Energy Savings from Information and Communications Technologies in Personal Travel

Shruti Vaidyanathan

December 2014

Report T1401

529 14th Street NW, Suite 600, Washington, DC 20045

Phone: (202) 507-4000 • Twitter: @ACEEEDC

Facebook.com/myACEEE • www.aceee.org

Contents

About the Author

Shruti Vaidyanathan is a senior transportation analyst with ACEEE and is the principal analyst for ACEEE's Greenercars.org, a comprehensive environmental ranking of consumer vehicles. Her recent work has also focused on scoring cities and states on their transportation initiatives as part of ACEEE's State and City Scorecards.

Shruti earned a bachelor of arts in economics with a minor in environmental studies from Grinnell College and a master of science in public policy and management from Carnegie Mellon University.

Acknowledgments

The author gratefully acknowledges external reviewers, internal reviewers, colleagues, and sponsors who supported this report. External expert reviewers included Daniel Becker from the Safe Climate Campaign, Deron Lovaas from the Natural Resources Defense Council (NRDC), Jesse Prentice-Dunn from the Sierra Club, and Anthony Shaw from the Intelligent Transportation Society of America (ITSA). Internal reviewers included Naomi Baum, Neal Elliott, Sameer Kwatra, Therese Langer, Steve Nadel, and Ethan Rogers. External review and support does not imply affiliation or endorsement. Lastly, we would like to thank Fred Grossberg, Kate Hayes, and Roxanna Usher for editing, Eric Schwass for publication design, and Patrick Kiker and Glee Murray for their help in launching this report.

Executive Summary

The transportation sector consumes approximately 28% of total energy used in the United States. Of that 28%, 60% is consumed by light-duty vehicles such as cars, light trucks, and motorcycles (Davis, Diegel, and Boundy 2014). In recent years, the federal government has made significant progress in limiting energy use in personal vehicles through updated mileage and emission standards. Nevertheless, there is still plenty of potential for efficiency improvements in passenger travel.

A comprehensive approach to transportation efficiency requires addressing overall system efficiency in addition to vehicle efficiency. Enter intelligent efficiency, which can address the untapped efficiency potential and reduce overall energy consumption in the transportation sector. "Intelligent efficiency" is a term used to describe information and communications technologies (ICT) that can respond and adapt to external stimuli and predict future outcomes that can help reduce energy consumption (Rogers et al. 2013).

Intelligent efficiency can affect the way people travel by

- Improving driving behavior by providing drivers with real-time feedback on vehicle conditions and fuel economy
- Enabling automatic controls that allow vehicles to drive efficiently without human intervention (e.g., adaptive cruise control)
- Making it easier for people to use alternatives to driving
- Moving traffic away from peak travel times
- Consolidating commuters into fewer vehicles

This report aims to present the reader with detailed information on a sample of ICT-based strategies that are currently in use in the transportation sector and could yield energy savings. These include car and bike sharing, real-time transit information, in-vehicle ICT applications, vehicle-to-vehicle (V2V) communications, and work-based transportation demand management (TDM) programs. We also provide an estimate of energy savings for each strategy in the near term (2015) and the potential for longer term (2030) savings to give readers a sense of what the ICT and transportation landscape could look like by 2030 once a number of applications have been fully phased in.

The strategies discussed in this report demonstrate that ICT can play a significant role in reducing energy consumption in the transportation sector. As highlighted in table ES1 below, the projected savings potential in 2030 from these six measures amounts to approximately 13% if we do not take into account any interactive effects.

Table ES1. Summary of energy savings

ICT strategy	2015 fuel consumption reduction (million gallons)	2030 fuel consumption reduction (million gallons)
In-vehicle feedback	26	2,617
Vehicle-to-vehicle communications	70	2,519
Car sharing	201	4,622
Telecommuting	127	1,127
Transit ridership apps	104	2,057
TOTAL	528	12,942

Source: ACEEE calculations

We should note that the widespread adoption of these programs is not a given. A number of barriers exist to prevent the implementation of ICT-enabled systems that can reduce energy use in the light-duty transportation sector in the United States. As in other energy-using sectors, these barriers prevent us from taking advantage of large opportunities for cost-effective savings. For instance, transportation data need to be made more widely and freely available in order for transit agencies and other third-party implementers to develop user-friendly tools. Additionally, ICT strategies can require significant up-front and operational costs that make them expensive to implement.

Introduction

The transportation sector consumes approximately 28% of total energy use in the United States. Of that 28%, 60% is consumed by light-duty vehicles alone such as cars, light trucks, and motorcycles (Davis, Diegel, and Boundy 2014). The federal government has made major progress in recent years to limit energy use and emissions from personal vehicles. In 2010, the Environmental Protection Agency (EPA) and the U.S. Department of Transportation (DOT) issued harmonized national standards for fuel economy and greenhouse gas (GHG) emissions for model years 2012 to 2016, calling for a fleet-wide average fuel economy of 34.1 miles per gallon by 2016. In 2012, the U.S. DOT and EPA subsequently finalized new standards for model years 2017 to 2025, calling for a fleet-wide average between 48.7 and 49.7 miles per gallon. Complementary GHG emissions standards at levels equivalent to 54.5 miles per gallon were also implemented. In addition to this progress, the state of California has a zero-emission vehicle (ZEV) program that requires increasing production of plug-in hybrid, battery-electric, and fuel-cell vehicles from 2018 to 2025, which many states across the country have also chosen to adopt.

Nevertheless, there is still plenty of potential for efficiency improvements in passenger travel. A comprehensive approach to transportation efficiency requires addressing overall system efficiency in addition to vehicle efficiency. Despite steady growth in the use of public transit over the course of the last 30 years (T4A 2012), and an increasing number of people who bike and walk, driving is still the predominant mode of travel across the country (T4A 2012; Alliance for Biking and Walking 2012). This trend has largely to do with the creation of post-World War II development patterns that require driving to get to most destinations.

Enter intelligent efficiency, which can address the untapped efficiency potential and reduce overall energy consumption in the transportation sector. "Intelligent efficiency" is a term used to describe information and communications technologies (ICT) that have the ability to respond and adapt to external stimuli and to also predict future outcomes that can help reduce energy consumption (Rogers et al. 2013). In essence, intelligent efficiency is the use of cost-effective ICT applications at the system level to save energy system-wide (Langer and Vaidyanathan 2014). Intelligent efficiency can affect the way people travel by

- Improving driving behavior by providing drivers with real-time feedback on vehicle conditions and fuel economy
- Enabling automatic controls that allow vehicles to drive efficiently without human intervention (e.g., adaptive cruise control)
- Making it easier for people to use alternatives to driving
- Moving traffic away from peak travel times
- Consolidating commuters into fewer vehicles

Hence there are multiple opportunities for the application of intelligent efficiency strategies to personal transportation.

What Is Intelligent Efficiency?

The growth of ICT applications in recent years has made system-wide efficiencies and reductions in energy use much more feasible. Such applications have allowed for equipment used in buildings, transportation, and manufacturing to be more adaptive to and anticipatory of environmental changes, in addition to being integrated with other components of the system (Rogers et al. 2013). Intelligent efficiency approaches allow for the improvement of overall productivity and efficiency in the following ways:

- Savings can be achieved at the system level.
- Intelligent efficiency uses highly efficient ICT-based technologies.
- By keeping the goal of the system in mind, intelligent efficiency optimizes the system components to achieve those goals. (Rogers et al. 2013)

Nevertheless, despite the benefits to be gained by implementing intelligent efficiency strategies, there are a number of reasons why these approaches have not seen widespread adoption. Like many cost-effective efficiency strategies, a number of barriers stand in the way of implementation (Vaidyanathan et al. 2013). Barriers to intelligent efficiency include imperfect information on the part of consumers and policymakers regarding intelligent efficiency and its benefits, the high up-front costs of researching and developing ICT-related systems, and regulatory obstacles that make implementing intelligent programs difficult (Rogers et al. 2013). Additionally, in the transportation sector, cultural barriers that place an importance on vehicle ownership and the perceived freedom that comes from driving can make implementing ICT-based strategies a challenge.

The Development and Rise of ICT Systems and Networks

Much of the discussion about intelligent efficiency and ICT-enabled applications in energy efficiency has come about thanks to recent innovations such as machine-to-machine communications and ubiquitous connectivity to the Internet. The growth of telecommunications services and social networking platforms in addition to the increased availability of data has changed the way people live, work, and commute on a daily basis. For example, ICT applications in transportation free many American households from the need to purchase and maintain a personal vehicle by making alternative modes of transportation viable options for more people (U.S. PIRG 2013).

The boom in Internet use in the United States started in the early 2000s with the advent of faster Internet speeds, allowing consumers to use the web in a greater variety of ways. The most recent survey by the Pew Research Center's Internet & American Life Project shows that currently 87% of all American adults use the Internet on a regular basis (see figure 1). The Internet is the primary way people disseminate and create information, learn about new issues or services, and communicate with others (Pew Research Center 2014). Internet use grew particularly rapidly between 1995 and 2005, up from 14% to 66% in those years, respectively. As demand for the Internet has risen, so has the proliferation of Internet providers, technologies, and services. Today's average American can choose among regular dial-up Internet (however antiquated), DSL, broadband Internet, and fiber-optic services.

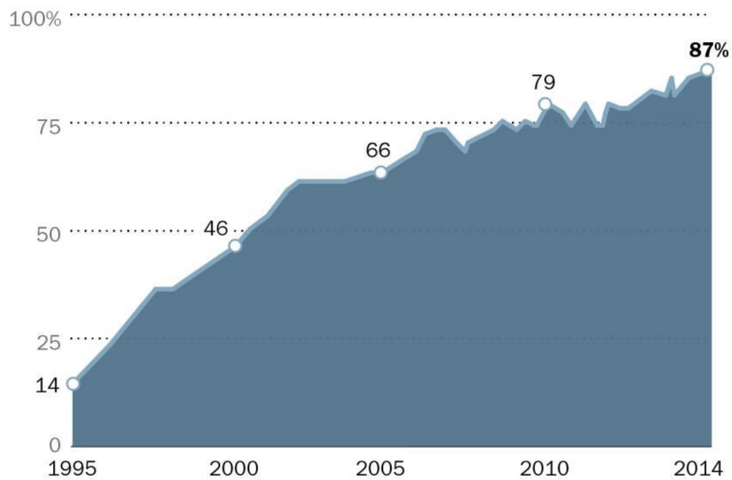

Figure 1. Percentage of Americans who use the Internet: 1995–2014.
Source: Pew Research Center 2014.

