Transportation innovations increased our mobility by an order of magnitude, but this imposed significant economic, social and environmental costs, and tends 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. 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 non-auto transport 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 lessons for future transport planning.

This is a draft report. Please send comments to litman@vtpi.org.

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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. The figure below indicates when new modes became widely available and their typical operating speeds.

Exhibit 1 New Modes’ Initial Availability and Typical Operating Speeds

![Diagram showing new modes' initial availability and typical operating speeds]

New transportation modes significantly increased potential travel speeds. 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; 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 try to spend less than 90 daily minutes, and 20% 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.

These increases in vehicle travel speed and distance had many economic, social and environmental impacts on our lives and communities, 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 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 2 Changes in Active Transport Conditions

<table>
<thead>
<tr>
<th>Factor</th>
<th>Changes 1900-2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment</td>
<td>Shoe, scooter and bicycle technologies improved and generally become more affordable.</td>
</tr>
<tr>
<td>Facilities</td>
<td>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 sidewalks in many suburban developments lacked sidewalks. Many communities are starting to implement pedestrian and bicycle improvement plans.</td>
</tr>
<tr>
<td>Motor vehicle traffic</td>
<td>Wider roads, and increases in motor vehicle traffic volumes and speeds, and resulting increases in traffic risk, noise and air pollution significantly degraded active travel conditions in most communities, often making active travel infeasible, particularly for vulnerable people such as children and people with mobility impairments. Complete streets policies and traffic calming are intended to improve walking and bicycling conditions.</td>
</tr>
<tr>
<td>Travel distances</td>
<td>Sprawled development increased travel distances, which made many communities too dispersed for convenient access by walking.</td>
</tr>
<tr>
<td>Social status</td>
<td>As middle-class people walked and bicycled less, they became stigmatized. Jaywalking laws forced pedestrians off of public streets.</td>
</tr>
</tbody>
</table>

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 there is limited data, available information indicate 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, 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 and, A Ride through Barcelona 101 Years Ago. 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.\textsuperscript{10} As a result, pedestrians are often blamed when injured in traffic accidents.\textsuperscript{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.\textsuperscript{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%.\textsuperscript{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 it 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.\textsuperscript{14} The figure below illustrates transit’s decline and partial recovery.

**Exhibit 3**  
**Public Transit Service\textsuperscript{15}**

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{transit_service_graph.png}
\caption{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.}
\end{figure}
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. 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 4 U.S. Roadway Miles

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 $\pi R^2$. 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.
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.

The factors that increased traffic speeds eventually reached their practical limits. Higher traffic speeds increase infrastructure costs, accident risks and environmental impacts. During most of the Twentieth Century, transportation planners considered highway expansions to be “improvements,” ignoring the negative impacts they have on pedestrians and residents. Starting in the 1970s, many communities experienced highway “revolts” which stopped or reduced planned highway expansions. Many communities now apply Complete Streets policies, road diets and even highway removals that reduce roadway capacity and traffic speeds. As a result, average automobile commute speeds declined after the 1970s, as illustrated below.

Average automobile commute speeds declined about 30% between 1970 and 2017.
**Summary of Travel Changes**
The figure below shows changes in per-capita travel miles during the last 120 years. In the pre-automobile period, people walked and biked three to four miles per day.\(^{24}\) Rail and public transit passenger-miles peaked early during the first half of the Twentieth Century. Motor vehicle travel increased steadily, from virtually zero in 1900 to approximately 10,000 annual miles per capita in 2000, when it peaked in U.S. and most other developed countries.\(^{25}\) This indicates that during the Twentieth Century, average mobility increased approximately ten fold.

**Exhibit 7  Travel Trends: Estimated Annual Passenger-Miles by Mode\(^{26}\)**

*Before 1900 people relied primarily on walking, with occasional bicycle and rail trips. Motor vehicle travel grew steadily during the Twentieth Century. About 10% of motor vehicle travel is for freight.*

**Long-Distance Travel**
During the last two centuries there were also tremendous increases in long-distance travel speed and affordability. 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.*
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. In the 1920s, a New York to Los Angeles train trip cost about $120, equivalent to about $2,000 in current dollars. 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. Since then air travel became much faster, cheaper and safer. Airfares declined 50% between 1979 and 2011, as illustrated below.

Air travel became significantly cheaper due to technological innovations and increased competition.
Faster and cheaper travel stimulated air travel, as illustrated below.

**Exhibit 10**  US Air Travel

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 these countervailing forces.

This significantly increased international tourism, as illustrated below.

**Exhibit 11**  International Tourism by World Region

Lower airfares encouraged huge increases in international tourism.

However, these growth trends will not necessarily continue. Airline operating speeds have not increased since the 1960s, and air travel became less convenient, comfortable and rapid as airlines cut costs and accommodate new security, health and environmental requirements. Although long-distance travel will probably increase with global economic growth, the growth rate 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 12  Railroad Freight Costs\textsuperscript{34}

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.\textsuperscript{35} Freight transport represents about 10\% of vehicle travel and more than a third of transport fuel consumption and emissions.\textsuperscript{36}

Exhibit 13  International Freight Volumes\textsuperscript{37}

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. Several factors can affect this accessibility:

- **Mobility.** The ease of physical movement, and therefore the quality (availability, frequency, speed, comfort, etc.) of travel modes (walking, bicycling, taxis, 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 14  How Transportation Affects City Size*

Ancient Rome and Paris were walking cities. London and Chicago developed as rail cities. Greater Atlanta is a sprawled, automobile dependent city where it is difficult to live without a car.
During the Twentieth Century, a cycle of automobile dependency and sprawl reduced accessibility, particularly for non-drivers. *Automobile dependency* refers to situations in which automobiles are the dominant travel mode and it is difficult to get around without a personal vehicle.  

