential and commercial activities separated
• Neighborhood scale commercial districts	• Regional scale commercial districts
• Streets designed for low traffic speeds	• Streets designed for higher traffic speeds
• Sidewalks and crosswalks on most streets	• Many streets lack sidewalks and crosswalks
• Public transit services link neighborhoods	• Little or no public transit services
• Limited off-street parking	• Abundant off-street parking
• Neighborhood schools and parks	• Regional schools and parks, required vehicle travel

Traditional communities have features that maximize multi-modal accessibility. Communities built after 1950 tend to be automobile-dependent, which reduces mobility options and increases the need to drive.

Exhibit 19 **1990-2013 Urban Expansion**[50]



This figure from the "[Atlas of Urban Expansion](#)" shows development patterns of 200 urban regions during the last three decades. This example shows how Raleigh, North Carolina expanded at low densities along major highways at the urban fringe, creating automobile-dependent communities.

Many transportation policies favor automobile travel over other modes and sprawl over compact development, as summarized in the box below. Most decision-makers, including elected officials, planners and engineers, were busy professionals who themselves experienced the benefits of increased automobile travel, while the people most harmed by the decline in non-auto modes – women, children, people who were poor or had mobility impairments – had less political influence.

Exhibit 20 Ten Common Policies that Increase Automobile Dependency and Sprawl[51, 52, 53]

1. Transportation planning that prioritizes speed over other goals (affordability, equity, public health, environmental quality, etc.), and therefore automobile travel more affordable and efficient modes.
2. Roadway design that favors automobile traffic over other modes.
3. Zoning codes that limit density and compact housing types, and mandate abundant parking.
4. Development policies that favor urban expansion over compact infill.
5. Public facilities (schools, post offices, courts, etc.) located to maximize automobile access.
6. Dedicated roadway funding that cannot be used for other modes or TDM strategies, even if they are more cost effective and beneficial overall.
7. Unpriced or low-priced roads and parking facilities, and fixed insurance and registration fees.
8. Fuel production subsidies and low fuel taxes.
9. Transportation planning that undercounts, overlooks and undervalues non-auto travel.
10. Travel models that ignore induced travel impacts, which exaggerates roadway expansion benefits.

Many common public policies and planning practices encourage automobile dependency and sprawl, which reduces non-auto access and results in economically-inefficient levels of automobile travel.

Many of these practices violate economic principles – they fail to respond to consumer demands for non-auto travel and underprice automobile travel – resulting in an economically inefficient and unfair transportation system.[54, 55] A rich vocabulary exists for describing *overpricing*; we say that consumers are "gouged," "gypped," and "fleeced," but there are no comparable words to describe *underpricing* although it is equally harmful and unfair, since it distorts consumption and requires often-regressive subsidies. For example, underpriced parking increases parking demand and total parking facility costs, which are incorporated into property taxes, rents and retail prices, which consumers pay regardless of how much parking they use, and since vehicle travel increases with income, this tends to be regressive.

Although these pro-auto and pro-sprawl policies may individually seem justified, their impacts are cumulative and synergistic, resulting in communities where it is difficult to get around without a personal vehicle. For example, underpriced parking causes people to own more vehicles, drive more, spend more money on transportation, and impose more external costs than they would choose with more efficient pricing.[56] High levels of automobile travel squeezes out other mobility options, which harms non-drivers and increases many economic, social and environmental costs.[57]

The decline of public transit service is sometimes blamed on a nefarious automobile industry plan to replace trolleys with less comfortable bus systems in U.S. cities; for this conspiracy, General Motors, Firestone Tire, Standard Oil and other companies were convicted and fined $5,000 in 1949.[58] However, by the time these events occurred, transit service was already in decline due to previously described policies that favored automobile travel and sprawled development.[59]

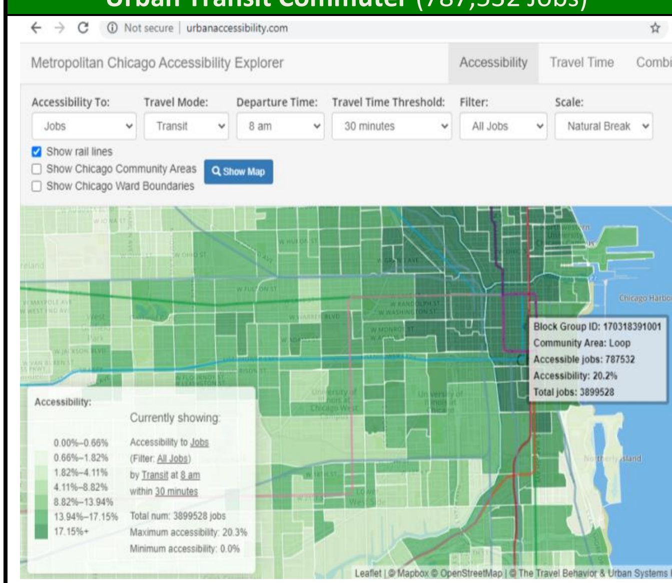
Policy makers and the general public eventually recognized the need for public transit. In 1964 the U.S. government established the Urban Mass Transportation Administration (later renamed the Federal Transit Administration) which provides technical assistance and funding to local transit agencies. Several recent trends are starting to make communities more multi-modal:

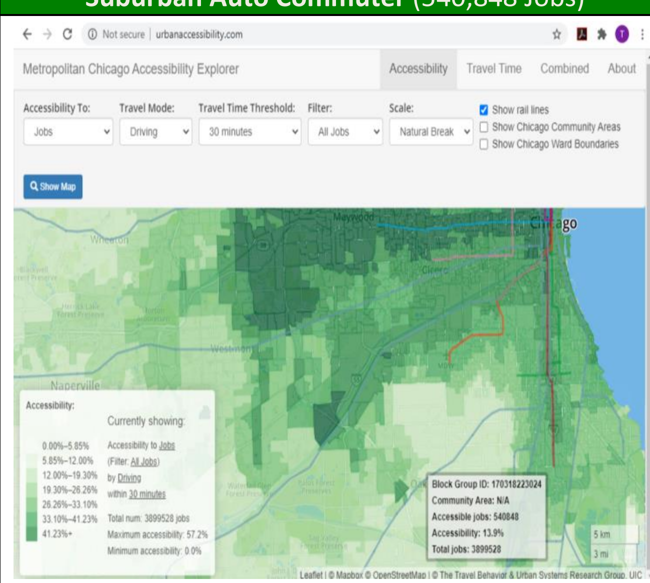
- Urban crime rates declined significantly, making cities more attractive.[60]
- Increased traffic congestion and sprawl reduced suburban accessibility and quality of life.
- Increased appreciation of urban economic productivity and quality of life advantages, and changing consumer preferences, made many households and businesses prefer central city locations.[61]
- Many governments started to apply more multi-modal transportation planning and funding, complete streets roadway design practices, pedestrian and bicycle planning, and various transportation demand management programs.[62, 63]
- Development movements, called *New Urbanism*, *Smart Growth*, or *Transit-Oriented Development* are creating more compact, multi-modal communities.[64]

As a result, the disparity between drivers and non-drivers has probably peaked in many areas. Although in most communities, motorists can access an order-of-magnitude more activities (jobs, schools, stores, etc.) than non-drivers,[65] some urban neighborhoods provide accessibility for non-drivers that is comparable to suburban motorists, with lower financial costs. For example, the figures below show that Chicago residents can access more jobs by public transit than suburban residents (e.g., Wheaton, Oak Lawn and Naperville) can access by car, and since cities tend to have higher wages and more diverse employment opportunities, central neighborhoods offer better economic opportunities overall. As a result, economic opportunity, increasingly depends on households' ability to find appropriate housing in an accessible urban neighborhood. Lower-income households that can find affordable housing in such areas tend to be more economically successful.[66]

Exhibit 21 **Comparing Urban Transit and Suburban Auto 30-Minute Job Access**[67]

Urban Transit Commuter (787,532 Jobs)	**Suburban Auto Commuter** (540,848 Jobs)





The "Urban Accessibility Explorer" shows that urban non-drivers often have better access than suburban motorists.

This analysis indicates that during the last 120 years, motor vehicle accessibility increased significantly, due to vehicle improvements and automobile-oriented planning, while non-auto accessibility declined due to degraded walking conditions, reduced public transport services, reduced roadway connectivity, and sprawled development. This created large disparities between motorists and non-drivers. A new planning paradigm is changing many of these practices, but progress is slow and variable, with better multi-modal access in some communities than others.[68] The following table summarizes these changes.

Exhibit 22 **Changes in Accessibility**

Factor	1900-2020 Changes
Automobile travel	Vehicle and roadway improvements significantly increased automobile travel speeds and reduced unit costs.
Automobile parking	Government-supplied and -mandated parking facilities increased automobile parking convenience and affordability.
Walkability	Fewer streets have sidewalks. Wider roads and increased traffic degraded walking conditions (called the *barrier effect*). Since 2000 many communities have started to improve walkability.
Bikability	Increased vehicle traffic degraded bicycling conditions. In recent years, many communities have started to improve bicycling conditions.
Public transit access	Public transit service improved 1900-1940, declined significantly 1940-1990, and has improved somewhat since.
Roadway connectivity	Before 1950 most neighborhoods were designed with dense street networks. 1950-2000 hierarchical roadway planning reduced connectivity. Since 2000, transportation planners have encouraged more connected roadway designs.
Local access	Most pre-1950 neighborhoods had good walkability plus mixed development so most commonly used services and activities (shops, schools, parks, public transit, etc.) were easy to reach without a car. After 1950, most new developments were automobile-oriented, with poor neighborhood accessibility.
Regional access	Pre-1950 most regional services and activities (major commercial, recreational and employment centers) where located in downtowns or other major activity centers with good transit access. After 1950, major regional services and activities were located along major roadways at the urban fringe where automobile access is convenient but transit access is poor.
Long distance travel	During the Twentieth Century, long distance travel became faster and cheaper, first as train service improved, and after 1950 as intercity highways and air travel developed and became affordable. After 1950, intercity bus and train service declined, reducing accessibility for moderate-distance (50-400 mile) travel without a car.
Mobility Substitutes	During the Twentieth Century, all types of mobility substitutes improved including fax, Internet and delivery services.
User information	Transportation information improved modestly during the Twentieth Century, and significantly during the Twenty-First Century with Internet and mobile telephone services.
Social status	During the last half of the Twentieth Century, non-auto modes tended to be stigmatized. In recent years, walking, bicycling and public transit gained social status in some communities.

This table summarizes how various accessibility factors changed during the last 120 years.

Economic, Social and Environmental Impacts

This section examines the various economic, social and environmental impacts of the increased motor vehicle travel that occurred during the last 120 years.

User Costs

When walking was the primary travel mode, the primary user expense was shoe leather. Horse, carriage, boat and train travel were expensive and seldom used for personal travel. In the late Nineteenth Century, bicycles became affordable. Many cities developed trolley networks which typically cost 5₵ per trip when most workers earned one to three dollars per day, so a round-trip trolley commute represented just 3-10% of most workers' income.[69] A 1901 survey of workingmen's families' expenditures had no category for transportation (see below), indicating that mobility costs were insignificant for most moderate-income families.