Also key to the development of ICT-enabled applications has been the growth in smartphone use in the United States. Smartphones allow for instant access to up-to-the-minute information on the Internet in addition to serving as location-aware devices (U.S. PIRG 2013). As of 2013, the Pew Research Center estimated that approximately 61% of all cell phone owners were smartphone owners (Pew Research Center 2013). Figure 2 breaks down the center's survey results by age and income bracket for a clearer picture of smartphone ownership in the United States.

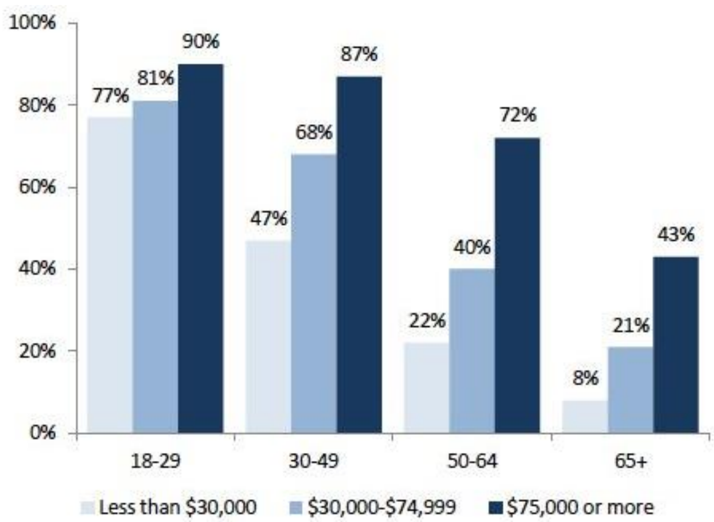

Figure 2. Smartphone ownership in 2013 in the United States by age and income bracket.
Source: Pew Research Center 2013.

The prevalence of smartphone adoption is highest in the 18–29 age group, with little variation between income brackets, suggesting that young adults are largely leading this technology sea change. In any case, telecommunications have advanced sufficiently to allow for the development of new and interesting applications that make use of freely available data to provide consumers with information and feedback at the touch of a button.

ROLE OF ICT IN TRANSPORTATION

ICT strategies in the light-duty transportation sector can be quite varied. ICT-enabled devices help drivers drive more efficiently but can also reduce the need to drive altogether and provide commuters with alternatives to using single-occupancy vehicles. The ICT strategies included in this report fall into the following categories:

1. Car and bike sharing
2. Real-time transit information
3. In-vehicle ICT applications
4. Vehicle-to-vehicle communications
5. ICT and transportation demand management (TDM) programs

This report aims to present the reader with detailed information on the above sample of ICT-based strategies that are currently in use in the transportation sector. We also provide an estimate of the energy savings for each strategy in the near term (2015) and potential savings in the longer term (2030) under an aggressive implementation scenario to give readers a sense of what the ICT and transportation landscape could look like by 2030 once a number of applications have been fully phased in. For each category, the report provides a description of the approach, the role of ICT in the approach, and a projection of the associated energy savings. The projections are meant only to illustrate a plausible scenario in which ICT-based strategies strongly influence personal travel. It is important to keep in mind that the technologies and examples discussed here do not cover the universe of ICT strategies that could be implemented in the transportation sector.

Car and Bike Sharing

Car and bike sharing programs have become very popular in many large urban centers across the United States. These programs offer a comprehensive network of shared vehicles that serve as alternatives to vehicle ownership or use. Insurance and parking rates tend to be high in city centers, making owning and using a car an expensive proposition. Bike sharing programs encourage use of alternative modes of transportation, while car sharing removes the onus of owning a vehicle by providing members with shared access to vehicles as and when they need them. Both cars and bicycles are available for short, spontaneous trips. While car sharing may increase vehicle miles traveled (VMT) of users who do not own cars, it can save energy overall by reducing car dependence. (VTPI 2014). Bike sharing can move some travel from cars to a zero-emission mode of transport, although its primary effects on transportation behavior are more complex. ICT applications are crucial for bike and car share members as they enable them to locate vehicles in the vicinity as well as identify return points. Modern bike sharing programs that take advantage of communications technology have started to appear all over the country, with as many as 30 programs in existence by 2013 (U.S. PIRG 2013). While energy benefits are generally difficult to pinpoint given the very recent emergence of these programs, surveys conducted in New York and Washington, D.C. indicate that 5% of bike share members have sold their personal vehicles since joining the program. Additionally, 25% of D.C. members and 40% of New York members report driving less as a result (U.S. PIRG 2013).

Real-Time Transit Information

Real-time transit data have become critical to transit commuters across the United States. Faced with the need to get to their destinations in a timely, efficient manner, commuters can benefit greatly from bus and train tracking systems, dynamic transit maps and schedules, and fare-based applications to navigate growing transit systems. Transit authorities also recognize the importance of such tools to commuters, and a growing number of urban transit companies have begun to invest heavily in the development of applications that interact with the user through GPS or smartphone interfaces to provide them with real-time feedback on transit arrivals, departures, stop locations, and interruptions. As data become available more widely, transit providers will be able to provide up-to-the-minute information needed to navigate transit systems efficiently, which is integral to moving commuters away from single-occupancy vehicles.

In-Vehicle ICT

Vehicle dashboards that provide drivers with real-time information about fuel economy and driving habits are another example of intelligent efficiency in the transportation sector. With competition for market share so fierce between auto manufacturers in the United States, in-vehicle technologies have become an important aspect of attracting buyers. While in most cases this means providing drivers with amenities such as in-vehicle video and music systems and hands-free calling, a number of manufacturers also have installed dashboards that interact with drivers to provide them with feedback on fuel economy and vehicle performance. Ford's standard-option SmartGauge EcoGuide interactive dashboard uses audio and visual cues to help drivers track instantaneous miles per gallon (mpg) in addition to average mpg over a period of time (Ford 2014), encouraging them to adjust their driving habits and techniques to maximize their vehicles' fuel efficiency.

Vehicle-to-Vehicle Communications and Driver Assist Technologies

Vehicle-to-vehicle communication (V2V) involves the dynamic, wireless exchange of data between vehicles that are using the same route or roads. Driver-assist technologies sense the conditions around a given vehicle to allow for adjustments in the vehicle's motion. These technologies have the potential to improve safety as well as fuel efficiency (DOT 2014a). V2V systems allow vehicles to talk to each other about their speed and upcoming traffic conditions, as well as potential road obstacles, thus reducing emissions, fuel consumption, and the potential for congestion (Bullis 2011).

V2V and driver assist systems are still in the experimental stages for personal vehicles, although more progress has been made in communication between vehicles in the commercial vehicle sector. Successful tests of such systems have been conducted in the EU and Japan, in which distances between vehicles were reduced to approximately 33 feet, thus improving the overall efficiency of the highway system (Jeschke 2013). The eventual vision for V2V systems could include not only vehicle-to-vehicle data exchange but also vehicle-to-infrastructure sharing.

ICT and Transportation Demand Management (TDM) Programs

Transportation demand management (TDM) strategies focus on reducing or changing travel patterns during peak commute times to make more efficient use of the roadway system (MRSC 2014). TDM approaches include such commute trip reduction strategies as telecommuting and flexible schedules, in addition to carpooling programs, shuttle services, and transit fare benefits. TDM programs can be initiated by local governments or employers, but the most successful programs include collaboration between both sets of stakeholders. Local governments have an important role to play in providing incentives and financing for TDM programs, which can often require a great deal of coordination and startup. The arrival of web-based communication services that allow commuters to coordinate travel with co-workers as well as telecommute from home has the potential to greatly increase the effectiveness of TDM programs.

Car and Bike Sharing

ICT DEVELOPMENTS

Car Sharing

Car sharing services provide drivers with access to shared vehicles on an hourly basis as an alternative or supplement to vehicle ownership. Car sharing programs essentially provide a vehicle where and when a given driver requires one. The emergence of companies such as Zipcar and Car2Go in recent years indicates that these programs are becoming more popular with metropolitan residents who don't want the cost and maintenance burden of owning underutilized personal vehicles.

Car sharing is concentrated in metropolitan areas and is only really effective in neighborhoods where walking, biking, and transit are viable alternatives to driving vehicles. These programs cannot compensate for auto-oriented land-use planning and policies, because they are designed to provide vehicles for only occasional use (TRB 2005).

The car sharing landscape has been dominated in recent years by a few select companies that have worked to develop business by coordinating with municipal governments. These companies include Car2Go, Zipcar, Enterprise CarShare, and Hertz On Demand. Car2Go and Zipcar follow similar models: customers pay an annual fee and are charged an hourly rate to rent vehicles when they are used. Zipcar users are required to pick up and return the vehicle to a designated Zipcar parking spot, while Car2Go users are allowed to return vehicles to any parking spot at the end of their trips. Enterprise CarShare and Hertz On Demand are newer programs run by car rental companies with a smaller market share. Like Zipcar, Enterprise and Hertz vehicles must be returned to a designated parking spot.

Car sharing programs rely on Internet-based platforms that allow users to do the following:

- Identify the location of available vehicles
- Locate drop-off points
- Report issues with vehicles used
- Pay for vehicle rentals

Car sharing services include the additional step of assigning members cards that contain a chip the car recognizes once it has been reserved (U.S. PIRG 2013). Car2Go's official app allows for total web mobility by allowing users to find the closest available vehicle and book it on the spot or in advance on their smartphone (Car2Go2014). Likewise, Zipcar's mobile app allows drivers to find available cars and reserve them in addition to letting drivers honk the vehicle's horn remotely to identify its location (Zipcar 2014). Car sharing programs further simplify the process of renting a vehicle by covering gas, insurance, and daily mileage until a certain cutoff. In order to do so, membership cards record information on driving habits, mileage, and fuel use using incorporated smart chip technology.

Bike Sharing

Like car sharing, bike sharing programs provide commuters and city residents with an additional travel option for short trips. Bike sharing systems operate by providing publicly accessible shared-use bicycles within an urban environment that are available for short, spontaneous trips.