*Sprawl* refers to dispersed, automobile-oriented development patterns. These increase automobile travel and reduce the convenience, comfort and safety of other modes, forcing people to drive more than they would choose if given better mobility options. Urban highway and high-volume arterials, large parking lots, and the heavy motor vehicle traffic, noise and air pollution they generated, degraded urban environments, making urban streets and neighborhoods unpleasant and undesirable environments. This created a self-reinforcing cycle of automobile-dependency and sprawl, as illustrated below.

**Exhibit 15** 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 recreation – are located within walking distance, creating what planners sometimes call a 15-minute neighborhood. If connected by public transit, such development patterns create communities that offer a high level of access for non-drivers. Most neighborhoods built between 1950 and 2000 provide far less access to non-drivers than motorists, and less accessibility than they would have had a century earlier. During this period, economic opportunities (jobs, shops and schools) sprawled, making them difficult to access without motor vehicle travel. This resulted from automobile-oriented planning which both allowed and required more dispersion to accommodate wider roads and increased parking, reduced sidewalks and crosswalks, and restrictions on denser development. This trend was compounded by racism and classism, sometimes called “white flight,” which made urban fringe suburbs attractive to middle-class families who wanted the perceived safety provided by isolation from poverty due to high transportation costs, as well as racial covenants which prohibited racial minorities in new developments. Most neighborhoods built during this period are automobile-dependent, designed for driving and difficult to access without a car. This greatly reduce non-drivers’ accessibility and freedom, and impose chauffeuring burdens on motorists.
Exhibit 16  1990-2013 Urban Expansion

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 public policies established during the last century, such as those listed in the box below, favor automobile travel over other modes and sprawl over compact development, reducing non-auto access. 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 17  Common Policies that Encourage Automobile Dependency and Sprawl\textsuperscript{48, 49}

- Transportation planning that favors traffic speed over other goals (affordability, public health, social equity, community livability, environmental protection, etc.).
- Roadway design that gives little consideration to walking, bicycling and public transit needs.
- Zoning codes that limit density and compact housing types, such as townhouses and apartments.
- Development policies that favor urban expansion over compact infill.
- Parking minimums which mandate abundant parking supply, and other parking subsidies.
- Public facilities (schools, post offices, courts, etc.) located to maximize automobile access.
- Dedicated roadway funding, which favors roadway spending over investments in other modes.
- Fuel production subsidies and low fuel taxes.
- Transportation planning that undercounts, overlooks and undervalues non-auto travel.
- 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 underprice automobile travel and fail to respond to consumer demands for non-auto travel – and so result in economically inefficient and unfair transportation.\textsuperscript{50, 51} A rich vocabulary exists for describing overpricing; we say that consumers are “gouged,” “gypped,” and “fleeced,” there are no comparable words to describe underpricing, although it is equally harmful and unfair, since it distorts markets and requires often-regressive subsidies. For example, underpricing parking increases parking demand and therefore 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. This forces people to own more vehicles, drive more, and spend more money on transportation than they prefer.\textsuperscript{52} High levels of automobile travel squeeze out other transportation options, which harms non-drivers and increases many economic, social and environmental costs.\textsuperscript{53}

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.\textsuperscript{54} 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.\textsuperscript{55}
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 (subsequently renamed the Federal Transit Administration) which provides technical assistance and funding to local transit agencies. Several recent trends are started to make communities more multi-modal:

- Urban crime rates declined significantly, making cities more attractive.\(^{56}\)
- 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.\(^{57}\)
- Many communities and transportation agencies started to implement multi-modal transportation planning and funding, complete streets roadway design practices, pedestrian and bicycle planning, and various transportation demand management programs.\(^{58,59}\)
- Development movements, called New Urbanism, Smart Growth, or Transit-Oriented Development are creating more compact, multi-modal communities.\(^{60}\)

As a result, the disparity between drivers and non-drivers has probably peaked in the urban regions that are implementing multi-modal planning and Smart Growth policies. Although in most communities, motorists can access an order-of-magnitude more activities (jobs, schools, stores, etc.) than non-drivers,\(^{61}\) multi-modal urban neighborhoods can 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.\(^{62}\)

**Exhibit 18  Comparing Urban Transit and Suburban Auto 30-Minute Job Access\(^{53}\)**

The “Urban Accessibility Explorer” shows that some urban transit users can access more jobs than suburban motorists.
In summary, this analysis indicates that during the last 120 years, motor vehicle accessibility increased significantly as vehicles and facility improvements, and automobile-oriented planning, while non-auto accessibility declined due to degraded walking conditions, reduced public transportation services, reduced transport network connectivity, plus sprawled development patterns. This created large disparities between motorists and non-drivers. Current planning practices can reverse these trends, but progress is slow and variable, with much better multi-modal access in some communities than others. The following table summarizes these changes.