Exhibit 23 **Average Expenditure of 2,567 Workingmen's Families**[70]

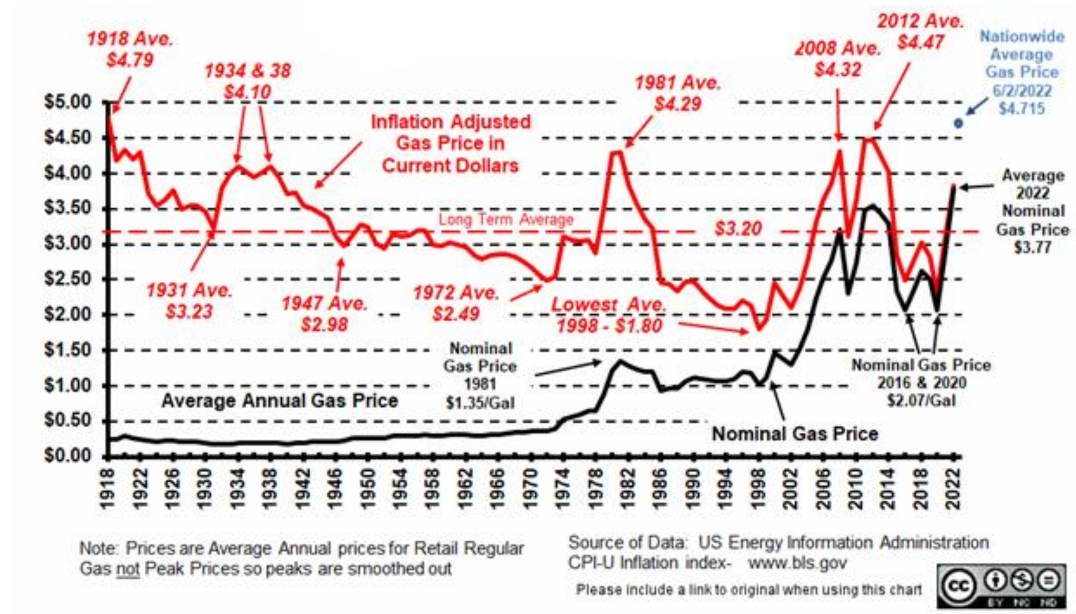
AVERAGE EXPENDITURE OF 2,567 WORKINGMEN'S FAMILIES FOR EACH OF THE PRINCIPAL ITEMS ENTERING INTO COST OF LIVING, AND PER CENT OF AVERAGE TOTAL EXPENDITURE, 1901.

Items of expenditure.	Expenditure based on all families.	
	Average.	Per cent of total expenditure.
Food	$326.90	42.54
Rent	99.49	12.95
Mortgage:		
Principal	a 8.15	1.06
Interest	b 3.98	.52
Fuel	32.23	4.19
Lighting	8.15	1.06
Clothing:		
Husband	33.73	4.39
Wife	26.03	3.39
Children	48.08	6.26
Taxes	5.79	.75
Insurance:		
Property	1.53	.20
Life	19.44	2.53
Organizations:		
Labor	3.87	.50
Other	5.18	.67
Religious purposes	7.62	.99
Charity	2.39	.31
Furniture and utensils	26.31	3.42
Books and newspapers	8.35	1.09
Amusements and vacation	12.28	1.60
Intoxicating liquors	12.44	1.62
Tobacco	10.93	1.42
Sickness and death	20.54	2.67
Other purposes	45.13	5.87
Total	768.54	100.00

A 1901 household expenditure survey had no category for transportation, indicating that prior to the automobile age, transportation expenses were insignificant for most families.

During the Twentieth Century, vehicle operating costs declined as vehicles became more durable, fuel economy improved and fuel became cheaper. Between 1930 and 1999, inflation-adjusted gasoline prices declined 30%, from $2.30 to $1.60, as illustrated below.

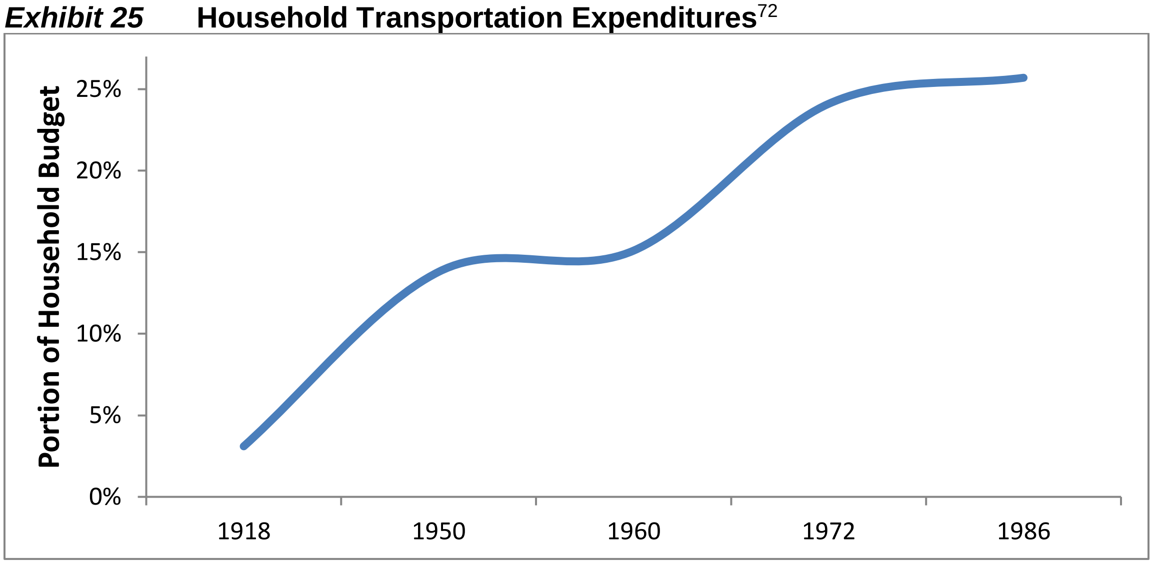
Figure 24 **Average Fuel Prices** (Inflation Data, 2022)



Real fuel prices declined and fuel efficiency increased during most of the Twentieth Century, making driving cheaper, but have started to increase.

These fuel price declines were more than offset by increased vehicle ownership costs and more vehicle travel. As a result, the portion of household budgets devoted to transportation increased substantially, from under 5% in 1918 to more than 20% in 1986, as indicated in the following graph.[71]

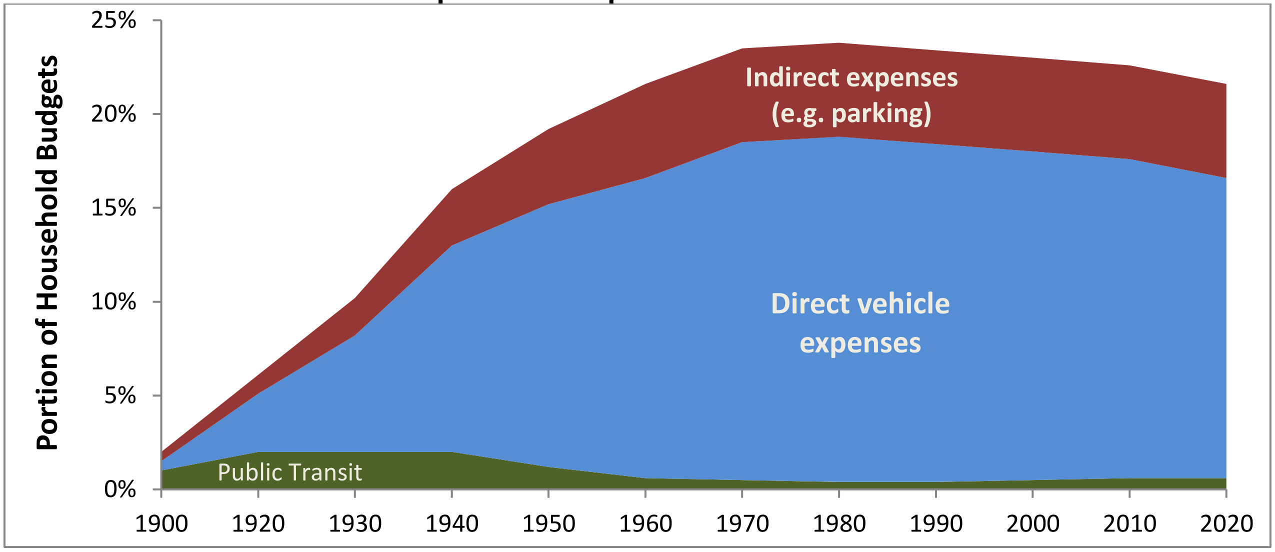
Exhibit 25 **Household Transportation Expenditures**[72]



Household transportation expenses increased significantly as motor vehicle travel grew.

Typical households now spend 16-18% of their budgets on transportation.[73] Vehicle travel also imposes indirect expenses such as residential parking and local taxes spent on roadways, which typically add 10-20% to housing costs.[74] The figure below illustrates estimated household transport costs trends.

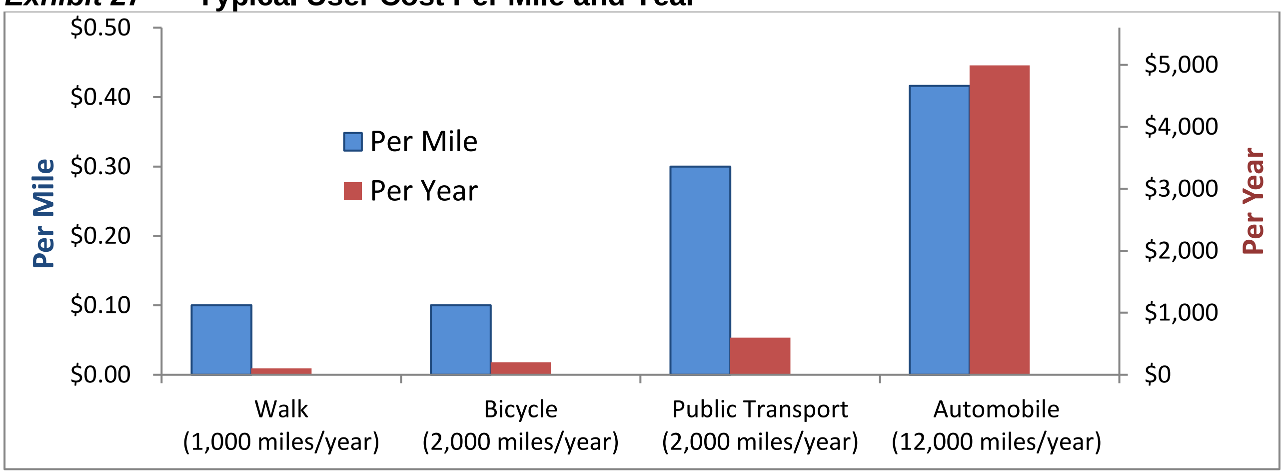
Exhibit 26 **Household Transportation Expenditures**[75]



Household transportation expenses increased significantly as motor vehicle travel grew.

What explains this huge growth in transportation expenses? The figure below compares the user costs of various modes. Walking and bicycling are the most affordable. Public transit and automobile travel have moderate costs per passenger-mile, but automobile travel has the highest annual costs due to the high annual vehicle-miles. Automobile travel provides benefits that may justify some additional transportation spending, but public policies that favored automobile travel over cheaper modes seem to have caused much higher cost increases than what households demand or is economically optimal.[76]

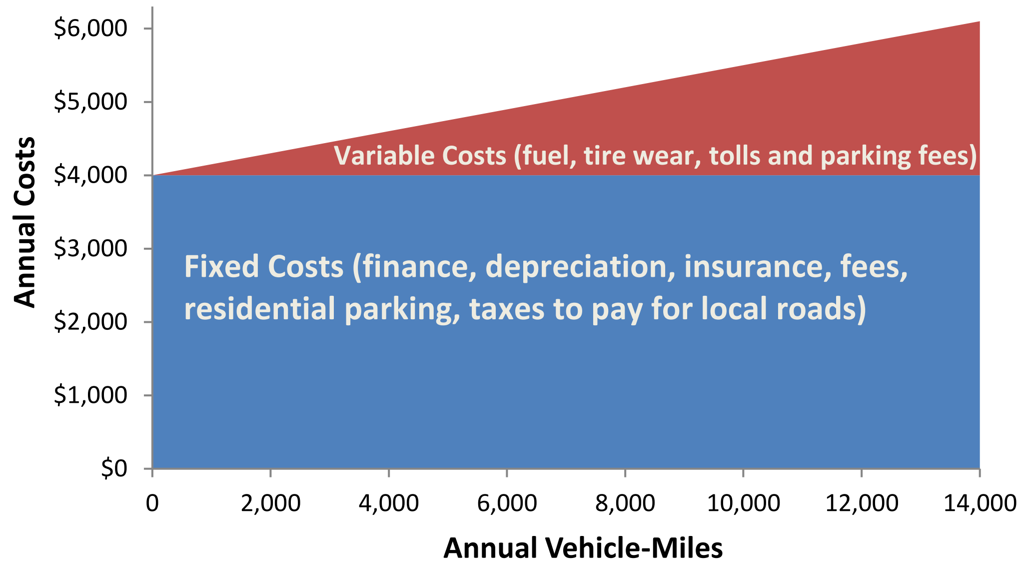
Exhibit 27 **Typical User Cost Per Mile and Year**[77]



Automobile travel tends to be the most expensive travel mode.