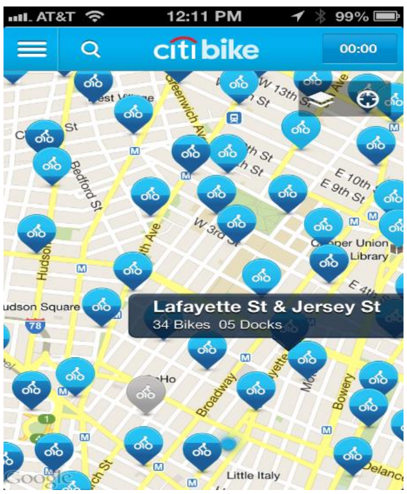

Figure 3. Citi Bike Share app interface. *Source*: NYC Bike Share

Critical to the success of modern bike sharing programs has been the development of Internet-enabled and smartphone-based applications that allow users to access a number of functions remotely and instantly. Most programs across the country involve the strategic placement of kiosks with docks that hold multiple bicycles. These kiosks are equipped with ICT services that allow kiosks to talk to each other and to a central server to ensure that staff can appropriately distribute bicycles among the kiosks (Sherman 2011). Additionally, users can download apps to locate the closest kiosks with available bicycles or empty slots where bikes can be returned (see figure 3). Bike sharing members are also provided with fobs to unlock bike stations in addition to allowing the company to collect information on the frequency of trips, length of the average trip, and overall miles traveled per month (Capital Bikeshare 2014). Capital Bikeshare has been making this data available to the public through its online Dashboard, allowing people to track biking habits within their communities (Capital Bikeshare 2014). Open access to information is critical to making both car and bike sharing programs an effective alternative to personal vehicle ownership and use if members are able to locate available vehicles at the touch of a button.

PREVALENCE AND NEW DIRECTIONS

Car sharing services are burgeoning across the United States. Approximately 50 cities in the United States have car sharing programs in operation. These include larger metropolitan centers such as New York City and Washington, DC, in addition to smaller urban areas such as Madison, Wisconsin; Gainesville, Florida; and Portland, Maine (Carsharing.net 2014). BMW is considering bringing its short-term car rental business to 10 locations in the United States in order to attract younger drivers (Automotive News 2014), and Car2Go will be expanding into Saint Paul, Minnesota, and the South Bay area of Los Angeles in 2014 (Mai-Duc 2014; Cox 2014). The largest all-electric car sharing fleet, BlueIndy, is set to launch in Indianapolis later this year as well.

Bike sharing programs are largely operated by two companies: Alta Bikeshare (often in collaboration with Bixi) and B-Cycle. Alta and Bixi are responsible for the successful operation of the two most commonly recognized bike share programs in the country, Capital Bikeshare in Washington D.C., and New York City's Citi Bike. As of 2013, 41 cities across the United States had a fully operational bike sharing program, with several more on the books for 2014 (Pedestrian and Bicycle Information Center, 2014a). See figure 4.

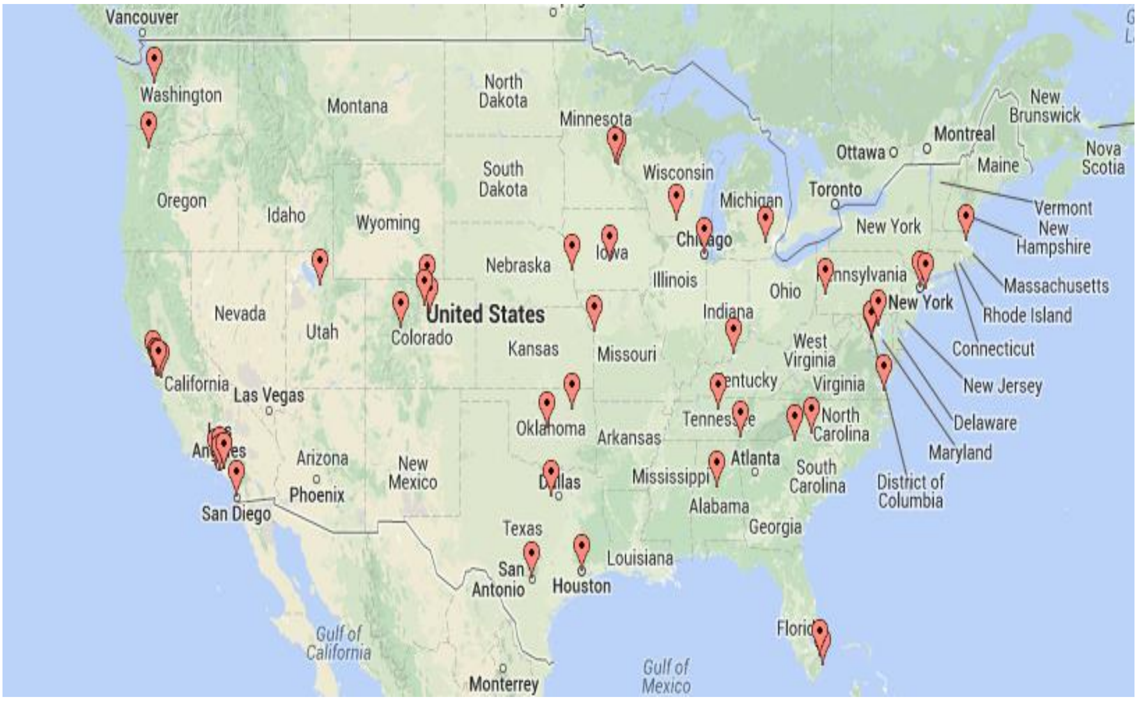

Figure 4. Locations of bike sharing programs across the United States. *Source:* Pedestrian and Bicycle Information Center (2014b).

The growth in bike sharing membership has been significant. The 2013 Capital Bikeshare Member Survey reported 22,000 members between Washington D.C., Arlington County, and the city of Alexandria (Capital Bikeshare 2013). After 11 months in operation, the Citi Bike program in New York City reported 105,367 members in April 2014 (NYCBS 2014). Likewise, car sharing services have proliferated and performed admirably in the last few years. Car2Go has 216,000 members across the United States as of January 2014 (Blanco 2014).

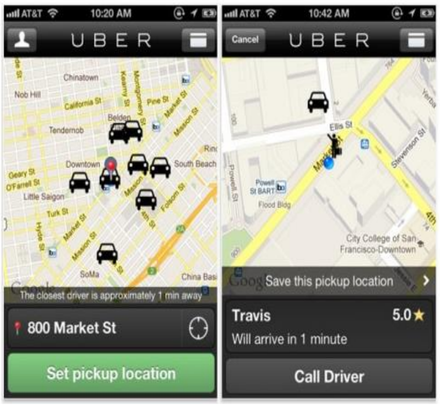

Figure 5. Uber smartphone interface. *Source:* Uber.

The success of these programs indicates that bike and car sharing can be implemented in cities where the demand exists for easy-to-use alternatives to owning personal vehicles. Plans are in the works for bike sharing programs in Pittsburgh, the King County region of Washington, and Baltimore (Larsen 2013).

Also part of the discussion of the future growth of shared mobility options are services such as Uber and Lyft. While not exactly car sharing programs, Uber and Lyft both provide feasible alternatives to car ownership by offering ride sharing services (see figure 5). Uber and Lyft started off as a network of professional drivers to ferry customers from one place to another at a fee significantly lower than regular taxi services. Recent developments in the business model allow for nonprofessionals to offer taxi services as long as they pass a thorough background check. These programs are poised to become a significant and necessary component of the conversation about vehicle sharing.

ENERGY SAVINGS

Car sharing enables some households to give up owning a first, second, or third vehicle and to rely on alternative modes of transportation for most travel. Results from the North American Shared Use Vehicle Survey show that the average number of vehicles per member household dropped from 0.47 to 0.24 after joining a car sharing program (Martin, Shaheen, and Lidicker 2010). Information from City CarShare, a nonprofit car sharing company that serves the Bay Area, states that each car share vehicle replaces approximately 6.9 privately owned vehicles (City CarShare 2011).

Car sharing could increase some users' vehicle-miles traveled (VMT) since it might allow people without cars to drive. At the same time, car sharing could decrease overall VMT by encouraging other users to give up owning cars and drive less (Lovejoy, Handy, and Boarnet 2013a). To estimate the impact of car sharing on energy use in the United States, we used historical car sharing membership data (Shaheen and Cohen 2012) to create a projection of car sharing membership out to 2030. Historical data were available from 1998 to 2012 and were collected directly from each car sharing operator in North America. We assumed a constant 29% annual growth rate until 2020 based on the increase in membership between 2011 and 2012. To give a sense of what widespread adoption of car sharing could achieve post-2020, we assumed that by 2030 half of all non-rural households had one car share membership and applied a constant growth rate of membership between 2020 and 2030 to achieve that outcome. Energy savings figures were obtained from Lovejoy, Handy, and Boarnet (2013), based on one of the few existing studies estimating the impact on individual drivers of having a car share membership (Lovejoy, Handy, and Boarnet 2013a). A 2011 study carried out in multiple cities across the United States showed that participants saw a statistically significant average reduction in VMT of 26.9% after joining car sharing services. We applied these savings to the average VMT per capita (based on our estimate of

2030 membership) to obtain a total reduction in VMT and gasoline consumption. Estimates of near-term and long-term energy savings are shown below in table 1.

Table 1. Energy benefits associated with car sharing in 2030

Benefits	Amount
Average reduction in energy use per car share member *	26.9%
Estimate of car sharing membership in 2030	60 million
2015 gasoline savings (million gallons)	201
2030 gasoline savings (million gallons)	4,622

* Lovejoy, Handy, and Boarnet 2013a

Bike sharing has been shown to increase mobility, increase use of public transit, and reduce overall energy use within a metropolitan area (Shaheen, Cohen, and Martin 2012). To estimate benefits from ICT-enabled bike sharing programs, we relied on estimates of energy savings from the District of Columbia Department of Transportation (DDOT). As part of a discussion of energy savings initiatives, the DDOT estimates that each bicycle sharing station saved an average of 155 gallons of gasoline between 2010 and 2012 based on the assumption that 20% of the 1.5 million miles traveled per year on Capital Bikeshare were transferred from car use to bike sharing (DDOT 2012). This estimate of savings is based on a Capital Bikeshare customer relations survey issued in the early days of the program (DDOT 2012).

We applied these savings to a projection of bicycle sharing stations out to 2030 to determine overall energy savings. We based this projection on data for 2013 from transportation planners at the Arlington County Department of Transportation (Malouff 2014). Between 2013 and 2014 we applied a 57% growth rate in the number of bike stations based on historical growth rate estimates (Schmitt 2013). We then phased down the growth rate gradually between 2014 and 2019 and held constant the number of bike stations until 2030. Table 2 below shows the resultant energy savings associated with bike sharing.

Table 2. Energy benefits associated with bike sharing in 2030

Benefits	Amount
Average net energy savings	<1%
Estimate of bike sharing stations in 2030	11,000
2015 gasoline savings (million gallons)	0.7
2030 gasoline savings (million gallons)	1.7

Source: DDOT 2012

This approach suggests very modest fuel savings from bike sharing. However, it is difficult to draw conclusions about the energy benefits associated with bike sharing because bike sharing is only now taking off in the United States, and the bike sharing landscape is changing rapidly. Bike sharing draws riders who would typically use a variety of other modes of transportation and can also boost the effectiveness of other modes, for example, including by providing last-mile transport to complement public transit options, Given the very small savings shown in table 2, we do not show bike sharing separately in our summary table of total energy savings, though we note that it could become a key element of the increasingly connected multimodal urban transportation system of the future.