<table>
<thead>
<tr>
<th>Exhibit 19</th>
<th>Changes in Accessibility</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factor</strong></td>
<td><strong>1900-2020 Changes</strong></td>
</tr>
<tr>
<td>Automobile travel</td>
<td>Vehicle and roadway improvements significantly increased automobile travel speeds and reduced unit costs.</td>
</tr>
<tr>
<td>Automobile parking</td>
<td>Government supplied and mandated parking facilities increases automobile parking convenience and affordability.</td>
</tr>
<tr>
<td>Walkability</td>
<td>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.</td>
</tr>
<tr>
<td>Bikability</td>
<td>Increased vehicle traffic degraded bicycling conditions. In recent years, many communities have started to improve bicycling conditions.</td>
</tr>
<tr>
<td>Public transit access</td>
<td>Public transit service improved 1900-1940, declined significantly 1940-1990, and has improved somewhat since.</td>
</tr>
<tr>
<td>Roadway connectivity</td>
<td>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.</td>
</tr>
<tr>
<td>Local access</td>
<td>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.</td>
</tr>
<tr>
<td>Regional access</td>
<td>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.</td>
</tr>
<tr>
<td>Long distance travel</td>
<td>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.</td>
</tr>
<tr>
<td>Mobility Substitutes</td>
<td>During the Twentieth Century, all types of mobility substitutes improved including fax, Internet and delivery services.</td>
</tr>
<tr>
<td>User information</td>
<td>Transportation information improved modestly during the Twentieth Century, and significantly during the Twenty-First Century with Internet and mobile telephone services.</td>
</tr>
<tr>
<td>Social status</td>
<td>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.</td>
</tr>
</tbody>
</table>

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, safety 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. 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 20 Average Expenditure of 2,567 Workingman’s Families

<table>
<thead>
<tr>
<th>Items of expenditure</th>
<th>Average</th>
<th>Per cent of total expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>$320.90</td>
<td>42.94</td>
</tr>
<tr>
<td>Rent</td>
<td>90.40</td>
<td>12.56</td>
</tr>
<tr>
<td>Mortgages</td>
<td>88.15</td>
<td>1.26</td>
</tr>
<tr>
<td>Interest</td>
<td>8.88</td>
<td>0.19</td>
</tr>
<tr>
<td>Fuel</td>
<td>32.23</td>
<td>4.36</td>
</tr>
<tr>
<td>Lighting</td>
<td>5.15</td>
<td>0.69</td>
</tr>
<tr>
<td>Clothing</td>
<td>29.11</td>
<td>3.90</td>
</tr>
<tr>
<td>Husband</td>
<td>48.25</td>
<td>6.29</td>
</tr>
<tr>
<td>Wife</td>
<td>6.79</td>
<td>0.95</td>
</tr>
<tr>
<td>Children</td>
<td>65.98</td>
<td>8.76</td>
</tr>
<tr>
<td>Taxes</td>
<td>6.57</td>
<td>0.87</td>
</tr>
<tr>
<td>Life Insurance</td>
<td>1.53</td>
<td>0.20</td>
</tr>
<tr>
<td>Organizations:</td>
<td>10.44</td>
<td>1.38</td>
</tr>
<tr>
<td>Labor</td>
<td>3.87</td>
<td>0.50</td>
</tr>
<tr>
<td>Other</td>
<td>5.18</td>
<td>0.67</td>
</tr>
<tr>
<td>Religious purposes</td>
<td>7.29</td>
<td>0.99</td>
</tr>
<tr>
<td>Charity</td>
<td>0.39</td>
<td>0.05</td>
</tr>
<tr>
<td>Furniture and utensils</td>
<td>20.31</td>
<td>2.69</td>
</tr>
<tr>
<td>Books and newspapers</td>
<td>8.35</td>
<td>1.09</td>
</tr>
<tr>
<td>Amusements and vacations</td>
<td>12.55</td>
<td>1.69</td>
</tr>
<tr>
<td>Intoxicating Liquors</td>
<td>12.44</td>
<td>1.62</td>
</tr>
<tr>
<td>Tobacco</td>
<td>10.93</td>
<td>1.42</td>
</tr>
<tr>
<td>Sickness and death</td>
<td>20.64</td>
<td>2.67</td>
</tr>
<tr>
<td>Other purposes</td>
<td>45.13</td>
<td>5.87</td>
</tr>
<tr>
<td>Total</td>
<td>769.54</td>
<td>100.00</td>
</tr>
</tbody>
</table>

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.
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.\textsuperscript{67}

\textbf{Exhibit 22} \textbf{Household Transportation Expenditures}\textsuperscript{68}

Household transportation expenses increased significantly as motor vehicle travel grew.

Typical households now spend 16-18\% of their budgets on transportation.\textsuperscript{69} Vehicle travel also imposes indirect expenses such as residential parking and local taxes spent on roadways, which typically add 10-20\% to housing costs.\textsuperscript{70} The figure below illustrates estimated household transport costs trends.
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.