Most automobile costs are fixed, not significantly affected by the amount a vehicle is driven, as illustrated below.[78] A marginal reduction in vehicle travel, for example, from 10,000 to 8,000 annual miles, provides little savings. This price structure encourages motorists to maximize their annual mileage in order to get their money's worth from their large investments. Motorists who pay $10 per day in fixed vehicle expenses have little incentive to spend another $5 to ride a bus to work; they may as well drive.

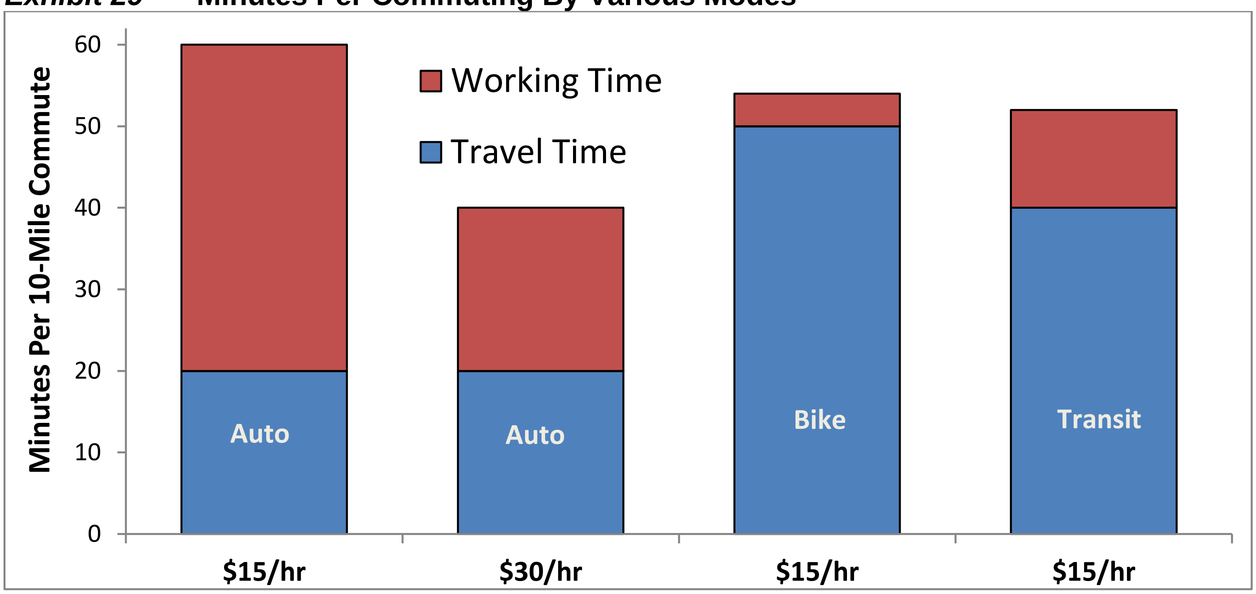
Exhibit 28 **Motor Vehicle Cost Structure**[79]



Most motor vehicle expenses are fixed. This gives motorists an incentive to maximize their mileage in order to get their money's worth, and provides little opportunity to save on transportation costs.

Motorists on average travel about five times as many annual miles and spend about five times as much money on transport than non-drivers.[80] Because of these high costs, automobile travel has relatively low *effective speeds*, measured as travel distance divided by time spent travelling *plus* time spent working for money to pay travel expenses.[81] Effective speeds vary depending on wage rates, vehicle expenses, and annual mileage. The figure below shows the number of minutes spent travelling and earning money for travel expenses for various modes and incomes.

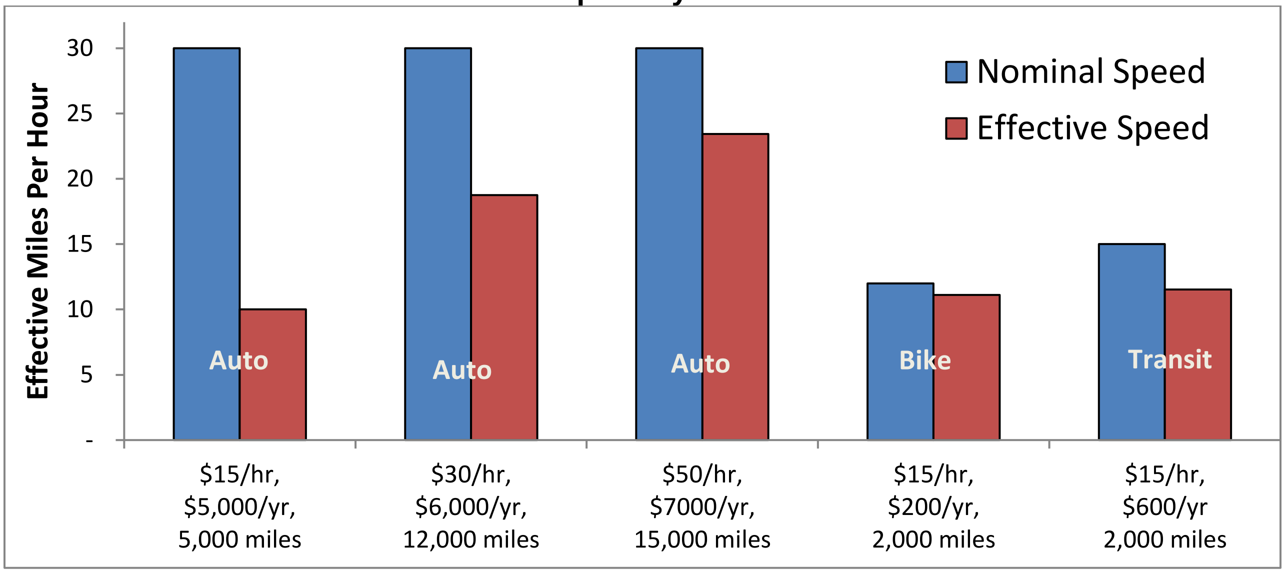
Exhibit 29 **Minutes Per Commuting By Various Modes**[82]



This figure shows effective speed: the time spent travelling and earning money to pay travel expenses, for various modes and incomes. Many lower-wage motorists spend more time earning money to pay their travel expenses than they spend travelling. Bicycling and transit are often faster than driving overall.

Measured by effective speed, automobile travel is regressive; lower-income workers must spend more total time to travel a given distance than higher-income workers. Most lower-wage motorists spend more time earning money to pay vehicle expenses than they do driving. A motorist who earns $15 per hour and spends $5,000 per year on their vehicle must devote about 2.5 hours each workday earning money to pay vehicle expenses. Their effective speed is generally lower than bicycling or public transit travel as illustrated below.

Exhibit 30 **Nominal Versus Effective Speed by Income and Mode**



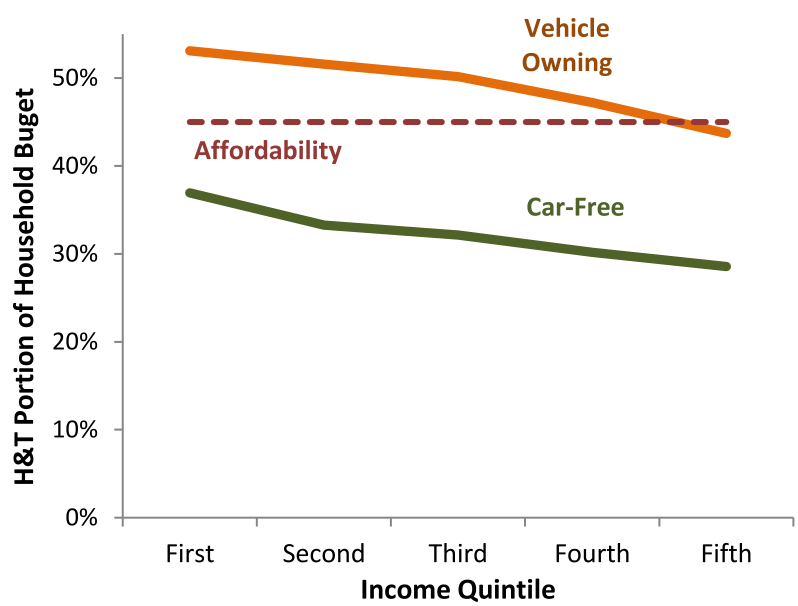
Effective speeds increase with income and are much lower than nominal speeds for lower-income motorists. As a result, policies that favor faster but expensive modes over slower but cheaper modes are regressive. Planning that evaluates transport quality based on nominal rather than effective speeds harms poor people.

Of course, every traveller has unique needs and abilities. Higher income people can afford the higher costs of automobile travel, and some lower-wage workers enjoy driving and have few other financial obligations, and so can afford the high costs of automobile travel. However, many low- and moderate-income households spend more on their vehicles than is affordable. When people say that they cannot afford healthy food, healthcare or education, or to work less and spend more time with their family or other valued activities, the root problem is often excessive motor vehicle expenses. As a result, many lower-income people would be better off if they could choose slower but cheaper travel options.[83]

Automobile-oriented transportation planning reduces affordability in several ways. Vehicle ownership is expensive. Although lower-income households use many strategies to minimize their vehicle expenses, including owning older vehicles, performing their own maintenance when possible, purchasing minimal insurance or driving uninsured, and minimizing their annual mileage, it is difficult to spend less than about $3,500 annually to legally operate a vehicle, even if it is driven few annual miles, and twice that if driven high annual miles. Motorists may spend less than this some years, but automobile travel sometimes incurs large, unpredictable expenses due to vehicle failures, crashes, and traffic citations. In addition, residential parking typically adds more than 10% to housing costs, and more for lower-priced housing.[84]

The figure below shows the vehicle ownership financial burden by income quintile (fifth of households), based on U.S. *Household Expenditure Survey* data. Many experts recommend that affordability be defined as households being able to spend less than 45% of their total budgets on housing and transportation (H&T) combined.[85] The analysis shows that all vehicle-owning households exceed that amount, excepting the highest income quintile, while all car-free households spend significantly less than is considered affordable due to vehicle and residential parking cost savings.

Exhibit 31 Housing and Transportation (H&T) Affordability by Vehicle Ownership[86]



This figure compares the portion of household spending devoted to housing and transportation (H&T) for vehicle owning and car-free households, assuming that housing for car-free households is 10% cheaper than average due to avoided residential parking costs.

Affordability is defined as households being able to spend less than 45% of their budgets on housing and transport combined. Excepting the highest income quintile, all vehicle-owning households spend more, and all car-free households spend much less, than is considered affordable.

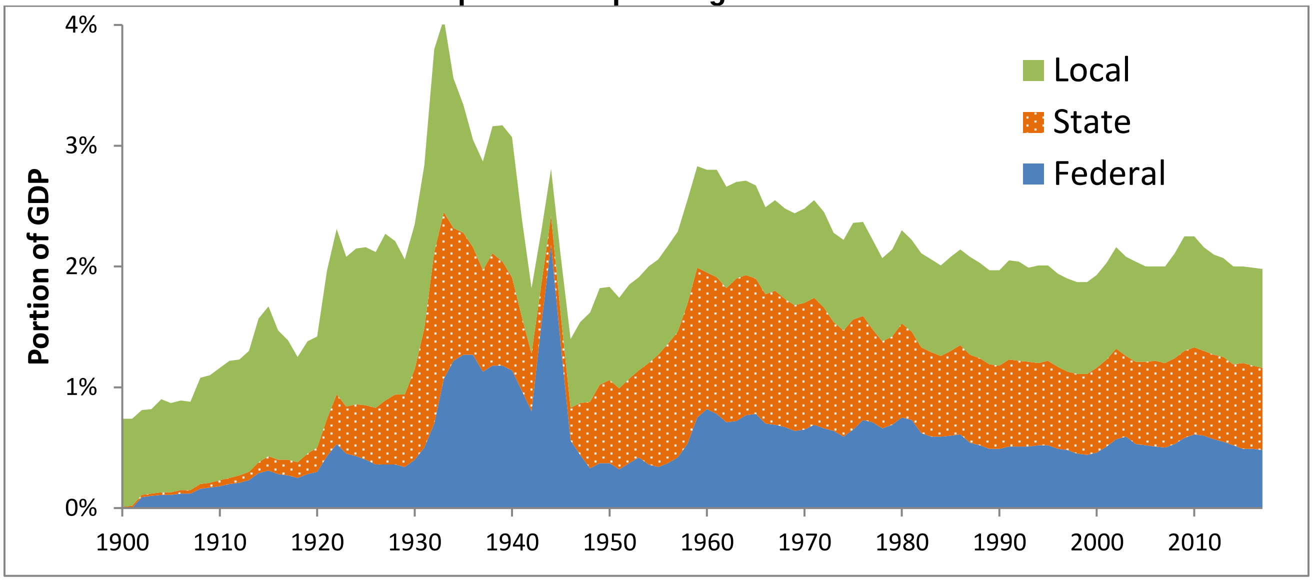
This analysis shows the large financial burden that automobiles impose on lower-income households. This burden is indicated by much lower housing foreclosure rates in more accessible, multi-modal neighborhoods than in automobile-dependent areas, reflecting the greater economic resilience of households that locate where they can minimize their vehicle expenses if needed due to financial shocks.[87] More accessible, multi-modal communities also have significantly greater economic mobility (the chance that children born in low-income families will become economically successful as adults).[88]

Some lower- and moderate-income households may benefit overall from vehicle ownership, which can provide access to better employment and housing options, as well as social and recreational activities. But automobile-dependency is a major economic burden for many households, either because they cannot drive and so have poor access to essential services and activities or spend more than they can afford on vehicles and parking facilities, including occasional large unplanned expenses that create a household financial crisis. During the last century, planning practices that favored faster but more expensive modes over slower but more affordable modes exacerbated these problems.