OVERCOMING BARRIERS TO ADOPTION AND INCREASED ENERGY SAVINGS

Culture, perception, and habit may create barriers to greater use of both car and bike sharing. Many people assume that not owning a vehicle makes traveling a hassle. For instance, drivers may see car sharing and bike sharing programs as inherently unreliable modes of transport if vehicles are not necessarily available when they need them. However, this is where Internet and mobile technology become crucial to increasing the spread of such transportation options by providing users with exact, up-to-the-minute information about the location and availability of vehicles in the vicinity and showing potential members that these services can indeed be reliable alternatives (U.S. PIRG 2013).

For services such as Uber and Lyft, the regulatory framework could pose an additional barrier. In recent months, these services have come up against a number of legal hurdles designed to protect taxi operations and drivers. Uber, for instance, is banned from operating in Miami and has recently fought fines and bans in Chicago, New York, and Toronto for operating without a valid taxicab license (Downes 2013). Cab drivers in several cities across the United States have also been participating in regular protests against these shared-use services (Hu 2014). However, cities are taking steps to accommodate new transportation options. For instance, in 2012, the Washington D.C. city council created a new class of digitally dispatched services as part of its city code to accommodate the rise of services such as Uber and Lyft (Downes 2013).

Transit Ridership Services and Applications

ICT DEVELOPMENTS

Greatly enhanced collection and deployment of data have increased the possibility of developing applications to track a bus's or train's progress and to plan a travel route (U.S. PIRG 2013). As a result, a number of transit authorities across the country have begun investing in the development of consumer-friendly transit information applications that enable commuters to more easily use transit services.

Transit authorities provide travelers with either static or real-time (dynamic) information. Static information such as bus and train schedules or system maps can be made available to users through the Internet and smartphones. Real-time information uses telecommunications technology to actually track the location of a given mode of transit, allowing users to make quick decisions about their transit choices (U.S. PIRG 2013).

These interfaces are also often smartphone enabled, allowing commuters to plan on the go, change routes, and receive information on interruptions to service. Additionally, a number of agencies have made schedule data available to services such as Google Maps and MapQuest, which also include public transportation trip-planning features. Transit authorities can make use of communication technologies in a number of ways including

- Route planning and location services
- Real-time arrival and departure information
- Fare service options

Route Planning and Location Services

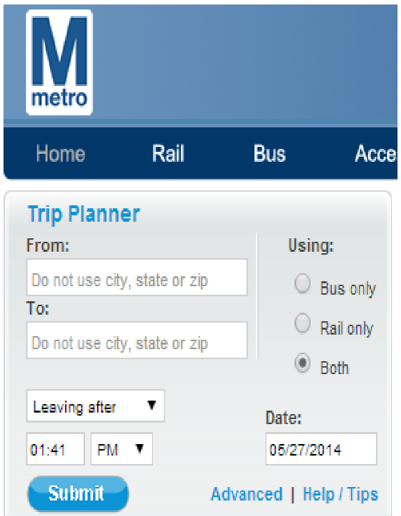

Figure 6. WMATA trip planner interface. *Source*: WMATA.com

Long headways, uncertain arrival times, and the prospect of multiple transfers all serve as disincentives for some to choose transit, encouraging them to rely on driving as their primary means of travel. At the very basic level, most agencies provide static maps and schedules online for commuters to refer to before they start their trips. More recently, transit websites have started to include user interfaces that provide exact directions and schedule information. The Washington Metropolitan Area Transit Authority (WMATA), which operates train and bus services (and soon, streetcars), has used available data to develop a variety of real-time, Internet-based services to make transit more attractive, feasible, and convenient (see figure 6). WMATA's apps equip riders with the information they need to navigate the transit system through a number of next-generation communication technologies (WMATA 2014a).

Real-Time Arrival and Departure Information

Part of the attraction of the car as a mode of transport is the ability to control your personal schedule and to know your general time of arrival. While urban transit systems do provide static information to commuters, in order to successfully shift travel from personal vehicles to public transit, commuters need access to real-time information. Taking advantage of up-to-the-minute data obtained from GPS systems on buses and trains, transit agencies are now able to provide commuters with dynamic information about arrivals, departures, and travel time. The Chicago Transit Authority (CTA) has contracted with application developers to come up with a variety of tracking apps that suit various needs (see figure 7).

AnyStop Chicago

Made by: Blinktag, Inc.

What it does: Shows scheduled bus and train arrivals and can use device location data to find routes and stops near you and display these on a map.

Notes:

Attractionseeker

Made by: Attractionseeker

What it does: Lets you search for local attractions and events, find discounts and provides easy access to get estimated arrivals for bus & train stops.

Notes:

Chicago Transit Tracker

Made by: jsdf, llc

What it does: Shows estimated arrivals for favorite or nearby bus or train stops, uses device location data, mapping, service alerts, shows time and date.

Notes:

FastTimes

Made by: Mike Kelley

What it does: Provides live bus and train predictions as well as a map with buses and transit stops. Users can easily add favorite 'L' and bus stops to the app homescreen.

Notes:

Figure 7. Sampling of CTA transit tracking applications. *Source:* CTA 2014.

Fare Service Options

A number of transit agencies have transitioned away from paper tickets to chip-enabled fare cars that can store information on travel habits and spending and are easily refilled online. WMATA's SmarTrip card (see figure 8) is a microchip-enabled device that allows Metro (subway) and bus riders to pay fares, track spending, monitor usage history, and recover the balance from lost cards. The card is accepted on multiple transit systems throughout Washington D.C., Virginia, and Maryland and makes transferring from one system to the next particularly easy for commuters. Additionally SmarTrip users pay less when travelling and transferring than those with paper fare cards. Paying with a SmarTrip card saves riders $1 a trip on the Metro and 20 cents per trip on the bus. Likewise, the Southeastern Pennsylvania Transportation Authority (SEPTA), which serves the greater Philadelphia area, will be rolling out its New Payment Technologies (NPT) program that will phase out paper tickets and tokens in favor of automated "contactless cards" that will be accepted on multiple transit lines (SEPTA 2014).

Figure 7.WMATA SmarTrip card. *Source*: WMATA

PREVALENCE AND NEW DIRECTIONS

Internet-based and smartphone-enabled services have become commonplace within most transit agencies and systems. According to U.S. PIRG and Frontier Group, more than 60% of all transit agencies in the country now provide their commuters with real-time information that they are able to access instantly through their smartphones (U.S. PIRG 2013). WMATA is a good example of such a transit agency. WMATA currently serves a population of 5 million, and average weekday daily ridership of the Metro in 2013 was approximately 726,000 passengers (WMATA 2014b). Weekday average bus ridership for fiscal year 2012 amounted to 438,000 trips across the whole bus system between DC, Virginia, and Maryland (WMATA 2014c). As the second largest subway system in the United States behind New York City, Metro has plenty of opportunity to encourage use by making travel easy.

Moving beyond single-system apps, a number of developers have gone so far as to create national transit apps that consolidate information for a range of transit systems across the United States. Anystop, an Android-based transit app, uses a device's GPS function to identify the transit options available in the vicinity of a user's location (Tedeschi 2010). The app covers 125 transit agencies and also has arrival and departure predictions for more than half of those agencies, giving users a single access point to accurate, real-time data for transit services in a variety of cities, thus encouraging the use of transit over personal vehicles (Tedeschi 2010). At the city level, Chicago has a comprehensive system of apps that covers all four major Chicago transit systems (CTA buses and trains, Pace, and Metra) and includes such features as reminders as to when to get off the bus or train (ITS 2014). Similarly, the Portland TriMet transit system has a number of apps that provide users with information regarding arrival and departure times as well as route information and trip planning for the Portland Transit Authority as a whole.

Programs such as RideScout are a sign of what is to come. They go one step further by collating information for a variety of transportation options to inform the user of the easiest route from point A to point B given the time of day and traffic conditions (RideScout 2014). RideScout goes one step further than Google Map services by factoring cost into the matrix of conditions to help determine the best mode of transport.

ENERGY SAVINGS

One of the attractions of driving even in transit-connected areas as the primary means of commuting or running errands is the ability to maintain control over a personal schedule and time constraints. Using communications technology to provide existing and new commuters with useful, accurate real-time data has therefore become a critical part of transit authority approaches to boosting ridership and shifting travel from personal vehicles to public transit. These apps not only provide existing commuters with real-time information but can also attract new riders by reducing wait times, increasing predictability, and helping to coordinate connections. An increase in overall ridership can have significant energy impacts.

Research suggests that transit systems that provide real-time transit information see more growth in ridership than those that rely on traditional forms of information dissemination (Jaffe 2012). A study of the Chicago Transit Authority's Bus Tracker system found that the system has managed to attract a significant number of new riders (Tang and Thakuriah 2012). Using longitudinal data on weekday ridership, the study evaluates the impact of a real-time bus information system for the Chicago Transit Authority (CTA) bus network. Results from the analysis show that ridership increased by 2%. This is one of the only studies available that quantifies the ridership impacts of Internet-based transit information systems, and the authors note that these results may not be indicative of the impacts that ICT-enabled services can have on transit ridership going forward.

To create a scenario that captures the impact transit user applications could have on ridership, we first created a baseline projection of transit's share of urban VMT by using current data and a growth rate of 1.4% out to 2030. This 1.4% growth rate was derived from transit ridership data between 2007 and 2012 (APTA 2014). This yields a 25% increase in the urban transit mode share by 2030. We then assumed that the optimal implementation of user apps and complementary services—such as bike sharing that can provide first- and last-quarter-mile connection—results in a doubling of the transit share of urban VMT by 2030 instead of the business-as-usual increase of 25%. An estimate of the energy savings associated with implementing ICT-based transit ridership services and applications (net of fuel used by transit) are estimated in table 3 below.

Table 3. Energy benefits associated with increased use of transit ridership applications in 2030

Benefits	Amount
Transit share of urban travel in 2030 with ICT *	8%
Transit passenger miles in 2030 (billion miles)	71.3
2015 gasoline savings (million gallons)	104
2030 gasoline savings (million gallons)	2,057

* ACEEE estimate derived from growth rates in APTA 2014.

OVERCOMING BARRIERS TO ADOPTION AND INCREASED ENERGY SAVINGS

The barriers associated with developing and implementing user-based ICT applications to navigate transit systems are twofold. Firstly, the availability of data necessary to operate these apps is not as widespread as it could be. While system data are critical to improving transit services and cost-effectiveness, transit providers have been slow to capitalize on the amount of data that their systems generate. However, as companies such as Google begin to use this data, apps will become more widely accessible as long as transit agencies continue to make data available to third-party users (U.S PIRG 2013).