Most automobile costs are fixed, not significantly affected by the amount a vehicle is driven, as illustrated below. 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.
Motorists on average travel about five times as many annual miles and spend about five times as much money on transport, as people who are car-free. Because of these high costs, automobile travel has relatively low effective speeds, which measures the total of travel time plus time spent working for money to pay travel expenses. Effective speeds vary depending on wage rates, vehicle expenses, annual vehicle travel, and travel mode. The figure below shows the number of minutes spent travelling and earning money for travel expenses for various types of travel.

This figure shows effective speed: the time spent travelling and earning money to pay expenses for various types of travel. Most lower-wage motorists spend more time earning money to pay their travel expenses than they spend travelling, so bicycling and transit are generally faster than driving overall.
Automobile travel effective speed is highly regressive: because they must work much more time to afford their vehicles, lower-income worker’s travel speed is much lower than for higher-income workers. Most lower-wage motorists spend more time earning money to pay vehicle expenses than they do driving. A motorist who earns $10 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, so their effective speed is generally lower than bicycling or public transit as illustrated in the figure below. For most lower-wage workers (under about $20 per hour take-home pay), bicycling and transit are overall faster than driving.

**Exhibit 27  Nominal Versus Effective Speed by Income**

<table>
<thead>
<tr>
<th>Income Level</th>
<th>Effective Speed</th>
<th>Nominal Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10/hr, $5,000/yr, 5,000 miles</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>$10/hr, $3,500/yr, 5,000 miles</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>$10/hr, $1,000/yr, 10,000 miles</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>$10/hr, $50,000/yr, 15,000 miles</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>$10/hr, $200/yr, 2,000 miles</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>$10/hr, $600/yr, 2,000 miles</td>
<td>4</td>
<td>15</td>
</tr>
</tbody>
</table>

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 people would be better off overall if they could choose slower but cheaper travel options.

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, depreciated 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 driven less than 5,000 annual miles, and about $5,000 annually for a vehicle driven 10,000 miles or more. Motorists may spend less than this amount some years, but automobile travel sometimes incurs large, unpredictable expenses including vehicle failure, crashes and traffic citations which can total thousands of dollars a year. Many lower-income motorists spend much more than they can afford due to high vehicle payments or insurance premiums. In addition, residential parking typically adds more than 10% to housing costs, and a larger percentage for lower-priced housing.
The figure below shows the vehicle ownership financial burden by income quintile (fifth of households), based on data from the U.S. Household Expenditure Survey. 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. 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.

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. 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).

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.

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**Exhibit 28** Housing and Transportation (H&T) Affordability by Vehicle Ownership

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.
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. 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 29 Government Transportation Spending Relative to GDP

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 fees, such as fuel taxes, vehicle registration fees and road tolls, cover all roadway costs, but in fact, they only fund about half of U.S. road expenditures. 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 averages 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. Several recent surveys have measured the total effects of these policies. A study by Geography Professor Amélie Y. Davis used detailed aerial photographs to count off-street parking spaces in Illinois, Indiana, Michigan, and Wisconsin. 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, Phoenix, New York, Philadelphia, Seattle, De Moines, and Jackson (Wyoming) 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.
These facilities are expensive. Constructing a parking space typically costs $2,000-10,000 for surface lots and $20,000-60,000 in structures. 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. 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 sort of matching grant for automobile travel.

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.
Exhibit 31  Transit Industry Profitability Trends

<table>
<thead>
<tr>
<th>YEAR</th>
<th>OPERATING REVENUE</th>
<th>OPERATING EXPENSES INCLUSIVE OF DEPRECIATION</th>
<th>NET REVENUE</th>
<th>ALL TAXES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1955</td>
<td>$ 681,400</td>
<td>$ 534,910</td>
<td>$ 146,490</td>
<td>$ 59,460</td>
</tr>
<tr>
<td>1960</td>
<td>737,000</td>
<td>598,630</td>
<td>138,370</td>
<td>42,690</td>
</tr>
<tr>
<td>1965</td>
<td>1,385,400</td>
<td>1,067,140</td>
<td>318,260</td>
<td>164,530</td>
</tr>
<tr>
<td>1970</td>
<td>1,452,100</td>
<td>1,296,490</td>
<td>155,610</td>
<td>89,040</td>
</tr>
<tr>
<td>1975</td>
<td>1,426,400</td>
<td>1,272,270</td>
<td>154,130</td>
<td>93,320</td>
</tr>
<tr>
<td>1980</td>
<td>1,349,500</td>
<td>1,271,360</td>
<td>144,740</td>
<td>89,050</td>
</tr>
<tr>
<td>1985</td>
<td>1,363,000</td>
<td>1,261,360</td>
<td>154,040</td>
<td>87,430</td>
</tr>
<tr>
<td>1990</td>
<td>1,349,500</td>
<td>1,265,850</td>
<td>183,650</td>
<td>77,060</td>
</tr>
<tr>
<td>1995</td>
<td>1,376,400</td>
<td>1,265,900</td>
<td>110,520</td>
<td>64,780</td>
</tr>
<tr>
<td>2000</td>
<td>1,407,200</td>
<td>1,289,850</td>
<td>117,350</td>
<td>86,670</td>
</tr>
<tr>
<td>2005</td>
<td>1,393,700</td>
<td>1,275,770</td>
<td>119,930</td>
<td>77,260</td>
</tr>
<tr>
<td>2010</td>
<td>1,403,500</td>
<td>1,265,900</td>
<td>147,600</td>
<td>77,000</td>
</tr>
<tr>
<td>2015</td>
<td>1,395,600</td>
<td>1,215,560</td>
<td>180,040</td>
<td>78,920</td>
</tr>
<tr>
<td>2020</td>
<td>1,398,100</td>
<td>1,242,280</td>
<td>156,290</td>
<td>77,920</td>
</tr>
<tr>
<td>2025</td>
<td>1,401,600</td>
<td>1,275,760</td>
<td>125,440</td>
<td>80,650</td>
</tr>
<tr>
<td>2030</td>
<td>1,418,500</td>
<td>1,323,270</td>
<td>165,230</td>
<td>91,810</td>
</tr>
<tr>
<td>2035</td>
<td>1,478,500</td>
<td>1,423,260</td>
<td>95,740</td>
<td>91,810</td>
</tr>
</tbody>
</table>