Infrastructure Costs

When somebody purchases a vehicle, they generally expect governments to provide roadways and businesses to provide parking facilities for their use. As automobile travel increases in a community, so do road and parking facility costs.[89] When vehicle travel increased during the first half of the Twentieth Century, public spending on transportation infrastructure more than doubled, from less than 1% to more than 2% of Gross Domestic Product (GDP), as illustrated below.

Exhibit 32 **Government Transportation Spending Relative to GDP**[90]



During the Twentieth Century, public spending on transportation infrastructure increased from less than 1% to more than 2% of Gross Domestic Product (GDP), due largely to the increased roadway spending.

Many people assume that user charges such as fuel taxes, vehicle registration fees and road tolls cover all roadway costs, but in fact they fund less than half of roadway expenditures in the U.S. The remainder is financed by general taxes that residents pay regardless of how they travel, representing a subsidy from people who drive less than average to those who drive more than average. For example, in 2016, U.S. governments spent $219 billion on roadways, of which $111 billion was funded by user fees, which averaged about $815 per vehicle of which $400 can be considered a subsidy.

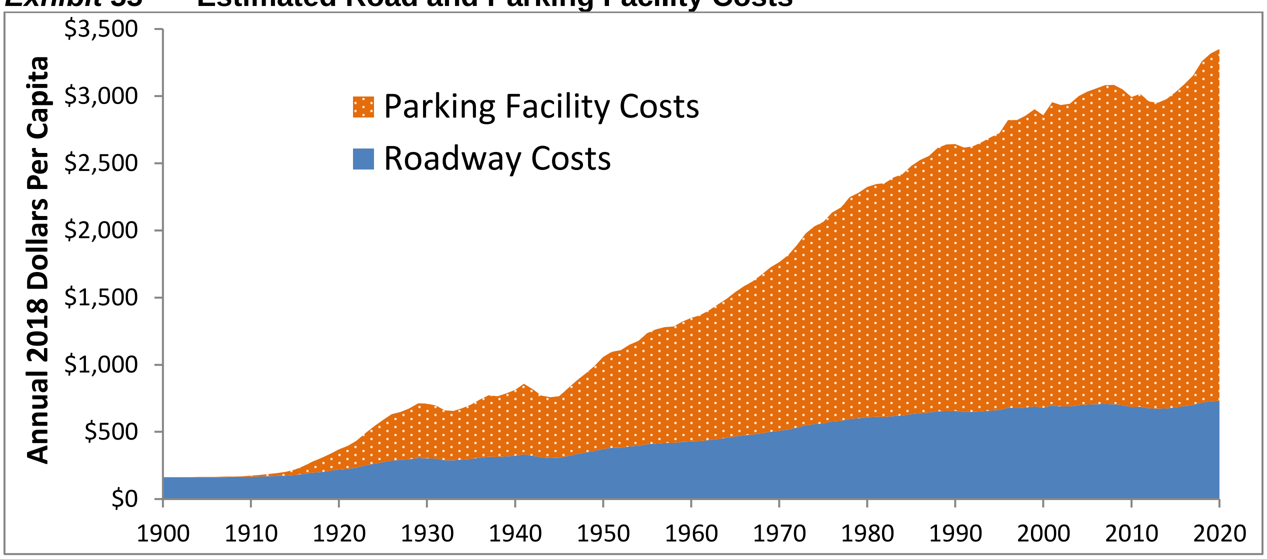
Automobile travel also requires parking at each destination. Most zoning codes mandate that property owners provide parking, typically 1-2 spaces per housing unit and 2-8 spaces per 1,000 square feet of commercial space.[91] Several recent surveys have measured the total effects of these policies.[92] A study by Geography Professor Amélie Y. Davis used detailed aerial photographs to count off-street parking spaces in Illinois, Indiana, Michigan, and Wisconsin.[93] They found approximately three non-residential off-street spaces per vehicle but this is an underestimate because it did not count spaces hidden in parking structures or tree canopies. Other major studies in Los Angeles,[94] Phoenix, [95] New York, Philadelphia, Seattle, De Moines, and Jackson (Wyoming)[96] also indicate that typical North American communities have three to eight government-mandated off-street parking spaces per motor vehicle, with lower rates in urban areas where parking facilities can be shared, and higher rates in suburban and rural areas where each destination must supply all of its own parking.[97]

These facilities are expensive. Constructing a parking space typically costs $2,000-10,000 for surface lots and $20,000-60,000 in structures.[98, 99] Considering land, construction, and operating expenses, the total annualized costs of a parking space ranges from approximately $500 for surface parking on inexpensive land up to $3,000 for structured parking in a prime location. Assuming three to six spaces per vehicle, this averages $2,000-6,000 total annual parking costs per vehicle. Many parking spaces are worth more than the vehicles that occupy them, and most vehicles are worth less than the total value of the numerous spaces provided for their use.

Of course, other modes also require public infrastructure: walking requires sidewalks, bicycling requires paths, and buses require roads, but automobiles require more costly infrastructure per capita, due to their size, weight, speed and distance.[100] A small car driving less than 30 mph can operate safely in a 9-foot lane with 30 foot spacing between vehicles, but a large automobile operating at 65 mph requires a 14-foot lane and 100 foot spacing, about five times as much space, plus more complex intersections and traffic control systems, and motorists travel five times as many annual miles as non-drivers.

The graph below illustrates how per capita vehicle road and parking costs increased since 1900. This indicates that for every dollar motorists spend purchasing a vehicle, somebody must spend more than a dollar for its infrastructure, a matching grant for automobile travel.

Exhibit 33 **Estimated Road and Parking Facility Costs**[101, 102]



As automobile travel increased during the last 120 years, so did road and parking infrastructure costs.

Public transit service grew during the first half of the Twentieth Century but declined significantly after 1950. Transit experiences economies of scale, so as ridership declined, urban streets became more congested and development sprawled, transit became less efficient (costs per passenger-mile increased), and unprofitable. The table below, copied from the 1969-1970 *Transit Fact Book*, shows that the transit industry earned a healthy 10-20% annual profit between 1935 and 1960, but net revenues subsequently declined, and starting in 1968 went into deficit. Transit service quality and cost recovery (portion of costs covered by fares) are much higher in older, transit-oriented cities such as Boston, New York and Chicago than in newer, automobile-oriented cities such as Atlanta, Houston and Nashville, suggesting that automobile-oriented planning reduced public transit efficiency.[103]

Exhibit 34 Transit Industry Profitability Trends[104]

TABLE NO. 1
Results of Transit Operations in the United States
At Five Year Intervals 1935-1955 and Annually 1955-1968

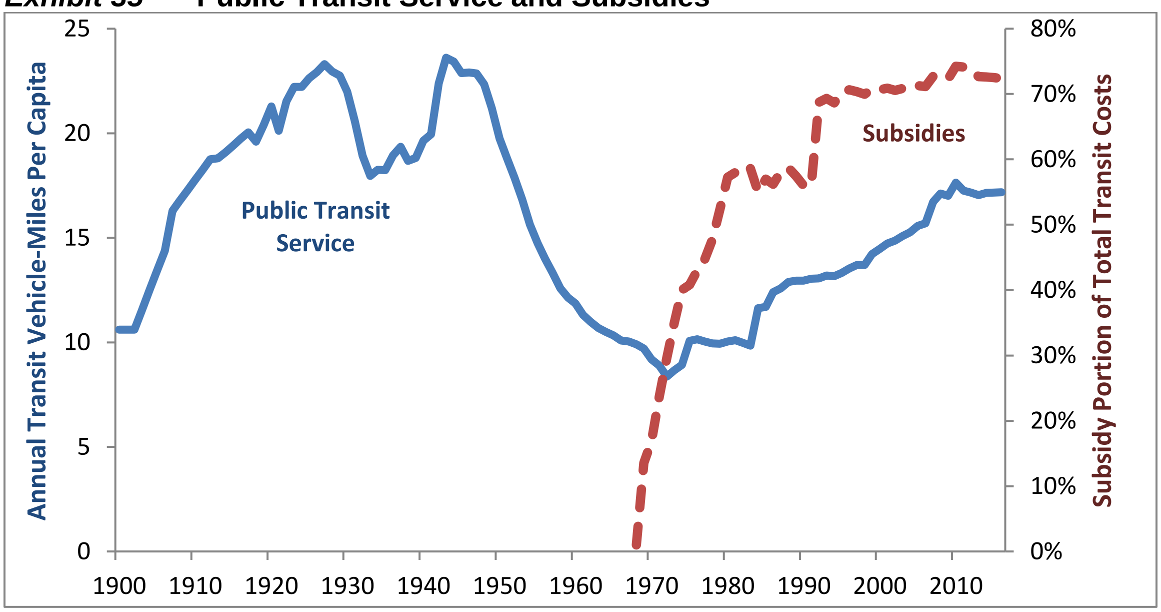
YEAR	OPERATING REVENUE	OPERATING EXPENSES (INCLUDING DEPRECIATION)	NET REVENUE	ALL TAXES
	(THOUSANDS)	(THOUSANDS)	(THOUSANDS)	(THOUSANDS)
1935	$ 681,400	$ 534,930	$146,470	$ 50,460
1940	737,000	598,030	138,970	62,690
1945	1,380,400	1,067,140	313,260	164,530
1950	1,452,100	1,296,690	155,410	89,040
1955	1,426,400	1,277,370	149,030	93,320
1956	1,416,100	1,271,360	144,740	89,050
1957	1,385,600	1,261,560	124,040	87,430
1958	1,349,500	1,265,850	83,650	77,060
1959	1,376,400	1,266,080	110,320	84,700
1960	1,407,200	1,289,850	117,350	86,660
1961	1,389,700	1,295,770	93,930	77,200
1962	1,403,500	1,306,000	97,500	77,800
1963	1,390,600	1,312,560	78,040	78,920
1964	1,408,100	1,342,580	65,520	77,910
1965	1,443,800	1,373,760	70,040	80,650
1966	1,478,500	1,423,760	54,740	91,810
1967	1,556,000	1,530,864	25,136	91,704
1968	1,578,285	1,609,768	(D) 31,483	98,497

The transit industry earned a healthy profit prior to 1960, but net revenues subsequently declined and went into deficit starting in 1968. This resulted from a combination of declining ridership, increased traffic congestion, and sprawled development patterns which reduced operating efficiencies and passenger revenues per vehicle-mile.

Most transit agencies were subsequently forced to rely on public subsidies.

Most transit companies went bankrupt and became government agencies. Public subsidies now cover about three quarters of transit expenses. In 2018, U.S. transit costs averaged $218 per capita, of which $49 was from fares and $169 was from public subsides.[105] This represents 10-15% of public spending on roads.[106] Despite this support, transit service is still much lower than during the pre-1950 peak, reflecting the inefficiencies caused by automobile-oriented transportation systems and sprawl.