Secondly, the costs involved in developing and proliferating these apps can vary significantly from transit agency to transit agency, which suggests that up-front costs could be high (TCRP 2011). Beyond contracting with developers, there are costs associated with marketing and promoting these apps in order to inform current commuters and attract new ones.

With so many agencies across the country already investing in the research and development of such applications, transit providers are likely to continue providing riders with the information they need to use transit systems efficiently and effectively as data become more widely available.

In-Vehicle Feedback Options

ICT DEVELOPMENTS

Much has been done in recent years to improve the efficiency of the American vehicle fleet through fuel economy regulations. However, the fuel efficiency of a vehicle also depends to a great extent on the way the vehicle is driven and the driving conditions. For instance, driving at 75 mph instead of at the national average speed limit of 65 mph can reduce fuel economy by approximately 10% (Greenercars.org 2014). Likewise, keeping a vehicle properly maintained and tuned up, in addition to keeping tires properly inflated, will go a long way to improving a vehicle's fuel efficiency.

However, drivers do not always have the information they need to adjust their driving behaviors to maximize vehicle fuel efficiency. This information gap can be filled by what is generally called "eco-feedback" technology (Froehlich, Findlater, and Landay 2010). Assuming that people lack awareness and understanding of how their behaviors (e.g., driving) interact with the environment, eco-feedback technology provides the appropriate feedback through smartphones and digital displays (Froehlich, Findlater, and Landay 2010). Instantaneous fuel economy readouts in vehicles are a perfect example of these eco-feedback technologies; many auto manufacturers are making these dashboard systems standard in their vehicles. Such technology allows for vehicle-driver interaction and prompts drivers to adjust their driving behavior and performance in response to information received from the onboard digital display (Tulusan et al. 2011). Feedback is provided in the following ways:

- *Momentary feedback*. Drivers react to real-time information and adjust their driving behavior in any given moment based on that feedback.
- *Accumulated feedback*. Information over a longer period of time (e.g., a single trip or multiple trips) is aggregated to give drivers feedback about their general driving behavior.
- *Offline feedback* provides detailed feedback on driving style, emissions, and fuel consumption through the use of Internet-based applications or social networking (Tulusan et al. 2011).

In-vehicle feedback systems generate data in a variety of different ways depending on the type of feedback that a driver wants to see. Eco-panels that aim to provide users with instantaneous, momentary feedback do so largely through the use of ambient displays that indicate an immediate change in conditions through a change in light or color. These ICT applications are most useful in these circumstances since the alerts can be sensed or seen peripherally, thus making it unnecessary for the driver to look away from the road.

In most diagnostic systems on the market today, longer-term feedback is provided either in terms of consumption (miles per gallon) or through dynamic diagrams such as growing leaves or trees (Tulusan et al 2011). The in-vehicle system tracks the average fuel efficiency, mileage, and speed for that time frame, and information is aggregated to show a vehicle owner how his or her driving habits vary over time. Ford's SmartGauge® with EcoGuide panel makes use of "efficiency leaves" that grow when the vehicle is being used efficiently (see figure 9) (Ford 2014). Likewise, Toyota outfits its family of Priuses with its Hybrid System Indicator dashboard to show drivers how their driving impacts the efficiency of the vehicle. The Toyota panel also includes a series of graphs that show how fuel economy, mileage, and speed change on a monthly basis (see figure 10) (Toyota 2014).

Figure 8. Ford SmartGauge with EcoGuide panel. *Source:* http://smartdesignworldwide.com/work/ford-smart-gauge/.

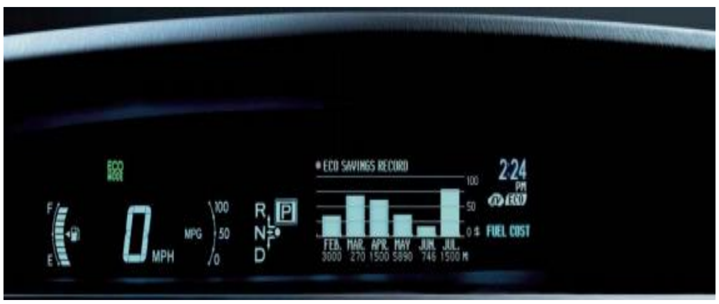

Figure 9. Toyota Prius Hybrid system indicator. *Source*: Toyota 2014.

PREVALENCE AND NEW DIRECTIONS

While Toyota and Ford are the only automakers that have really embraced the use of feedback panels in their vehicle offerings, a number of other companies are making smaller but significant steps toward incorporating this technology in their cars and light trucks. For example, Honda and Nissan have begun to roll out similar features in their American offerings. Nissan has started incorporating eco pedals that improve overall fuel efficiency by indicating whether a driver is speeding or driving aggressively. These pedals alert drivers to excessive pressure on the accelerator pedal through a fuel consumption indicator on the dashboard and also through increased pedal pushback (Nissan Motor Company 2014).

ENERGY SAVINGS

In general, ICT applications in vehicles that improve driving habits and the overall efficiency of a given vehicle complement technologies that focus on moving traffic from personal vehicles to alternative modes by targeting all aspects of transportation efficiency. Drivers who are given the necessary information about their driving habits and vehicle fuel economy are more likely to adjust their driving behavior to improve the overall efficiency and save money on fuel costs.

An estimate of the benefits associated with in-vehicle ICT applications are outlined in table 4. To determine the energy benefits of implementing in-vehicle feedback technologies in light-duty vehicles, we used energy savings figures that show that in-vehicle feedback devices improve the average fuel efficiency of vehicles by approximately 2.9% (Lovejoy, Handy, and Boarnet 2013b). This estimate of savings was derived from a study conducted in Davis, California with 118 participants that found statistically significant impacts on fuel economy of 2.9%, even after controlling for impacts such as weather, road conditions, and trip types (Kurani et al. 2013; Lovejoy, Handy, and Boarnet 2013b). With regard to market penetration of these technologies, we assumed that by 2020, 100% of all new vehicles would be outfitted with interactive panels and the required feedback equipment. With eco panels installed in every vehicle on the road, drivers are adjusting their driving behaviors and patterns to maximize fuel efficiency, as they are now outfitted with the necessary information to connect their driving technique to the fuel consumption of their vehicle.

Table 4. Energy benefits associated with in-vehicle feedback applications in 2030

Benefits	Amount
Average energy savings per vehicle from in-vehicle feedback applications *	2.9%
2015 gasoline savings (million gallons)	26
2030 gasoline savings (million gallons)	2,617

* Lovejoy, Handy, and Boarnet 2013b

OVERCOMING BARRIERS TO ADOPTION AND INCREASED ENERGY SAVINGS

Recent advancements in vehicle engineering have been accompanied by a boom in in-vehicle eco-feedback options. With Toyota and Ford already providing buyers with eco panels as part of standard vehicle purchases and Honda and Nissan starting to roll out similar features, it is only a matter of time before automakers are able to reduce the costs associated with producing and installing these systems. We see widespread adoption of such technologies in a larger selection of vehicles. Additionally, as fuel prices continue to fluctuate and drivers potentially become more concerned with the performance of their vehicles, the demand for feedback technology along with interest in high-efficiency vehicles, such as plug-in electric hybrids and pure battery-electric vehicles, will likely rise and become an important aspect of a vehicle buyer's decision-making process.

Vehicle-to-Vehicle Communications and Driver Assist Applications

ICT DEVELOPMENTS

The next generation of ICT-enabled transportation technologies involves the idea of using wireless connectivity to change the movement of vehicles. While a lot of recent buzz has focused on the autonomous vehicle or self-driving car, which by itself would completely revolutionize the transportation and travel sector, a separate subset of technologies that enables communication between vehicles is also coming to light.

Vehicle-to-vehicle (V2V) technologies encompass the dynamic wireless exchange of data between vehicles that are using the same route or roads. This exchange of data has the potential to improve safety as well as the overall efficiency of the highway and roadway system and the vehicles that use it (DOT 2014a). V2V systems allow for the exchange between vehicles of information traditionally collected by onboard diagnostic systems such as tire pressure, speed, and GPS location. Vehicles could talk to each other about their speed, upcoming traffic conditions, and potential road obstacles, thus reducing emissions, fuel consumption, and the potential for congestion (Bullis 2011). Vehicles can avoid stop-start driving and idling in traffic jams, actions that inherently waste fuel. Driver-assist technologies sense the conditions around a given vehicle to allow for adjustments in the vehicle's motion. Adaptive cruise control (ACC), for instance, uses a forward-looking radar sensor to adjust the speed of a given vehicle in response to the proximity and speed of the vehicle ahead (Shaw 2014). Likewise, cooperative adaptive cruise control (CACC) uses the same technology as ACC systems but relies on wireless networking to "cooperate" with other vehicles on the road and form a "platoon" for saving fuel (Shaw 2014).

Current discussions about V2V technologies describe it as a network where every node (vehicle) would be able to send, capture, and transmit signals and information in order to provide a status of road conditions up to a mile ahead. The driver may then receive the transmitted signal as an alert on either a separate instrument panel or the dashboard and will be able to adjust his course or speed appropriately (Howard 2014).

PREVALENCE AND NEW DEVELOPMENTS

Automatic control systems are still largely in the experimental stages in the light-duty transportation sector. The U.S. Department of Transportation has conducted a pilot program with real drivers by offering a series of driver clinics and outfitting vehicles with V2V communication units (DOT 2014b). However, this pilot has been largely focused on the safety benefits of V2V rather than the energy savings impacts. In August of this year, the National Highway Transportation Safety Administration (NHTSA) within DOT unveiled a plan to implement V2V software and wireless transmitters in vehicles for safety purposes. As part of this plan and in collaboration with the federal government, a number of automakers have been developing V2V technologies for their vehicles. These include Toyota, Ford, and Honda (Nelson 2014).

There have not been many practicable examples of using V2V and driver assist as efficiency interventions in the United States. IBM has been working with the city of Eindhoven in the Netherlands on a pilot project to demonstrate how shared information on braking, acceleration, and location can be used by the central traffic authority to improve the efficiency of the overall road network (IBM 2013).

More progress has been made in communication between vehicles in the commercial sector. Successful tests of such systems have been conducted in the EU and Japan, in which distances between vehicles were reduced to approximately 33 feet to improve the overall efficiency of the highway system (Jeschke 2013).