The transit industry earned a healthy 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.

Many transit agencies went bankrupt and became government-supported 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 subsidies. 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 32  Public Transit Service and Subsidies

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 increase 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 33  Public Transit Mode Share Versus Cost Recovery**

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 34  Estimated Per Capita Vehicle and Infrastructure Costs**

As automobile travel grew during the last 120 years, per capita vehicle, road and parking facility costs increased significantly.
This type of analysis is challenging due to limited historical cost data. These impacts can vary by location, demographic group and perspective. 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 these impacts 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.\textsuperscript{104}

These are lower-bound estimates because they only consider direct financial costs. They exclude indirect and non-market external costs such as the congestion, accident risk and pollution damages that automobile traffic imposed on other road users, the environmental and social costs imposed by road and parking facilities, or the various costs of sprawl. Incorporating these impacts would significantly increase the total estimated costs of motor vehicle travel.\textsuperscript{105}

\textbf{Transportation Planning Practices}

During the last 120 years, transportation planning practices evolved in response to changing consumer demands, community goals and technologies. During the last half of the Twentieth Century, transportation planning was automobile-oriented, but in recent decades there have been efforts to support other modes and integrate transport and land use planning, but it will take more decades for changes in planning practices to fully affect day-to-day travel conditions.

\textbf{Exhibit 35} \textbf{Transportation Planning Trends}\textsuperscript{106}

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Major Trends</th>
<th>Modal Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900-1920</td>
<td>Initially focused on rail. “Good roads” movement supported roadway paving and design improvements. Highway departments established.</td>
<td>Initially rail-focused, increasingly multi-modal.</td>
</tr>
<tr>
<td>1920-1940</td>
<td>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.</td>
<td>Multi-modal, with increasing focus on highways.</td>
</tr>
<tr>
<td>1940-1960</td>
<td>1956 Federal Highway act provided funding and technical support to build the interstate highway system. States provided similar highway programs, and local government expanded urban roadways and parking minimums. Highway Capacity Manual standardized roadway engineering practices. Federal Transit Administration established.</td>
<td>Automobile-oriented</td>
</tr>
<tr>
<td>2000-2020</td>
<td>Growing emphasis on multi-modal planning and design including multi-modal level-of-service standards, complete streets design guides,\textsuperscript{107} and multi-modal accessibility models.\textsuperscript{108} A growing number of jurisdictions establish VMT reduction targets.\textsuperscript{110}</td>
<td>Increasing multi-modal</td>
</tr>
</tbody>
</table>

\textit{Transportation planning evolved during the last 120 years in response to emerging travel demands and technologies. Between 1950 and 1990, planning was automobile-oriented with little effort to support other modes, but in recent decades planning has become somewhat more multi-modal.}
Exhibit 36  **Level of Service (LOS) Maps**

<table>
<thead>
<tr>
<th>Automobile Level of Service</th>
<th>Walking and Cycling Level of Service</th>
</tr>
</thead>
</table>

Twentieth Century transport modelling focused on automobile traffic conditions (left), which justified roadway expansions. Newer evaluation tools (right) are more multi-modal, which supports more multi-modal planning.

Planning tools were developed to evaluate transportation problems and impacts. 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, although few communities collect the detailed data needed to effectively evaluate walking, bicycling and public transit quality of service.

**Exhibit 37  Degree that Transport Planning is Automobile-Oriented**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>20%</td>
<td>40%</td>
<td>60%</td>
<td>80%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

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 investments are still devoted to automobiles, and 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 38  Real GDP and VMT Per Capita (1900 – 2018)**

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 motor vehicles are scarce, they tended to be used for high-value travel such as freight transport and buses. However, as vehicle travel grew an increasing portion was for less productive purposes, such as longer-distance commutes and recreational travel, and vehicle traffic can reduce productivity by increasing congestion, accident, and facility costs.\(^ {114}\) Beyond an optimal level, increased vehicle travel is associated with lower GDP, as illustrated below.