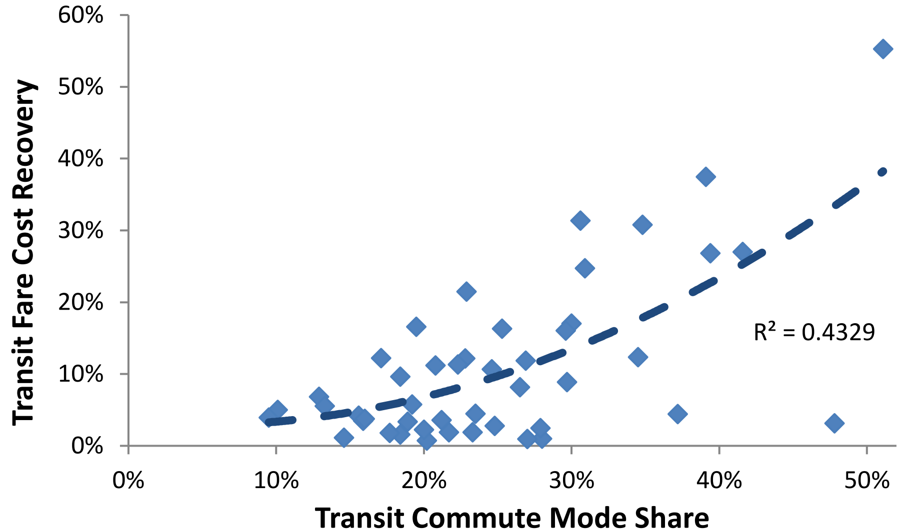
Exhibit 35 Public Transit Service and Subsidies[107]



Per capita transit service grew during the first half of the Twentieth Century, but subsequently declined as travellers shifted to automobiles, which reduced service efficiency. Many transit systems went bankrupt. After 1968, service increased due to public subsidies, which quickly grew to cover about three quarters of transit expenses. Transit service quality and cost recovery (portion of costs covered by fares) are much higher in more transit-oriented cities, suggesting that automobile-oriented planning reduced public transit efficiency.

Transit service cost-recovery (the portion of costs paid by fares) tends to increases with ridership, indicating that transit becomes more cost-efficient as service and ridership increase, indicating strong economies of scale. Other modes have similar cost profiles: as more people walk or bicycle, facility unit costs decline. In this way, automobile-oriented planning reduced the efficiency of other modes.

Exhibit 36 **Public Transit Mode Share Versus Cost Recovery**[108]

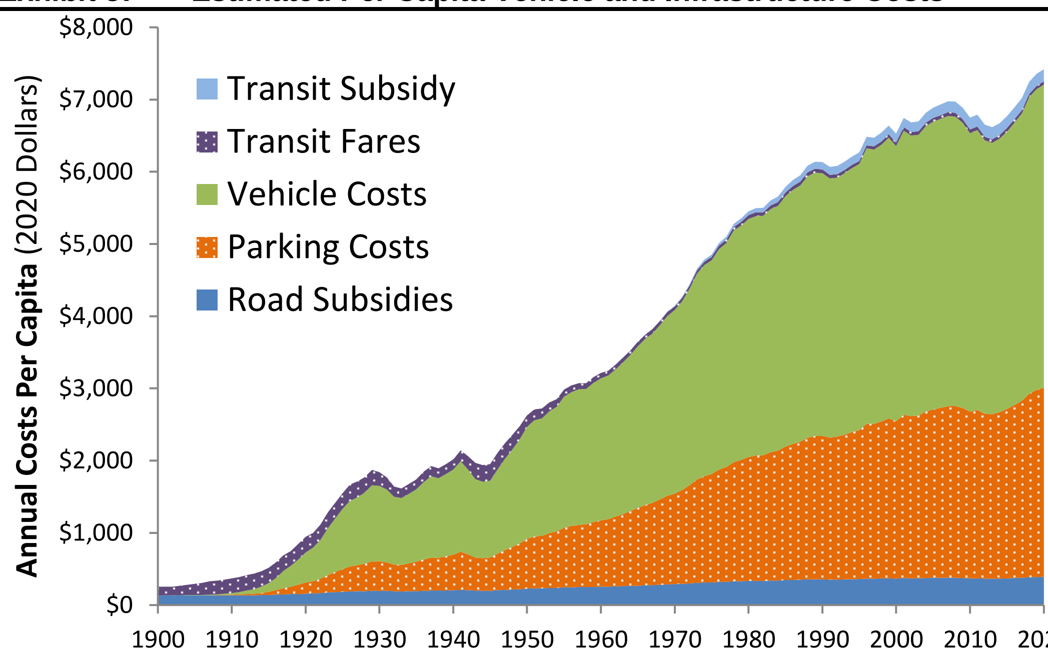


As transit ridership increases in a community, so does cost recovery (portion of transit costs paid by fares). This indicates economies of scale: increased ridership and service reduces unit costs and subsidy requirements.

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

The figure below shows the growth in real (inflation-adjusted) per capita vehicle and infrastructure costs, which increased substantially as automobile travel grew.

Exhibit 37 **Estimated Per Capita Vehicle and Infrastructure Costs**[109]

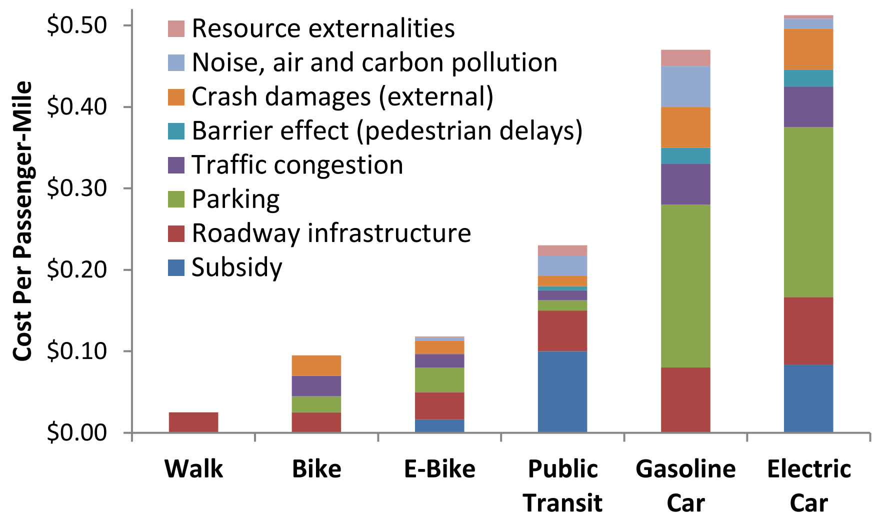


As automobile travel grew during the last 120 years, per capita vehicle, road and parking facility costs increased significantly.

External and Total Costs

In addition to user and infrastructure costs, automobile travel imposes various external costs on other people.[110] Because they are large, fast and resource-intensive they require far more space for travel and storage and therefore more costly road and parking infrastructure, they impose more congestion and barrier effect (delay that roads and traffic impose on pedestrians and bicyclists), crash risk, pollution emissions and resource externalities (external costs caused during vehicle, infrastructure and fuel production) than other modes. The following figure summarizes estimates of these costs.

Figure 38 **External Costs by Mode** (Litman 2021)

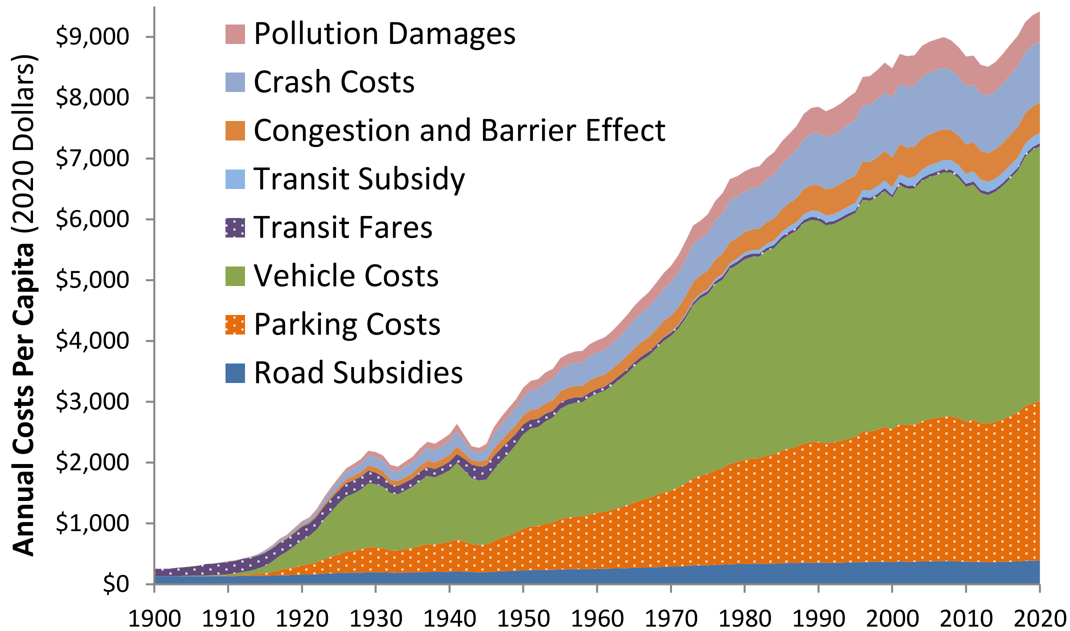


This figure compares the external costs of six modes. Because they are large, fast and resource-intensive automobiles require far more travel and storage space, and therefore more costly road and parking infrastructure, impose more congestion and barrier effect, crash risk, pollution emissions and resource externalities than other modes.

Although various policies and technical innovations are intended to reduce these costs, they are still significant. For example, roadway expansions have failed to reduce urban traffic congestion and increase barrier effects (delays that motor vehicle traffic imposes on pedestrian travel), traffic crashes continue to cause numerous deaths, injuries and property damage, and emission reduction strategies have not eliminated vehicle pollution, including emissions that occur during vehicle, infrastructure and fuel production. This indicates that automobiles typically impose costs that are an order of magnitude higher than walking, bicycling e-bikes measured per travel-mile, and because motorists typically travel five to ten times more annual miles than people who rely on non-auto modes, their total annual external costs are even larger.

These are estimated to average about $500 annually per capita for congestion and barrier effect delays, $1,000 annually for crash damages, and $500 annually pollution damages. This analysis indicates that automobile travel imposes total costs, including costs to users (for vehicles and internal risk), governments (for roadways and traffic services), businesses (for off-street parking), and communities (for congestion delays, crash and pollution damages imposed on other people) that total $8,000 to $10,000 annually per capita, as illustrated in the following figure. Some of these are market costs paid with money, others are non-market costs such as pain, suffering and environmental degradation caused by crash and pollution damages.

Exhibit 39 **Estimated Vehicle, Infrastructure and External Costs**[111]



As automobile travel grew during the last 120 years, per capita vehicle, infrastructure and external costs increased significantly.

This type of analysis is challenging due to data limitations. These impacts vary by time, location, vehicle type and demographic group. For example, these costs tend to be higher in suburban and rural areas, and for wealthier households, due to their higher vehicle ownership rates, and they look very different if costs are measured per vehicle-mile rather than per capita. As a result, detailed analysis is needed to estimate costs for a particular location, group or situation.

Transportation Planning Practices

During the last 120 years, planning practices evolved in response to changing consumer demands, community goals and technologies. For much of the Twentieth Century, transport planning was automobile-oriented. In recent decades there have been reforms to support other modes. However, it may take more decades for planning reforms to create truly multi-modal transportation systems.