ENERGY SAVINGS

Preliminary estimates have been made of the impact of drive-assist applications and V2V on gasoline consumption. Table 5 below attempts to shed some light on the benefits associated with these technologies. We estimate the impact of two of these technologies, adaptive cruise control (ACC) and cooperative adaptive cruise control (CACC), using the methodology outlined in a report by the Intelligent Transportation Society of America (ITS America) in 2014. The report assumes that neither of these technologies would be utilized 100% of the time. The usage rates are 49% and 28.6%, respectively, for the average vehicle, and the penetration rate for both is 5% per year. Usage rates for ACC were derived by ITS from a study conducted in Europe as part of a field test of adaptive cruise control technology. Since no test data exist for CACC, ITS assumed that the usage rate for this technology was proportionally smaller (Shaw 2014).

The fuel consumption improvement figures of 2.8% for ACC and 13.8% for CACC in light-duty vehicles were also taken from the ITS report (Shaw 2014). The rate for ACC was taken from the same European study of ACC described above. The 13.8% used for cooperative adaptive cruise control was taken from the SARTRE project in Europe, a research effort focused on the real-world impact of CACC (Shaw 2014) and was based on energy savings from three light-duty vehicles following a heavy-duty vehicle in a platoon. Based on those assumptions we arrive at the energy savings in table 5.

Table 5. Energy benefits associated with V2V technologies

Benefits	Amount
Average fuel economy improvements (ACC) *	2.8%
Average fuel economy improvements (CACC) *	13.8%
2015 gasoline savings (million gallons)	70
2030 gasoline savings (million gallons)	2,519

*Shaw 2014

While these technologies could be a promising approach to reducing fuel consumption in the transportation sector, it is essential to acknowledge that they allow more and more vehicles to access roads and highways by improving traffic flow and reducing vehicle spacing. This in turn induces new travel, offsetting some of the fuel consumption reduction associated with the technology. Nevertheless, as an example of automatic control in the transportation sector, this technology could very well change the way people travel in the future. The eventual vision for V2V and driver-assist systems could include not only V2V data exchange but also vehicle-to-infrastructure sharing. Vehicle-to-infrastructure communications enable the wireless exchange of data between vehicles and highway infrastructure such as stoplights, roadside signals, and traffic management centers to mitigate congestion and accidents while improving the efficiency of the highway system (DOT 2014c).

OVERCOMING BARRIERS TO ADOPTION AND INCREASED ENERGY SAVINGS

There are still a number of outstanding questions that will need to be resolved before V2V and driver-assist applications become feasible components of the transportation system. The first of these is ensuring that these communications technologies work across a variety of vehicle types and platforms. Secondly, as these technologies become more popular, outreach programs will be necessary to educate drivers on how to interact with vehicle interfaces that are consistently being updated with new information. Additionally, it will be necessary to develop the most effective driver interface to prevent driver issues from taking away from the effectiveness of V2V technologies (DOT 2014a). Finally, with the development of these vehicle communications technologies come cybersecurity and data privacy concerns. The application of V2V technology inherently requires the collection of driver data and the tracking of vehicles through the use of IP addresses, which could make these systems vulnerable to hackers. In order for V2V to be successfully implemented, a set of policies and protocols will likely need to be developed to ensure data safety.

Work-Based Transportation Demand Management

ICT DEVELOPMENTS

Driving to the workplace accounts for approximately a quarter of all vehicle trips in the United States (Zuehlke and Guensler 2007). The primary goal of transportation demand management (TDM) programs is to reduce the frequency of single-occupancy work trips or to shift auto trips out of peak traffic periods (SDOT 2008). TDM strategies include

- Telecommuting
- Flexible work schedules
- Subsidized transit passes
- Parking cash-out programs
- Ride sharing (carpooling, HOV lanes, and so on)

TDM programs can be implemented by either employers or municipalities. The recent growth in Internet use and smartphone ownership has made coordinating alternative modes of transportation for work commuters easier. Access to computers, smartphones, and widespread wireless Internet capability means that employees can be connected at all times, no matter their location. These technology changes can lead to gradual but significant changes in work-related travel patterns and transportation choices for commuters.

The growth of ICT-enabled and web-based services has made the coordination between parties interested in taking advantage of TDM programs significantly easier. Websites that enable passengers to sign up for carpooling or ridesharing services have become a critical part of transportation demand management programs. The Memphis Area Rideshare Program (MAR), for instance, has partnered with private company vRide to create an interactive social network for commuters in the Memphis metropolitan region. Once commuters sign up, they can search for rides to and from work based on location or place of employment, in addition to creating their own vanpools or carpools (vRide 2014). In Seattle, Microsoft has a variety of online resources that enable its local employees to coordinate their commutes (Henretig 2014).

However, many commuters are choosing to stay off the roads altogether by telecommuting. As part of trip-reduction programs, some states and municipalities offer incentives to employers that allow employees to telecommute. For some, virtual private network (VPN) connections and the development of remote desktop software can make working remotely at least as productive as working in the office, as resources and files are easily accessible. Research from the Telework Research Network shows that allowing employees to work at home half the time can save companies up to $10,000 per employee per year. The bulk of these savings can be attributed to increases in productivity, while the remainder is due to reduced facility costs, lowered absenteeism, and reduced turnover (Rapoza 2013). Data from AT&T in Atlanta have shown a $100 million increase in productivity thanks to the company's telecommuting program (Commute Solutions 2000). Free web conferencing and video chat software similarly enable meetings and conferences to be held remotely.

Telecommuting is a normal part of operations on BP's Houston campus where approximately 200 of the 6,000 employees work remotely on a regular basis. The company implemented a remote networking system that allows even engineers and geoscientists who use complex analytical programs to tele-work.

The federal government has also been taking steps since 2010 to create a comprehensive tele-work program that will improve overall productivity. The Office of Personnel Management has made efforts to overcome key barriers such as management resistance and information security risks in addition to actively promoting tele-work as a feasible alternative to the traditional workday. Between 2011 and 2012, the number of employees eligible for tele-working increased by 49% while the number of employees who actually took advantage of work-at-home opportunities went up by 24% (OPM 2013).

PREVALENCE AND NEW DIRECTIONS

Trip reduction programs have become valuable resources in communities that experience several hours of traffic congestion daily and among companies hoping to improve the productivity of employees.

Additionally, the rise of web-based tools has made these programs easier to implement and coordinate because they provide commuters with necessary information at the touch of a button. Similarly, the popularity of social network platforms and web-based interfaces has enabled companies to use these tools to match commuters with rides (Chan and Shaheen 2011). The rise of social networking platforms such as Facebook has enabled ride sharing companies to use this interface to match potential rides between friends or acquaintances more easily.

In general, TDM programs have been gaining traction in recent years. According to statistics collected by the Telework Research Network, between 2007 and 2012, the number of people telecommuting on a frequent basis grew by approximately 32% across the United States (Global Workplace Analytics 2013).

ENERGY SAVINGS

As mentioned previously, the primary goal of TDM programs is to reduce the amount of commuter traffic altogether or to shift it to off-peak hours in addition to making the workday more convenient for employees. Carpooling, ride sharing, and telecommuting all serve to improve the overall efficiency of the transportation system by shifting travel from single-occupancy vehicles to alternative modes of transportation or off the road altogether. Comprehensive trip reduction programs save commuters from paying the high cost of decreased productivity due to long commutes while reducing local fuel consumption and greenhouse gas emissions. They can also save energy and reduce emissions by reducing building footprints: with more people telecommuting, less space is need for workers, and as a result, less energy has to be expended on heating, cooling, and lighting.

While there are a number of strategies available, we focus our energy savings estimates on the impacts of telecommuting, since this is the approach for which there is the greatest amount of research and evidence of energy savings. An estimate of future energy savings associated with telecommuting is outlined in table 6 below. We created a projection of the number of people who telecommute on a regular basis out to 2030 using historical growth trends (Global Workplace Analytics 2013). Since the most recent data point we were able to obtain was from 2012, we applied an annual participation growth rate of 3.7% between 2012 and 2030 based on the increase in the number of telecommuters between 2011 and 2012. We then assumed that the use of ICT doubles the rate of growth in participation annually out to 2030 given advances in tele-working technologies. Telecommuting can reduce gasoline consumption per average household in a region by 1.1% if 1.5% of the regional workforce telecommutes on any particular day (Handy, Tal, and Boarnet 2013). Using these assumptions, we derived the annual energy savings estimate for 2030 shown below.

Table 6. Energy benefits associated with ICT-enabled increases in telecommuting in 2030

Benefits	Amount
Increase in tele-workers in 2030 (as a percentage of total workforce) *	3.0%
Estimate of tele-working workforce in 2030 (million)	12
2015 gasoline savings (million gallons)	127
2030 gasoline savings (million gallons)	1,127

* ACEEE estimate

OVERCOMING BARRIERS TO ADOPTION AND INCREASED ENERGY SAVINGS

Employers have barriers to overcome if they are to implement a successful TDM program. TDM programs work best if they are incentivized. As with some of these other strategies, finding the necessary funding can be problematic. This is where support from municipal and state agencies can be most helpful. In addition to providing the money needed for implementing and managing, these agencies can play a significant role in providing employers with the guidance necessary to set up an effective program.

Another big challenge for implementing TDM programs is taking into account the varied and changeable needs of employees (Zuehlke and Guensler 2007). Taking alternative modes of transportation to work may be a feasible alternative for some commuters, while others may not live close enough to transit facilities to take advantage of available incentives. The ideal approach should include a package of policies that all workers can make use of.

TDM programs must also address cultural barriers. For instance, employers may hold the perception that tele-working implies a reduction in productivity due to a lack of oversight. Employees may also be less willing to participate in TDM programs due to the difficulties and inconveniences they perceive in coordinating trips with colleagues or using shared ride services.

Nevertheless, with support from municipal and state programs to make transportation demand management a priority, these programs can be replicated in communities and by larger employers across the country. Employers can receive incentives from cities to encourage their employees to change their travel behavior. TDM programs work best in collaboration with other policies such as transit improvements and parking pricing (VTPI 2013). Employer-based programs can be mandated or encouraged at the state or local level, or they can be implemented by individual employers. Local governments can encourage the implementation of employer-based programs by creating a network of local business leaders, government representatives, and employers to gather support for trip reduction measures and by providing incentives to employers to create these programs.

Discussion and Conclusion

While progress has been made in recent years to address the fuel efficiency of vehicles at the federal level, there is still a significant amount of untapped efficiency potential in transportation systems. A comprehensive approach to addressing this untapped efficiency must incorporate strategies that target both vehicle efficiency and transportation system efficiency. Given the steady increase in Internet and smartphone use in the last decade, it only makes sense that intelligent efficiency and ICT should play a big role in reducing light-duty energy consumption. The programs discussed in this report demonstrate that ICT strategies can play a significant role in reducing energy consumption in the transportation sector. As highlighted figure 11 and table 7, our projections of savings potential in 2030 from these six measures amounts to approximately 13% if we do not take into account any interactive effects.