**Exhibit 39  GDP and VMT Per Capita**

Automobile mode shares tend to increase with economic productivity up to a peak, after which automobile trips tend to decline as cities become more economically successful.
Economic research suggests that in automobile-oriented communities, increased vehicle travel no longer increases economic productivity, a concept called economic decoupling.\textsuperscript{116} All else being equal, more sprawled, automobile-dependent areas tend to have lower per capita GDP than more compact, multi-modal areas.\textsuperscript{117} The figure below illustrates this relationship. As an urban region’s automobile mode share increases, per capita economic productivity tends to decline. This makes sense because as vehicle travel increases, an increasing portion is used for non-productive uses, such as longer distance commutes and recreational travel. In addition, people who drive less spend less money on imported vehicles and fuel, leaving households with more money to spend on local goods that support more local jobs and businesses. This suggests that in the future, policies that increase transportation system efficiency support economic growth more than policies that increase vehicle travel.\textsuperscript{118}

\textbf{Exhibit 40 Per Capita GDP and VMT for U.S. States}\textsuperscript{119}

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

\textbf{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 displacement. 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,\textsuperscript{120} and why U.S. residents have shorter lifespans than in most peer countries.\textsuperscript{121} Of course, older modes imposed significant harm. Horses, electric trolleys and steam engines caused accidents, pollution and diseases.\textsuperscript{122} According to one study, horse and train travel had higher traffic fatality rates and produced comparable amounts of pollution (waste and soot) per mile as automobiles,\textsuperscript{123} but as motor vehicle travel grew, so did total accidents, pollution and health problems.\textsuperscript{124} 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.
Although many factors affect traffic crash rates, all else being equal, crashes increase with vehicle mileage. Since most casualty crashes involve multiple vehicles, everybody’s risk increases as vehicle traffic grows in an area.

Experts recommend that people engage in moderate physical activity at least 150 minutes per week or 22 minutes per day. In 1900, when walking and bicycling were dominant travel modes, most people easily achieved these targets; now, most automobile-dependent community residents do not. Automobile-oriented transportation reduced walking and bicycling, and therefore public fitness and health. 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. The figure below shows how obesity rates increased in conjunction with growing automobile travel and declining active travel, between 1960 and 2018.
Motor vehicles emit harmful pollutants including particulates, NOx, VOCs, toxins, carbon dioxides and noise. 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. 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. 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. Motor vehicles are also producing about a third of total climate change emissions, the largest single source, and growing.

In addition, motor vehicles damage the environment by increasing the amount of land paved for roads and parking facilities, and encouraging urban-fringe development. Increasing impervious surface area reduces groundwater recharge, increases flooding and stormwater management costs, increases heat island effects (high ambient temperatures in sunny conditions), displaces greenspace, and disrupts habitat. 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. As a result, per capita impervious surface footprint (land covered by buildings, concrete and asphalt) increased significantly during the last century.
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. 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 fill 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 increases 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 travel 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.

Current policies that favor drivers over non-drivers are unfair. 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. Zoning code parking minimums reduce housing affordability and force people who drive less than average to subsidize the infrastructure costs of others who drive more than average. 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, and imposes chauffeuring burdens on drivers.

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 43  Transportation Trends – Winners and Losers**

<table>
<thead>
<tr>
<th>Winners</th>
<th>Losers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorists who drive more than 10,000 annual miles</td>
<td>People who drive less than about 10,000 annual miles</td>
</tr>
<tr>
<td>Higher-income households</td>
<td>Lower-income households</td>
</tr>
<tr>
<td>Vehicle and petroleum industries</td>
<td>People with mobility impairments and special needs</td>
</tr>
</tbody>
</table>

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). 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. This reduction in neighborhood connections tends to increase social isolation, loneliness, depression and crime. 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.”

Conversely, more walking and pedestrian orientation provides “eyes on the street,” which tends to reduce neighborhood crime. Residents of more walkable communities are more likely to know their neighbors, participate politically, trust others, and be socially engaged. 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.”
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.\textsuperscript{161} 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.\textsuperscript{162}

In the past century, automobile-oriented planning often damaged urban neighborhoods by imposing traffic danger, noise, pollution and excessive pavement.\textsuperscript{163} Many of these were well-established African-American, Latinx, Asian and artistic communities, but the problem is not purely racial.\textsuperscript{164} The root of the problem was the assumption by policy makers and transportation professionals that: 1) faster is better than slower, so; 2) automobile travel is better than slower travel 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, 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.\textsuperscript{165} 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.\textsuperscript{166} It fails to respond to critical demands, such as the desire to have neighborly shops, schools and pubs, and therefore a vibrant and inclusive community.

If you evaluate automobile transportation as a technology, these changes are 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 development, testing, approval, commercial release, product improvement, market expansion, differentiation, maturation, and eventually saturation and decline, as illustrated below.

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

Previous vehicles innovations followed this pattern. Below are examples.

- **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.