Exhibit 40 **Transportation Planning Trends**[112, 113]

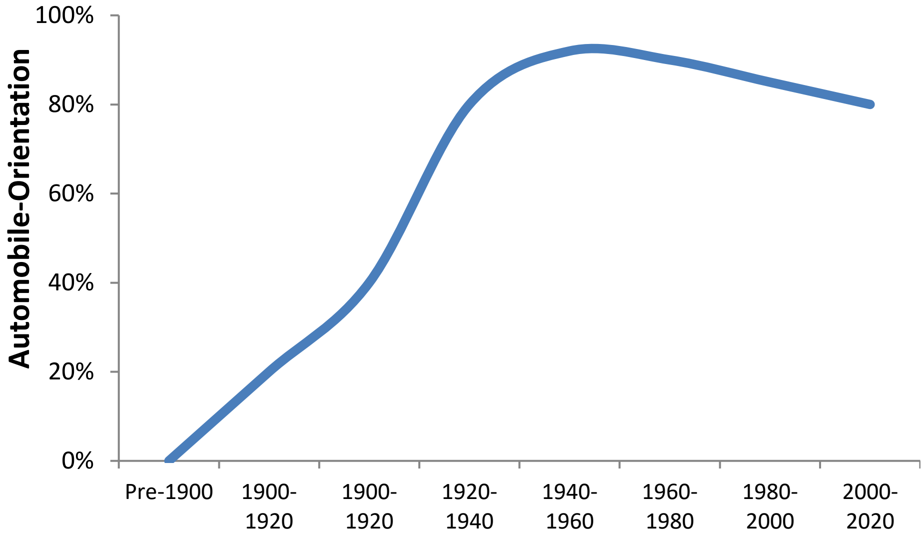
Time Period	Major Trends	Modal Scope
1900-1920	Initially focused on rail. "Good roads" movement supported roadway paving and design improvements. Highway departments established.	Initially rail, increasingly automobile.
1920-1940	Road and rail planning and technological development. Fuel taxes established to finance highways. Streets and highways were the most common U.S. Federal Public Works Administration projects, representing 33% of all PWA projects.	Multi-modal, with increasing focus on highways.
1940-1960	1956 Federal Highway act provided funding and technical support to build the interstate highway system. States provided similar highway programs, and local government expanded roadways and incorporated parking minimums into zoning codes. Highway Capacity Manual standardized roadway engineering practices. Federal Transit Administration established.	Automobile-oriented
1960-1980	Interstate Highway System developed. Continual expansion of urban roadways and parking. Growing resistance to urban highways.	Automobile-oriented
1980-2000	Early TDM programs to reduce traffic congestion. Initial development of pedestrian and bicycle, Transit Oriented Development, and Smart Growth planning. The 1991 *Surface Transportation Efficiency Act* supported more integrated and multi-modal planning.	Modest efforts at multi-modal
2000-2020	Growing emphasis on multi-modal planning and design including multi-modal level-of-service standards,[114] complete streets design guides,[115] and multi-modal accessibility models.[116] A growing number of jurisdictions establish VMT reduction targets.[117]	Increasing multi-modal

Transportation planning evolved during the last 120 years in response to emerging travel demands and technologies. Between 1940 and 1990, planning was automobile-oriented with little effort to support other modes, but in recent decades planning has become somewhat more multi-modal.

During most of the Twentieth Century, transportation planning assumed that urban traffic congestion is the primary transportation problem.[118] Planning tools were developed to evaluate transportation problems and potential solutions. The *Highway Capacity Manual*, first published in 1950, standardized methods for measuring traffic conditions. Starting in 1960 the U.S. Census started to collect "Journey to Work" data, and cities performed travel surveys and developed traffic models, making it easy to predict where roadway level-of-service (LOS) will "fail," justifying roadway expansions. These methods were subsequently expanded to include other modes, and data collection and analysis has improved,[119] although few communities collect the detailed data needed to effectively evaluate walking, bicycling and public transit quality of service.

Many jurisdictions, particularly in the U.S., established transportation funding programs that provided significant funding for roadways. Accounting for inflation, highway spending per vehicle-mile was two or three times higher than it is now. Much of this money was spent on urban highways, intended to reduce traffic congestion, with the recognition that these would displace urban transit services and high-accessibility urban neighborhoods, creating automobile-dependent communities.[120]

Exhibit 41 **Degree that Transport Planning is Automobile-Oriented**

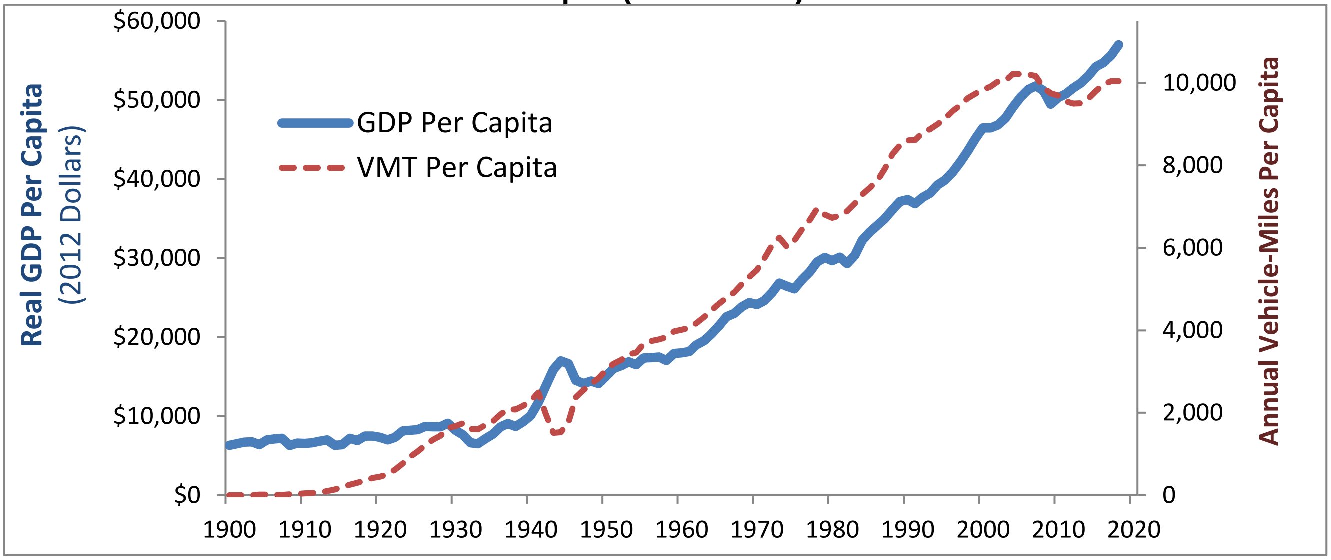


During most of the Twentieth Century transportation planning was automobile-oriented. In recent decades there has been growing support for other modes, but most transport infrastructure funding is still devoted to roads and parking facilities. It will take decades before current multi-modal planning fully affects day-to-day travel conditions.

Economic Productivity

During the last 120 years, Gross Domestic Product (GDP, an indicator of economic productivity) and Vehicle Miles Travelled (VMT) both grew significantly, as illustrated below.

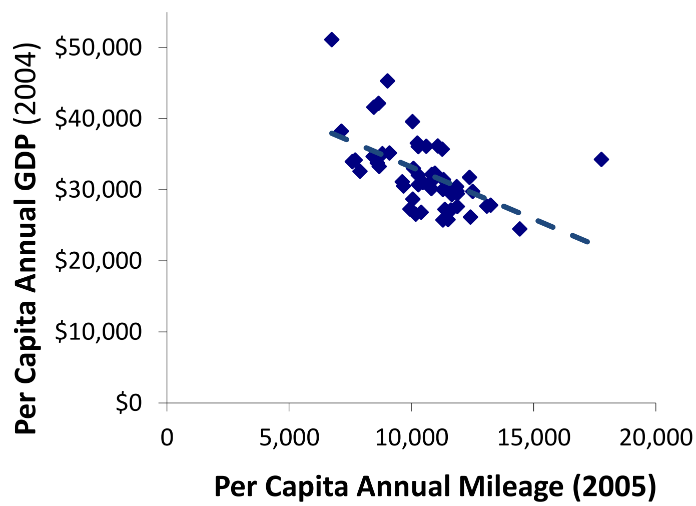
Exhibit 42 **Real GDP and VMT Per Capita (1900 – 2018)**[121]



Between 1900 and 2018 Gross Domestic Product (GDP) and vehicle miles traveled (VMT) both increased significantly, but that does not prove that increased VMT increases economic productivity.

However, this does not mean that increased vehicle travel necessarily increases productivity. Although some mobility contributes to productivity, beyond an optimal level these gains tended to decline, reflecting diminishing marginal benefits. When vehicle travel is limited it tends to be used for high-value mobility such as freight and public transport, but as it increases the additional mobility serves less productive purposes such as longer-distance commutes and recreational travel, while traffic congestion, accidents, and facility costs increase.[122] Beyond an optimal level, more vehicle travel does not increase productivity, a concept called *economic decoupling*.[123] All else being equal, more sprawled, automobile-dependent areas tend to have lower per capita GDP than more compact, multi-modal areas.[124] The figure to the right illustrates the negative relationship between per capita vehicle travel and economic productivity. This suggests that policies that increase transportation system efficiency support economic growth more than policies that increase vehicle travel.[125]

Exhibit 43 **Per Capita GDP and VMT** (FHWA and BLA Data)



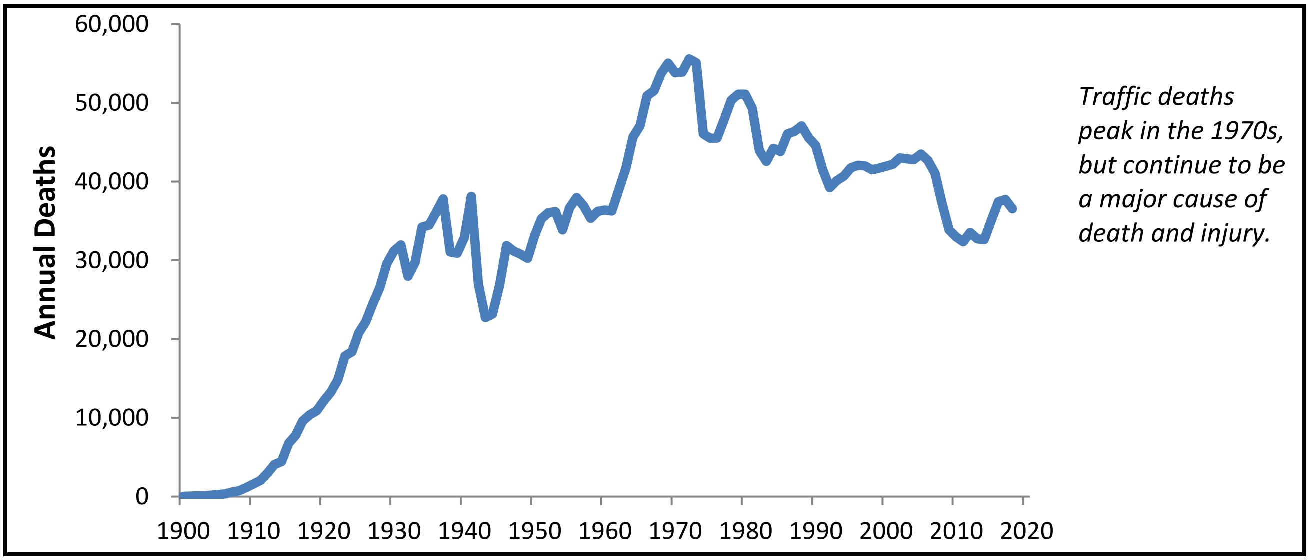
Per capita economic productivity declines as vehicle travel increases. (Each dot is a U.S. state.)