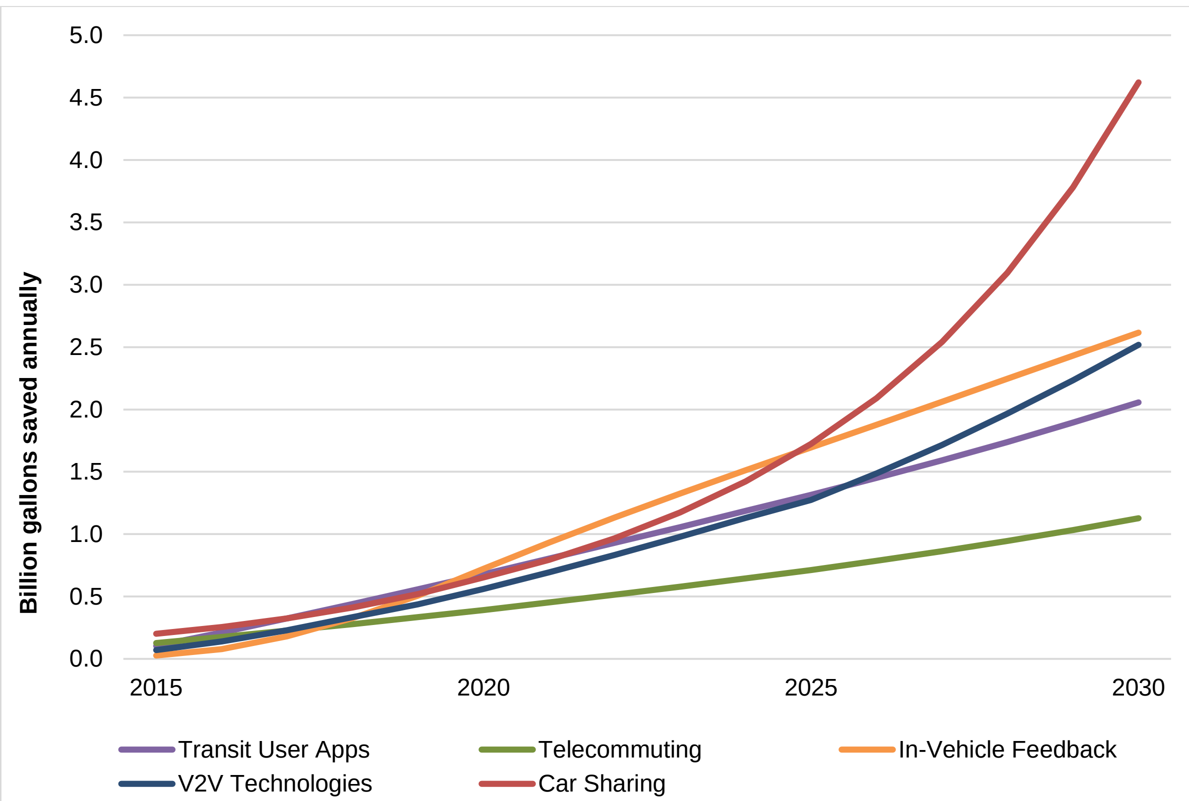

Figure 10. Annual fuel savings of ICT strategies

Table 7. Summary of energy savings

ICT Intervention	2015 fuel-consumption reduction (million gallons)	2030 fuel-consumption reduction (million gallons)
In-vehicle feedback	26	2,617
Vehicle-to-vehicle communications	70	2,519
Car sharing	201	4,622
Telecommuting	127	1,127
Transit ridership apps	104	2,057
TOTAL	528	12,942

Source: ACEEE calculations

It is important to keep in mind that the strategies described in this report are only a subset of the various ICT-based technologies that could be implemented to save energy in the transportation sector. Research has shown that comprehensively incorporating ICT into the transportation sector could reduce energy use from between 13% and 26% in the long run, although these studies are largely based on analyses of European economies (OECD 2010; European Commission 2008). Beyond the examples described here, ICT can be used to influence a variety of factors in the transportation sector. These include

- Reducing the need for automotive travel
- Influencing travel choices
- Changing driver and vehicle behavior
- Increasing the efficiency of the overall transportation network (OECD 2010)

Additionally, this report deals solely with personal transportation. A separate white paper released by ACEEE discusses the range of ICT applications relevant for the heavy-duty and freight transportation sector (Langer & Vaidyanathan 2014). These applications would bring with them additional energy savings for the transportation sector as a whole.

Nevertheless, the widespread adoption of these programs is not a given. A number of barriers exist to prevent the implementation of ICT-enabled systems that can reduce energy use in the light-duty transportation sector in the United States. Like other energy efficiency interventions, these barriers prevent us from taking advantage of large opportunities for cost-effective savings. Some of these barriers are discussed below.

Lack of information about savings and other non-energy-related benefits is one of the most widespread barriers to the adoption of intelligent efficiency and ICT-based applications. Knowledge of the performance of equipment, technologies, and systems in general are difficult to pinpoint, which makes their impact difficult to measure. Additionally, information related to energy consumption is imperfect since energy savings are difficult to measure, future energy costs are unknown, and the energy use of individual devices is often hard to separate (Vaidyanathan et al. 2013). Energy efficiency benefits for many ICT interventions are somewhat of an ancillary benefit to other end-use benefits. As such, data about the energy impacts of these interventions may not be collected. Therefore, for all the

ICT applications described in this report, identifying their true impact serves as a real barrier toward their incorporation in existing systems.

Another key barrier to overcome, in order for the continued development of ICT-enabled solutions to transportation issues, is that transportation data must be made widely and freely available. Transit agencies and third-party implementers require access to comprehensive transport data sets in order to contract with developers to generate user-friendly tools. ICT-enabled transit apps in particular must use dynamic, up-to-the-minute information in order for commuters to successfully navigate public transportation facilities. On a larger scale, freely available data are critical to spurring more innovation as well as improving public agency effectiveness and accountability. As a result, ensuring that transit agencies continue to collect detailed information and make it publicly accessible is vital.

The last critical barrier to overcome is the notion that there are significant up-front and operational costs related to the implementation of ICT-based systems. Research, development, and the constant fine-tuning of intelligent efficiency interventions in the transportation sector can make these investments an expensive proposition (TCRP 2011). For instance, the development of in-vehicle feedback systems requires years of R&D as well as significant up-front capital for the installation of these systems. Likewise, the capital required for a system-wide rollout of transit ridership applications can make these projects intimidating to implementing stakeholders. Nevertheless, incorporating ICT approaches as part of the existing transportation system to reduce fuel consumption is significantly cheaper than installing and operating new transportation infrastructure.

Finally, while governmental intervention can be beneficial in some cases, governmental regulation and involvement can sometimes create additional barriers (Vaidyanathan et al. 2013). For example, zoning and parking regulations can make it difficult for the proliferation of car-sharing vehicles and parking spots. Similarly, services such as Uber have come up against much red tape as they try to expand across the country. Regulations can be slow to keep up with changing technologies and markets, serving to prevent the implementation of technologies that reduce energy consumption in the transportation sector (Vaidyanathan et al. 2013.)

In summary, there remains plenty of opportunity for the incorporation of intelligent efficiency solutions in the transportation sector as a means to reduce fuel consumption. While we're starting to see the proliferation of these technologies and programs across the sector, it is still unclear how ICT-based strategies as a whole will affect transportation energy consumption in the United States. However, the energy savings envisioned in this report indicate that there is likely the potential for substantial gains from applications of ICT to the transportation sector.

References

Alliance for Biking and Walking 2012. *Bicycling and Walking in the United States: 2012 Benchmarking Report.* Washington, DC: Alliance for Biking and Walking.

APTA (American Public Transportation Association). 2014. *2014 Public Transportation Fact Book.* Washington, DC: American Public Transportation Association.

Automotive News. 2014. "BMW Considers Expanding Car-Sharing Program to 10 U.S. Locations." *Automotive News.* March 5. http://www.autonews.com/article/20140305/OEM/140309920/bmw-considers-expanding-car-sharing-program-to-10-u.s.-locations.

Blanco, S. 2014. "Someone Starts a New Car2go Carsharing Trip Every 2.5 Seconds." *Autobloggreen.com*. January 17. http://green.autoblog.com/2014/01/17/new-car2go-carsharing-trip-every-2-seconds/#continued.

Bullis, K. 2011. "How Vehicle Automation Will Cut Fuel Consumption." *MIT Technology Review.* October 24. http://www.technologyreview.com/news/425850/how-vehicle-automation-will-cut-fuel-consumption/.

Capital Bikeshare. 2013. *2013 Capital Bikeshare Member Survey Report: Executive Summary*. Washington, DC: Capital Bikeshare. http://www.capitalbikeshare.com/assets/pdf/cabi-2012surveyreport-execsum-5-15-13-revtitle.pdf.

——. "System Data." Accessed August 2014. http://www.capitalbikeshare.com/system-data.

Car2Go. "Car2Go Apps." Accessed August 2014. https://www.car2go.com/en/austin/car2go-apps/.

Carsharing.net. "Where Can I Find Carsharing?" Accessed October 2014. http://www.carsharing.net/where.html.

Chan, N., and S. Shaheen. 2011. *Ridesharing in North America: Past, Present, and Future. Transport Reviews*, 32(1): 93-112.

City CarShare. 2011. *Bringing Car-Sharing to Your Community*. http://citycarshare.org/wp-content/uploads/2011/12/CCS_BCCtYC_Short.pdf.

Commute Solution. 2000. *Telework Case Studies.* https://www.mysolutionis.com/hr-management/_images/CS-Telework_CaseStudies-102808.pdf.

Cox, P. 2014. "St. Paul Approves Deal with Car2Go." *MPRNews.* June 19. http://www.mprnews.org/story/2014/06/19/st-paul-approves-deal-with-car2go.

CTA (Chicago Transit Authority). "App Center." Accessed August 2014. http://www.transitchicago.com/apps/.

Davis, S., S. Diegel, and R. Boundy. 2014. *Transportation Energy Data Book*. Knoxville: Oak Ridge National Laboratory.

DDOT (District Department of Transportation). 2012. *Department Energy Savings Initiatives*. Washington, DC: District Department of Transportation.

DOT (U.S. Department of Transportation). 2014. "Vehicle-to-Vehicle (V2V) Communications for Safety." June 26. http://www.its.dot.gov/research/v2v.htm.

——. 2014b. "Connected Vehicle Safety Pilot Frequently Asked Questions." November 10. http://www.its.dot.gov/research/safety_pilot_faq.htm.

——. 2014c. "Vehicle-to-Infrastructure (V2I) Communications for Safety." August 8. http://www.its.dot.gov/research/v2i.htm.