- **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, only about 1% 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 45 Vehicle Technology Deployment Summary**

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

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

Vehicles are becoming more durable, which reduces fleet turnover. 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 10th year, and 5,000 miles their 15th year, so vehicles over ten years represent about 50% of vehicle fleets but only 20% of mileage. 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.
Criticisms and Reforms
Automobile-dependency and sprawl development have faced their share of pushback. 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.171 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.172

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.173 These apply various roadway design strategies including streetscaping, road diets, traffic calming and road space reallocation. These concepts have been embraced, to various degrees, by transportation professional organizations such as the Institute of Transportation Engineers174 and the National Association of City Transportation Officials (NACTO).175

Criticisms of current practices also lead to development policy reforms that help create more compact, mixed, multi-modal communities, variously called Smart Growth, New Urbanism, Transit-Oriented Development, Location Efficient Development, and 15-Minute Neighborhoods.176 These strategies can significantly reduce residents’ vehicle ownership and use, and increase their use of resource-efficient modes.177 Since 2020, 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.178 Recently, some jurisdictions have eliminated parking minimums.179 These reforms are often described as climate emission reduction strategies, and so tend to be applied initially in jurisdictions with stronger environmental commitments,180 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, majority of transportation funds are still dedicated to roadways and the majority of North American jurisdictions still discourage multi-family housing in most residential neighborhoods and impose parking minimums on property owners, representing a huge subsidy of automobile travel. Most transportation professionals and many public officials support more multi-modal planning and compact development, but face opposition from residents who fear constraints on their driving. This suggests that, for various reasons, public policies and planning practices will gradually shift away from automobile-dependency and sprawl, but these changes will take decades.

This suggests that, in the previously-described cycle of innovations, in most developed countries vehicle travel has reached saturation levels: mobility increased to the point that additional travel provides little incremental benefits and imposes significant costs, so many people would prefer to drive less and rely more on alternatives. Although automobile travel will not disappear, but per capita vehicle travel will decline somewhat as alternatives develop. This suggests that future planning should support more diverse and efficient mobility options to serve consumer demands and community needs.
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. More sprawled development increased travel distances and reductions in non-auto travel options. However, many of these trends are declining or reversing.\(^{181}\)

Aging populations, declining workforce participation, stagnant real incomes, changing consumer preferences, and increased health and environmental concerns are reducing travel demands.\(^ {182}\) New communications technologies and services are reducing the need for physical travel.\(^ {183}\) Youths care more about their cell phones and personal computers than cars,\(^ {184}\) which helps explain younger people’s lower driver’s licensure rates\(^ {185}\) and less vehicle travel compared with previous generations at the same ages.\(^ {186}\) Many urban regions are reaching their limits of geographic expansion, and many jurisdictions have vehicle travel reduction targets.\(^ {187}\) As a result, many jurisdictions are investing more resources in non-auto transportation improvements and transportation demand management programs.\(^ {188}\)

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 46**  Factors Affecting Travel – Past and Future Trends

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

Several factors contributed to increased vehicle travel during the Twentieth Century. Many of these conditions are likely to change in the Twenty-First Century.
Conclusions
Let’s summarize some key insights from this review of the impacts of previous transport innovations.

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 travel modes. Travel became much faster and cheaper. We now travel about ten times faster and farther than in 1900. This huge increase in mobility transformed our lives and communities in countless ways. At the start of the Twentieth Century, most people lived, worked, shopped and played in their neighborhood; by the end of the century it was normal to drive hundreds of miles per week to destinations scattered throughout a region, and to fly thousands of miles for holidays.

Second, 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 somewhat slower after 2000 due to new security, health and environmental requirements. Per capita automobile travel is likely to decline as it is displaced by new technologies that reduce the need for physical travel, and due to vehicle travel reduction policies. Travel could be faster if we were willing to bear higher financial, safety and environmental costs, but there is inadequate public support; few citizens demand, “Please raise my taxes to finance more highway expansions and supersonic jets.”

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 for any reason cannot, should not, or prefer not to drive, plus many motorists, were 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.

Fourth, high levels of mobility do not necessarily reflect consumer preferences. For most of the last century, public policies favored automobile travel and dispersed development over other modes and compact development, creating automobile-dependent communities. 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, walkable neighborhoods, provided these options are convenient, comfortable and affordable.

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, 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?”
Endnotes

1 Various sources.
4 ABW (various years), Bicycling and Walking in the U.S.: Benchmarking Reports, Alliance for Biking & Walking (www.peoplepoweredmovement.org); at http://bikingandwalkingbenchmarks.org.
6 Complete Streets Coalition (www.completestreets.org).
8 Miles Brothers (1906), A Trip Down Market Street, UTube; at www.youtube.com/watch?v=8QSNUr642BU.
14 Jonathan English (2018), Why Did America Give Up on Mass Transit? (Don’t Blame Cars.), Streetcar, bus, and metro systems have been ignoring one lesson for 100 years: Service drives demand,” Bloomberg CityLab (www.bloomberg.com); at https://bloom.bg/2NqYfLS.
15 APTA (various years), Fact Book: Appendix A, tables 8, 62 and 80.
17 FHWA (various years), Highway Statistics, Federal Highway Administration (www.fhwa.dot.gov); at www.fhwa.dot.gov/policyinformation/statistics.cfm). Table HM-212. Early years from the “Summary to 1995.”
24 Assuming 60-80 average daily minutes of walking at 3 mph in 1900. According to the National Household Travel Survey, in 2009 Americans walked or biked 0.37 average daily miles. Pucher, et al. (2011).


29 Based on advertisements from contemporary sources. Also see, Matthew J. Boylan (2013), *Cross Country Travel in 1912*, New York Public Library (www.nypl.org); at www.nypl.org/blog/2013/03/15/cross-country-travel-1912.