Health and Environmental Impacts

Motor vehicle travel imposes health and environmental risks including traffic crashes, sedentary living (reduced physical activity and fitness), harmful pollutants, and habitat loss. These impacts help explain why residents of sprawled, automobile-dependent areas have more chronic diseases and worse health outcomes than in more compact, multi-modal communities,[126] and why U.S. residents have shorter lifespans than most peer countries.[127] Of course, older modes also caused health risks. Horses, steam trains and electric trolleys caused accidents, pollution and disease.[128] According to one study, horse and train travel had higher traffic fatality rates and produced comparable pollution (waste and soot) per mile as automobiles,[129] but as vehicle travel grew, so did total accidents, pollution and health problems.[130]

U.S. traffic deaths peaked in 1972 and subsequently declined somewhat, due to vehicle and roadway design improvements and traffic safety programs. However, despite this progress, traffic crashes continue to be a major cause of injury and death, as illustrated below. The United States has the highest traffic fatality rate among peer countries, probably due to high rates of automobile dependency, which results in high rates of per capita vehicle travel and therefore crash exposure.[131]

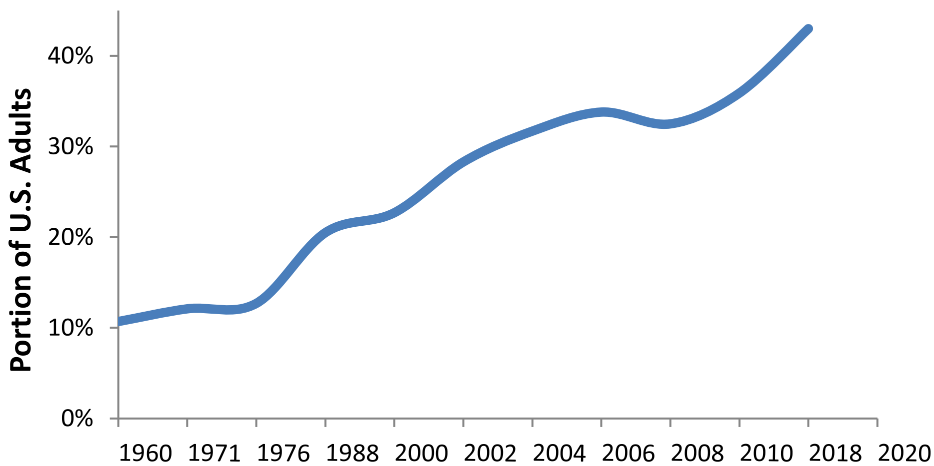
Exhibit 44 **U.S. Traffic Deaths**[132]



Public health experts recommend that, to be healthy, people engage in moderate physical activity at least 150 minutes per week, approximately 22 minutes per day.[133] Prior to the automobile age, most people probably exceeded these targets, spent 60-80 daily minutes walking and bicycling. Now, most automobile-dependent community residents do not.[134] According to the *National Household Travel Survey*, in 2009 Americans walked or biked just 0.37 average daily miles, which takes about 7 minutes, less than a third of these targets. Of course, there are many possible ways to exercise, including organized sports and gym workouts, but those require special time and financial costs, and so are difficult for most people to maintain lifelong, particularly if they are sedentary and overweight. A study by Frederick, Riggs, and Gilderbloom, "Commute Mode Diversity and Public Health: A Multivariate Analysis of 148 US Cities," found that, accounting for other demographic and economic factors, residents of communities where commuters walk, bike and use public transit have significantly better health outcomes including less sedentary behavior and obesity, greater longevity, and higher birth weights (an indicator of infant health).[135]

Although many factors affect physical activity and health, numerous studies find that obesity, cardiovascular disease, diabetes, and some forms of cancer tend to increase with vehicle travel and sprawl.[136, 137] The figure below shows how obesity rates increased between 1960 and 2018, a period when automobile travel increased and active travel declined.

Exhibit 45 **U.S. Obesity Rates (BMI >30) Ages 20-74**[138]



Obesity rates (Body Mass Index over 30) increased substantially between 1960 and 2016. Research indicates that increased driving and less active travel (walking and bicycling) contributed to these trends.

Motor vehicles emit harmful pollutants including particulates, NOx, VOCs, toxins, carbon dioxide and noise.[139] Although control technologies reduced per-mile emission rates, this is partly offset by increased vehicle mileage, so vehicle emissions continue to cause significant health and environmental damages.[140] Recent studies show that disease and death rates tend to be much higher for residents who live near busy highways, indicating that vehicle emissions continue to impose significant health damages.[141] According to one major study, motor vehicles are the single largest cause of U.S. air pollution deaths, resulting in approximately 53,000 annual fatalities.[142] Motor vehicles are also producing about a third of total climate change emissions, the largest single source, and growing.[143]

In addition, motor vehicles damage the environment by increasing the amount of land paved for roads and parking facilities, and encouraging urban-fringe development.[144] Increasing impervious surface area reduces groundwater recharge, increases flooding and stormwater management costs, increases heat island effects (high ambient temperatures in sunny conditions), reduces greenspace, and disrupts habitat.[145] On average people require about 400 square feet of land for their home (assuming 2.5 residents in a 2,000 square foot, 2-story home), but each motor vehicle generates about 3,000 square feet of pavement for roads and parking facilities.[146, 147] As a result, per capita impervious surface footprint (land covered by buildings, concrete and asphalt) increased significantly during the last century.[148, 149]

Opportunity and Equity

The quality of transportation options affects non-drivers' ability to access important basic services and activities, and therefore their economic and social opportunities.[150] During the last century, new transportation technologies helped physically, economically and socially disadvantaged people in some ways, but harmed them in others. For example, *universal design* standards improve mobility for people with impairments and other special needs. Public transit and ridehailing service improvements benefit non-drivers. However, these do not offset the many ways that automobile dependency and sprawl harm non-drivers:

- Pedestrians lost their rights to use public roads, and their dignity. Early in the century, pedestrians filled urban streets, but as automobile travel became common, pedestrians were squeezed out, and required by law and safety to yield to automobiles.
- Wider roads and increased vehicle traffic degrades walking and bicycling conditions, including crash risk, noise and air pollution. This forces non-drivers to endure unpleasant and dangerous conditions, reduces their mobility, or forces them to shift from their preferred mode to automobile travel.
- Shifts from public transit to automobile travel reduced transit system efficiency and service quality.
- More sprawled development increased travel distances, reducing non-auto accessibility.
- Reduced walking, bicycling and public transit travel reduced political and economic support for sidewalks and bicycle facilities, traffic speed control, transit services, and compact urban design.
- Non-drivers must bear large roadway and parking facility costs.
- Reduced walking, bicycling and public transit by economically successful traveller stigmatized these modes.

In most North American communities, non-drivers now have less independent mobility than people had a century ago due to less safe walking and bicycling conditions, reduced public transportation services, and sprawled development patterns. Anybody who doubts this can perform a little experiment: try getting around without a car in various types of communities. I can report from personal experience that it is easy to live car-free in an older urban neighborhood, because such areas have comprehensive sidewalk networks, narrow roads that limit vehicle traffic, well-established public transit services, and compact development which locates common destinations within convenient walking distances. In contrast, most newer suburban areas are automobile dependent and sprawled, making travel convenient and comfortable for motorists but difficult and dangerous for non-drivers.[151]

Current policies that favor drivers over non-drivers are unfair.[152, 153] For example, it is unfair for governments to spend significantly less and devote less road space to support walking, bicycling and public transit travel than to automobile travel.[154, 155] Zoning code parking minimums (requirements to include a specified number of parking spaces in zoning codes) reduce housing affordability and force people who drive less than average to subsidize the infrastructure costs of others who drive more than average.[156] Since automobile travel tends to increase with income, these policies are *regressive* meaning that they harm lower-income people. Automobile-oriented planning reduces non-drivers' economic opportunities,[157] and imposes chauffeuring burdens on drivers.[158]

The table below indicates the types of people and businesses that tend to win or lose from these trends. Overall, people who drive more than about 10,000 annual miles probably win overall – their benefits exceed their costs. People who out of necessity or preference drive less than 10,000 annual miles, or would choose to do so if given better mobility options, are likely to lose overall. Of course, many people's status changes over time, so they may benefit overall during one period in their life but lose overall during another.

Exhibit 46 Transportation Trends – Winners and Losers

Winners	Losers
• Motorists who drive more than 10,000 annual miles • Higher-income households • Vehicle and petroleum industries	• People who drive less than about 10,000 annual miles • Lower-income households • People with mobility impairments and special needs • Youths and others who lack driver's licenses • Motorists with heavy chauffeuring responsibilities • Law abiding drinkers • Local businesses • People injured by traffic accidents and vehicle pollution • People who prefer non-auto travel, and their pets

Transportation trends of the last 120 years, with more motor vehicle travel and sprawl, benefit people who travel a lot by automobile, but harm people who cannot, should not, or prefer not to drive.

Community and Culture Impacts

Increased mobility and sprawl changed the way people interact in their communities. In pre-automobile communities, most activities occurred within a neighborhood: residents relied on local stores, played in local parks, and their children attended local schools. Because most travel was by walking, neighbors had many opportunities to interact, creating *community cohesion* (positive relations among community members).[159] In contrast, automobile transportation and sprawl tend to shift daily activities to a regional scale. This has negative effects.

As traffic volumes increase, walking declines and activities become more dispersed, residents become less connected to their neighbors and local community.[160] This reduction in neighborhood connections tends to increase social isolation, loneliness, depression and crime.[161] Various writers criticize the "placelessness" resulting when urban space is optimized for vehicle traffic. As urban researchers Daniel Carlson, Lisa Wormser, and Cy Ulberg explained, "*Automobile-based development has reduced opportunities for public life and magnified the polarization of our society by aggravating the geographical and time barriers between people with different incomes, and by making it more difficult for those who don't own cars to participate in life outside their communities."*[162]

Conversely, more walking and pedestrian orientation provides "eyes on the street," which tends to reduce neighborhood crime.[163] Residents of more walkable communities are more likely to know their neighbors, participate politically, trust others, and be socially engaged.[164, 165] As researchers Richard Untermann and Anne Vernez Moudon explained,

> "A deeper issue than the functional problems caused by road widening and traffic buildup is the loss of sense of community in many districts. Sense of community traditionally evolves through easy foot access–people meet and talk on foot, which helps them develop contacts, friendships, trust, and commitment to their community. When everyone is in cars there can be no social contact between neighbors, and social contact is essential to developing commitment to neighborhood."[166]

Automobile-oriented, sprawled development also reduces the quality and diversity of local commercial activity. Urban regions with more compact, multi-modal neighborhoods tend to have more independent restaurants rather than chains.[167] A shopping mall may have a pub that *looks* nice, with wood paneling, brass hardware, and perhaps even dart boards, but lacks the soul of independent establishments. Why? There are two reasons. First, mall pubs must be large to achieve economies of scale: bigger is more profitable, so a mall pub is a corporate enterprise operated by a crew of low-wage workers who have no commitment to pub culture. Second, a mall pub lacks local regulars who visit frequently enough to build a community of friendly barflies. The beer may taste the same, but the experience is inferior. Although community and culture impacts are difficult to measure, they are important. This helps explain the growing consumer preferences for living in walkable neighborhoods.[168]

In the past century, automobile-oriented planning often damaged urban neighborhoods by imposing traffic danger, noise, pollution and excessive pavement.[169] Many of these were well-established African-American, Latinx, Asian and artistic communities, but the problem is not purely racial.[170] The root of the problem was the assumption by policy makers and transportation professionals that: 1) faster is better than slower, so; 2) automobiles are better than slower modes, so; 3) everybody aspires to an automobile-oriented lifestyle, so; 4) suburbs are better than cities, so; 5) highways to accommodate suburban commuters should replace “blighted” urban neighborhoods,[171] and 6) abundant Federal and State funding makes highway projects financially attractive, so; 7) everybody wins with expanded highways and parking facilities. You could call this the “myth of universal benefits.”

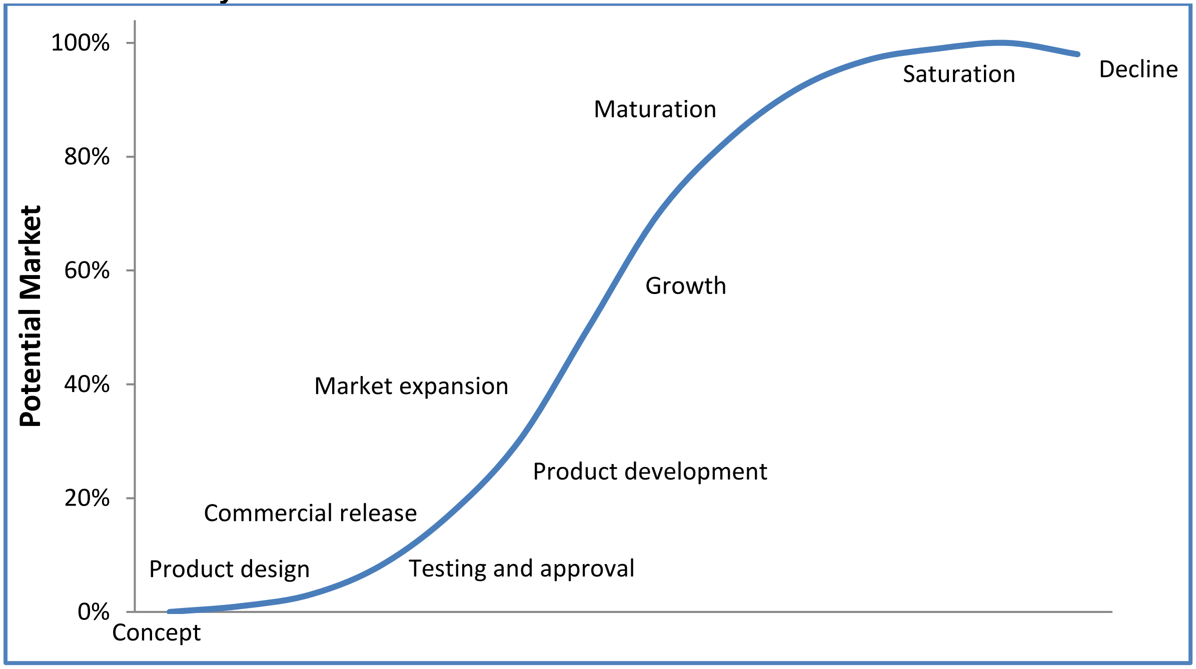
These assumptions were common in the 1950s and 60s, but eventually encountered public opposition that resulted in reforms, including more community involvement in the planning process and more flexible funding that allows some highway dollars to be “reprogramed” to public transit projects.[172] Transportation professionals increasingly recognize that for many people (particularly anybody who cannot, should not or prefers not to drive), and in many situations (particularly in urban areas and lower-income communities), automobile-oriented planning is unfair and inefficient.[173] It fails to respond to critical demands, such as the desire to have neighborly shops, schools, restaurants and pubs, and therefore a vibrant and inclusive community.

If you evaluate automobile transportation as a technology, this cycle of growth, saturation and decline is predictable, as discussed in the following section. We have passed the growth cycle peak and are now in the saturation and decline phases. Many people are ready for new mobility technologies and services that better serve their needs. This has important implications for predicting and evaluating future innovations.

Cycles of Innovation

Technological development generally follows a predictable cycle: an initial concept undergoes design, testing and approval, commercial release, product development, market expansion, growth, maturation, and eventually saturation and decline, as illustrated below.

Exhibit 47 **Cycle of Innovation**[174]



Most innovations follow a predictable deployment pattern, often called an innovation S-curve.

Previous vehicle innovations followed this pattern. Below are examples.[175]

- *Automobiles.* Became commercially available about 1900, and mass production started in 1908 with the Ford Model T. During the first half of the Twentieth Century, vehicles improved, diversified and specialized. Per capita vehicle ownership increased during the Twentieth Century, but reached saturation levels about 2000, as previously described.
- *Automatic Transmissions*. First developed in the 1930s, it took until the 1980s for them to become reliable and affordable. When optional, they typically cost $1,000 to $2,000. They are included in 90% of new vehicles in North America, and 50% in Europe and Asia.
- *Air Bags*. First introduced in 1973. Initially an expensive and sometimes dangerous option (they caused injuries and deaths), they became cheaper and safer, becoming standard on some models starting in 1988, and mandated by U.S. federal regulation in 1998.
- *Hybrid Vehicles*. These became commercially available in 1997 but were initially unreliable and expensive. Their performance has improved, but typically adds about $5,000 to vehicle prices. In 2016 they represented about 2% of total vehicle sales.
- *Remote lock/unlock, diagnostics, emergency response and navigation services.* OnStar became available in 1997, TomTom in 2002. Such services typically cost $150-750 annually.
- *Vehicle Navigation Systems*. These were initially expensive accessories. In the 1990s, factory-installed systems became available on some models for about $2,000. Their performance improved and prices

declined and are now standard in many higher-priced models. Vehicle navigation apps, such as Google Maps and Waze, are available for free or a fee.

- *Electric vehicles*. Battery-electric cars developed in the late 1800s but were uncommon during most of the Twentieth Century. In the 1990s, major manufacturers produced improved models, and by 2020 many companies sold high quality electric cars. Despite this progress, less than 2% of current vehicle sales are electric, and high-performance models are expensive.

The table below summarizes the deployment cycle, typical costs and market saturation levels of some of these technologies. All these technologies required decades from initial commercial availability to market saturation, and some may never be universal.

Exhibit 48 **Vehicle Technology Deployment Summary**

Technology	Deployment Cycle	Typical Cost Premium	Market Saturation Share
Automatic transmissions	50 years (1940s-90s)	$1,500	90% U.S., 50% worldwide
Air bags	25 years (1973-98)	A few hundred dollars	100%, due to federal mandate
Hybrid vehicles	25+ years (1990s-2015+)	$5,000	Uncertain. Currently about 4%.
Subscription services	15 years	$400 annual	5-10%
Navigation systems	30+ years (1985-2015+)	$500 and rapidly declining	Uncertain; probably over 80%.
Electric vehicles	100+ years	$10,000 for high-performance	Probably 80%+

New technologies usually require several decades between commercial availability to market saturation.

Vehicles are becoming more durable, which reduces fleet turnover.[176] As a result, new vehicle technologies typically require three to five decades to penetrate vehicle fleets. Annual mileage tends to decline with vehicle age: vehicles average approximately 15,000 miles their first year, 10,000 miles their 10^{th} year, and 5,000 miles their 15^{th} year, so vehicles over ten years represent about 50% of vehicle fleets but only 20% of mileage.[177] As a result, new vehicle technologies, such as electric and self-driving cars, are likely to take several decades to penetrate vehicle fleets unless large numbers of otherwise functional vehicles are scrapped prematurely to accelerate their use.

Implications for Future Mobility

Many factors contributed to the last century's immense growth in mobility, including improved travel efficiency and income growth that allowed households to afford more travel and purchase more goods. Increased female employment raised incomes and commute travel amounts. Sprawled development increased travel distances and reduced non-auto travel options. However, many of these trends are declining or reversing.[178]

Aging populations, declining workforce participation, stagnant real incomes, changing consumer preferences, and increased health and environmental concerns are reducing travel demands.[179] New communications technologies and services are reducing the need for physical travel.[180] Youths care more about their cell phones and personal computers than cars,[181] which helps explain younger people's lower driver's licensure rates[182] and less vehicle travel compared with previous generations at the same ages.[183] Many urban regions are reaching their limits of geographic expansion, and many jurisdictions have vehicle travel reduction targets.[184] As a result, many jurisdictions are investing more resources in non-auto transportation improvements and transportation demand management programs.[185]

This suggests that many factors that stimulated vehicle travel in the past are changing. As a result, it is inappropriate to assume that the high levels of vehicle travel that developed during the last century will necessarily continue into the future. The table below summarizes various factors that affected mobility during the past century, and their likely impacts during this century.

Exhibit 49 **Factors Affecting Travel – Past and Future Trends**

Factor	Twentieth Century	Twenty-First Century
Travel speed	Travel speeds increased significantly, but peaked during the 1970s.	Speeds are unlikely to increase significantly in most conditions, and may decline somewhat due to congestion, plus safety and environmental goals.
User travel costs	Per-mile vehicle operating costs declined, although total annual costs increased.	Electric vehicles may reduce some vehicle costs, but most user costs are unlikely to decline.
Travel options	Non-auto modes declined.	Multi-modal planning is improving non-auto modes.
Technologies	New technologies made driving more convenient and comfortable.	New technologies are improving all modes, including bicycling, carsharing, ridehailing, public transit, telework, and delivery services.
Demographics and incomes	Large population, employment and income growth.	Slower population growth, declining workforce participation, and stagnant incomes.
Consumer preferences	Automobile and suburban homes were major status goods.	Many people prefer non-auto travel and living in more walkable neighborhoods. Growing concerns about affordability, health and environmental quality.
Land use development	Significant urban expansion (sprawl).	Many urban regions have reached expansion limits and encourage more compact development.
Planning goals	Planning favored automobile travel and sprawl.	Many jurisdictions have VMT reduction targets, and so are implementing TDM and Smart Growth policies.

Several factors contributed to increased vehicle travel during the Twentieth Century. Many of these conditions are likely to change in the Twenty-First Century.

Criticisms and Reforms

Automobile-dependency and sprawl development have faced opposition. Critics include urbanists who highlight the negative impacts that roadway expansions and increased vehicle traffic have on cities, including Lewis Mumford (*The City in History*), Jane Jacobs (The Death and Life of Great American Cities) and Jane Holtz Kay (*Asphalt Nation*). Recently, transportation professionals have criticized automobile-oriented planning practices, including Peter Newman and Jeffrey Kenworth (*Cities and Automobile Dependency* and *The End of Automobile Dependence*), Samuel Schwartz (*Street Smart*), and Janette Sadik-Khan (*Street Fight*). Many health professionals highlight the public health risks of automobile dependency.[186] Some critics challenge the high social status of automobile travel and the stigma of non-auto modes, and describe high levels of vehicle travel as hyper-mobility.[187]

These criticisms had some effects, starting in the 1970s with *freeway revolts*, in which planned urban highways were abandoned or downsized, and recently with *complete streets* policies to ensure that urban streets accommodate diverse users and uses.[188] These apply various roadway design strategies including streetscaping, traffic calming and road space reallocation. These concepts have been embraced, to various degrees, by transportation professional organizations such as the Institute of Transportation Engineers[189] and the National Association of City Transportation Officials (NACTO).[190]

These criticisms lead to policy reforms, called *Smart Growth*, *New Urbanism*, and *Transit-Oriented Development*, which help create more compact, mixed, multi-modal communities where most common services are accessible in a 15-minute walk.[191] These strategies can significantly reduce residents' vehicle ownership and use, and increase their use of resource-efficient modes.[192] Since 2000, a growing number of jurisdictions have implemented vehicle travel reduction targets, which justify transportation and land use policy reforms that reduce automobile dependency and sprawl.[193] Recently, some jurisdictions have eliminated minimum parking requirements.[194] These reforms are often described as climate emission reduction strategies, and so tend to be applied initially in jurisdictions with stronger environmental commitments,[195] but are also justified as traffic congestion reduction, infrastructure cost savings, affordability, and public health strategies.

So far, these reforms have been limited. In 2020, most transportation funds are still dedicated to roadways, most North American jurisdictions still impose parking minimums, and in other ways public policies continue to favor automobile travel over other modes, and sprawl over compact development. Many transportation professionals and many public officials support more multi-modal planning and compact development, but face opposition from residents who fear constraints on driving. This suggests that, for various reasons, public policies and planning practices will gradually shift away from automobile-dependency and sprawl, but these changes could take decades.

This suggests that in most developed countries, vehicle travel has peaked. Mobility increased to the point that additional travel provides little incremental benefits and imposes significant costs. Surveys indicate that many people would prefer to drive less and rely more on alternatives. Although automobile travel will not disappear, per capita vehicle travel is likely to decline somewhat as alternatives improve. This suggests that future planning should support more diverse and efficient mobility options in response to changing consumer demands and community goals.

Conclusions

Let's summarize some key insights from this study.

During the last 120 year, motor vehicle travel greatly increased the speed and distances that people could travel within their limited time and money budgets. Our world accelerated! Developed country residents now travel about ten times faster and farther than in 1900. Although this provides benefits, it also imposes significant economic, social and environmental costs, including large increases in household expenses, infrastructure costs, and health problems, plus reduced mobility options. These costs offset a major portion of benefits, and tend to be inequitable; they harm people who cannot drive or have low incomes. If measured by effective speed – travel distance divided by time devoted to travel plus time spent earning money to pay travel expense and maintain vehicles – automobile travel is often slower than other modes, particularly for lower-wage workers.

This has important implications for transportation planning. When evaluating new transportation technologies and services. It is important to consider all impacts, including potential indirect and long-term costs and inequities. For efficiency and equity sake, planning should favor affordable and resource-efficient options, and be willing to regulate, price and restrict innovations that impose significant external costs or contradict strategic goals. Faster modes may be beneficial for some trips, but may be harmful overall if they degrade slower travel options or stimulate sprawled development which increases the distances that everybody must travel to access services and activities.

With smart planning communities can maximize existing modes while benefiting from emerging transportation technologies and services.

Endnotes

[1] Various sources, including appropriate Wikipedia pages.

[2] Asif Ahmed and Peter Stopher (2014), "Seventy Minutes Plus or Minus 10 — A Review of Travel Time Budget Studies," *Transport Reviews*, Vo. 34:5, pp. 607-625 (DOI: 10.1080/01441647.2014.946460).

[3] Todd Litman (2001), "Generated Traffic: Implications for Transport Planning," *ITE Journal*, Vol. 71 (4), Institute of Transportation Engineers (www.ite.org), pp. 38-47; at www.vtpi.org/gentraf.pdf.

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