51 Shill (2019).


61 See Accessibility Observatory (http://ao.umn.edu) studies which measure accessibility by various modes.


63 http://urbanaccessibility.com


Based on Bureau of the Census (1908), Johnson, Rogers and Tan (2001) and BLS (various years). 1900 vehicle and parking expenses reflect the small portion of households that had horses and carriages for personal use. Indirect costs assume 15% of the 33% of household budgets devoted to housing are devoted to residential parking and property taxes devoted to local road improvements.

Assumes a pedestrian who walks 1,000 annual miles must spend $100 per year on shoes; a bicyclists who rides 2,000 annual miles spends $200 per year on bikes; public transit fares are based on Transit Fact Book (APTA 2020) data; automobiles cost 50¢ per vehicle-mile and carry 1.2 average passengers.

Some costs, such as depreciation and insurance, are partly variable, since more driving increases vehicle wear and the chance of a crash which can raise future premiums, but most motorists underestimate these costs, as described in Mark A. Andor, et al. (2020), “Running a Car Costs Much More Than People Think,” Nature, Vo. 580, pp. 453-455 (doi: 10.1038/d41586-020-01118-w); at www.nature.com/articles/d41586-020-01118-w.

Assumes an average automobile has $4,000 in fixed expenses (financing, depreciation, insurance, registration fees, scheduled maintenance and residential parking, plus 15¢ per mile in operating expenses (fuel and tire wear). Based on Todd Litman, Transportation Cost and Benefit Analysis, Victoria Transport Policy Institute (www.vtpi.org).


Assumes the following average cost and per-mile cost: bicycling 12 mph, 10¢/mile; Public Transit 15 mph, 30¢/mile; Automobile 25 mph.

Henry David Thoreau made a similar argument in the book, Walden, pointing out that the fare for the 30-mile train ride to Fitchburg would require about a day of labor, so walking is actually faster overall. He concluded, “We do not ride on the railroad; it rides upon us.” (www.wired.com/2010/08/0809thoreau-walden-published)


CNT (2018), Housing + Transportation Affordability Index, Center for Neighborhood Technology (http://htindex.cnt.org).

BLS (2018), Consumer Expenditures, Bureau of Labor Statistics (www.bls.gov); at www.bls.gov/cex/home.htm. Assigns total transportation expenses minus transit, plus housing costs to vehicle owning households. Assigns transit costs plus 90% of housing costs (assuming that vehicle parking adds 10% of housing costs) to car-free households.


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97 Roadway costs are based on FHWA (2018), Table HF10 data which indicate that governments currently spend $814 per vehicle on roadways. Parking costs are based on estimates that there are four to eight off-street parking spaces per vehicle with $500-3,000 annualized costs (including land, construction and operating costs), totaling $3,000 per vehicle-year. For more discussion of these costs see Chester, et al. (2015), Litman (2017), and Scharnhorst (2018).
100 APTA (2018), indicates $49,482 B operating expenses, $21,772 B capital expenses, and $16,090 B fare revenue.
101 APTA (various years), Fact Book: Appendix A, tables 8, 62 and 80.
102 APTA (2005).
103 The analysis for this graph is contained in the Estimated Total Costs spreadsheet (https://vtpi.org/ETC.xlsx). It assumes that, adjusting for inflation, vehicle, road, parking and transit unit costs did not change significantly between 1900 and 2020. Although historical cost data are incomplete, available information supports this assumption. For example, although a new Ford Model T was about half the inflation-adjusted price of current cars, fuel tires and repairs were more expensive, so total costs per vehicle-year were similar. Early in the Twentieth Century the standard transit fare was about 1¢ per passenger-mile, which adjusted for inflation is approximately equivalent to the 28¢ per passenger-mile reported in the 2018 APTA Fact Book. Newer building techniques reduced some infrastructure construction costs, but these were offset by higher design standards, so inflation-adjusted infrastructure costs per vehicle-year were probably similar. Roadway costs are estimated to average $855 per vehicle-year in 2020 dollars, based on FHWA Highway Statistics reports. Parking costs assumes there were two off-street spaces per vehicle in 1900, which increased to four by 2000, with $750 average annual cost per space. Vehicle costs assumes $4,806 average annual cost in 2020, based on the U.S. Bureau of Labor Statistic’s Consumer Expenditure Surveys. Transit costs and subsidies are based on APTA Transit Facts from various years.
106 Various sources including APTA (www.apta.com/about/apta-history); McShane (1994); TRB (www.trb.org/History/Blurbs/180180.aspx).
111 Various sources including APTA (www.apta.com/about/apta-history); McShane (1994); TRB (www.trb.org/History/Blurbys/180180.aspx).
125 FHWA 2018, Table Fl-201

152 Litman (2015).


Appleyard and Appleyard (2012).


Brinkman and Lin (2019).


Litman (2020).


Institute of Transportation Engineers, *Complete Streets* (www.ite.org/technical-resources/topics/complete-streets)


Boarnet (2013).


Michael Sivak and Brandon Schoettle (2016), Recent Decreases in the Proportion of Persons with a Driver’s License across All Age Groups, University of Michigan Transportation Research Institute (www.umtri.umich.edu); at www.umich.edu/~umtriswt/PDF/UMTRI-2016-4.pdf.


ELTIS Case Study Database (www.eltis.org) European Local Transport Information Service.