Downes, L. 2013. "Lessons from Uber: Why Innovation and Regulation Don't Mix." *Forbes.com*. February 6. http://www.forbes.com/sites/larrydownes/2013/02/06/lessons-from-uber-why-innovation-and-regulation-dont-mix/.

European Commission. 2008. *ICT for Energy Efficiency*. Brussels: European Commission.

Ford (Ford Motor Company). "Next-Generation SmartGauge® with EcoGuide." Accessed August 2014. http://www.ford.com/cars/cmax/features/Feature4/#page=Feature4.

Froehlich, J., L. Findlater, and J. Landay. 2010. *The Design of Eco-Feedback Technology.* Seattle: University of Washington.

Global Workplace Analytics. 2013. *Latest Telecommuting Statistics.* Accessed September 2014. http://globalworkplaceanalytics.com/telecommuting-statistics.

Greenercars.org. "Green Driving Tips." Accessed August 2014. http://greenercars.org/drivingtips.htm.

Handy, S., G. Tal, and M. Boarnet. 2013. *Policy Brief on the Impacts of Telecommuting Based on a Review of the Empirical Literature*. Sacramento: California Air Resources Board.

Henretig, J. 2014 "Making Commuting Easy, Enjoyable and Sustainable." Microsoft Green Blog, Microsoft. http://blogs.msdn.com/b/microsoft-green/archive/2014/09/12/making-commuting-easy-enjoyable-and-sustainable.aspx.

Honda Motor Company. "2014 Insight." Accessed August 2014. http://automobiles.honda.com/insight-hybrid/fuel-efficiency.aspx.

Howard, B. 2014. "V2V: What are Vehicle-to-Vehicle Communications and How Do They Work?" *ExtremeTech.com*. February 6. http://www.extremetech.com/extreme/176093-v2v-what-are-vehicle-to-vehicle-communications-and-how-does-it-work.

Hu, E. 2014. "Uber's Rapid Growth Pits Innovation Against Existing Laws." All Tech Considered, NPR. June 12. http://www.npr.org/blogs/alltechconsidered/2014/06/12/321008384/ubers-rapid-growth-pits-innovation-against-existing-laws.

IBM. 2013. "Dutch City Region of Eindhoven Works with IBM and NXP to Improve Traffic Flow and Road Safety." February 21. http://www-03.ibm.com/press/us/en/pressrelease/40212.wss.

ITS (Intelligent Transportation Society of America). "National/Regional Smartphone Apps." Accessed August 2014. http://www.itsa.org/knowledgecenter/market-data-analysis/smartphone-apps.

Jaffe, E. 2012. "Do Real-Time Updates Increase Transit Ridership?" *The Atlantic*. March 6. http://www.citylab.com/commute/2012/03/do-real-time-updates-increase-transit-ridership/1413/.

Jeschke, S. 2013. "Vehicles, Loading Units and ICT: Smart Solutions for the Intermodal Transport Chain." Presentation to Truck and Bus World Forum, Lyon, France. November.

Kurani, K., T. Stillwater, M. Jones, and N. Caperello. 2013. "Ecodrive I-80: A Large Sample Fuel Economy Feedback Field Test, Final Report." *ITS UC Davis Working Paper*. Davis: University of California.

Langer, T., and S. Vaidyanathan. 2014. *Smart Freight: Applications of Information and Communications Technologies to Freight System Efficiency.* Washington, DC: American Council for an Energy-Efficient Economy.

Larsen, J. 2013. "Dozens of U.S. Cities Board the Bike-Sharing Bandwagon." Plan B Updates (blog), Earth Policy Institute. May 14. http://www.earth-policy.org/plan_b_updates/2013/update113#Table.

Lovejoy, K., S. Handy, and M. Boarnet. 2013a. *Policy Brief on the Impacts of Carsharing (and Other Shared-Use Systems) Based on a Review of the Empirical Literature.* Sacramento: California Air Resources Board

——. 2013b. *Policy Brief on the Impacts of Eco-driving Based on a Review of the Empirical Literature.* Sacramento: California Air Resources Board.

Mai-Duc, C. 2014. "Car2Go Launches Car-Sharing Service in South Bay." *Los Angles Times.* June 6. http://www.latimes.com/local/lanow/la-me-ln-car-sharing-south-bay-20140606-story.html.

Malouff, D. 2014. "Here Are America's Largest Bikesharing Systems in 2013." GreaterGreaterWashington.org (blog). January 6. http://greatergreaterwashington.org/post/21260/here-are-americas-largest-bikesharing-systems-in-2013/.

Martin, E., S. Shaheen, J. Lidicker. 2010. "Impact of Carsharing on Household Vehicle Holdings: Results from North American Shared-Use Vehicle Survey." *Transportation Research Record: Journal of the Transportation Research Board* 2143: 150–158.

MRSC (Municipal Research and Services Center). "Transportation Demand Management." Accessed August 2014. http://www.mrsc.org/subjects/transpo/tdm.aspx.

Nelson, G. 2014. "U.S. Details Plans For Car-to-Car Safety Communications." *Automotive News*. August 18. http://www.autonews.com/article/20140818/OEM11/140819888/u.s.-details-plans-for-car-to-car-safety-communications.

Nissan Motor Company. "Environmental Activities." Accessed August 2014. http://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/eco_pedal.html.

NYCBS (New York City Bike Share). 2014. *NYCBS April 2014 Monthly Report*. Brooklyn: New York City Bike Share. http://www.citibikenyc.com/assets/pdf/april_2014_citi_bike_monthly_report_final.pdf.

OECD (The Organisation for Economic Cooperation and Development). 2010. *Greener and Smarter: ICTs, the Environment and Climate Change*. Paris: The Organisation for Economic Cooperation and Development.

OPM (U.S. Office of Personnel Management). 2013. *2013 Status of Telework in the Federal Government: Report to the Congress.* Washington: U.S. Office of Personnel Management.

Pedestrian and Bicycle Information Center. 2014a. "Bike Share Programs." Accessed August 2014. http://www.pedbikeinfo.org/pdf/Programs_Promote_BikeSharePrograms_041213.pdf.

——. 2014b. "Bike Sharing." Accessed August 2014. http://www.pedbikeinfo.org/programs/promote_bikeshare.cfm.

Pew Research Center. 2013. *Smartphone Ownership: 2013 Update*. Washington, DC: Pew Research Center.

——. 2014. *The Web at 25 in the U.S.* Washington, DC: Pew Research Center.

Rapoza, K. 2013. "One In Five Americans Work From Home, Numbers Seen Rising Over 60%." Forbes.com. February 18. http://www.forbes.com/sites/kenrapoza/2013/02/18/one-in-five-americans-work-from-home-numbers-seen-rising-over-60/.

RideScout. "Our Story." Accessed September 2014. http://www.ridescoutapp.com/about-us/.

Rogers, E., R. Elliott, S. Kwatra, D. Trombley, and V. Nadadur. 2013. *Intelligent Efficiency: Opportunities, Barriers, and Solution.* Washington, DC: American Council for an Energy-Efficient Economy.

Schmitt, A. 2013. "The American Bike-Share Fleet Has Doubled Since January." StreetsBlog USA. August 30. http://usa.streetsblog.org/2013/08/30/the-american-bike-share-fleet-has-doubled-since-january/.

SDOT (Seattle Department of Transportation). 2008. *7 Best Practices in Transportation Demand Management*. Seattle: Seattle Department of Transportation.

SEPTA (Southeastern Pennsylvania Transportation Authority). "New Payment Technologies: Frequently Asked Questions." Accessed August 2014. http://www.septa.org/fares/npt/faq.html.

Shaheen, S., A. Cohen, and E. Martin. 2012. *Public Bikesharing in America: Early Operator Understanding and Emerging Trends*. Washington, DC: 2013 Transportation Research Board Annual Meeting.

Shaheen, S., and A. Cohen. 2012. *Innovative Mobility Carsharing Outlook: Carsharing Market Overview, Analysis and Trends*. Berkeley: University of California.

Shaw, A. 2014. *Accelerating Sustainability: Demonstrating the Benefits of Transportation Technology.* Washington, DC: Intelligent Transportation Society of America.

Sherman, A. 2011. "How 4 Cities Are Deploying High-Tech Bike Sharing Programs." Mashable. July 13. http://mashable.com/2011/07/13/bike-sharing-cities/.

T4A (Transportation for America). 2012. *Thinking Outside the Farebox: Creative Approaches to Financing Transit Projects*. Washington, DC: Transportation for America.

Tang, L., and P. Thakuriah. 2012. *Ridership Effects of a Real-Time Bus Information System: A Case Study in the City of Chicago*. Transportation Research Part C 22: 146–161.

TCRP (Transit Cooperative Research Program). 2011. *Use and Deployment of Mobile Device Technology for Real-Time Transit Information.* Washington, DC: Transit Cooperative Research Program, Transportation Research Board.

Tedeschi, B. 2010. "Transit Maps in the Palm of Your Hand (No Refolding Required)." *New York Times*. June 2. http://www.nytimes.com/2010/06/03/technology/personaltech/03smart.html?_r=1&.

Toyota. "2014 Prius E-brochure." Accessed August 2014. http://www.toyota.com/prius/ebrochure/.

TRB (Transportation Research Board). 2005. *TCRP Report 108: Car Sharing: Where and How it Succeeds*. Washington, DC: Transportation Research Board.

Tulusan, J., L. Soi, J. Paefgen, M. Brogle, and T. Staake. 2011. *Eco-efficient Feedback Technologies: Which Eco-Feedback Types Prefer Drivers Most?* New York: Institute of Electrical and Electronics Engineers.

U.S. PIRG (U.S. PIRG Education Fund and Frontier Group). 2013. *A New Way to Go: The Transportation Apps and Vehicle-Sharing Tools that Are Giving More Americans the Freedom to Drive Less.* Boston: U.S. PIRG Education Fund.

Vaidyanathan, S., S. Nadel, J. Amann, C. Bell, A. Chittum, K. Farley, S. Hayes, M. Vigen, and R. Young. 2013. *Overcoming Market Barriers and Using Market Forces to Advance Energy Efficiency*. Washington, DC: American Council for an Energy-Efficient Economy.

vRide. "Memphis Area Rideshare." Accessed August 2014. http://www.vride.com/locations/memphis-area-rideshare?start=&end=

VTPI (Victoria Transport Policy Institute). 2013. "Commute Trip Reduction." March 12. http://www.vtpi.org/tdm/tdm9.htm.

——. 2014. "Carsharing: Vehicle Rental Services That Substitute for Private Vehicle Ownership." September 10. http://www.vtpi.org/tdm/tdm7.htm.

WMATA (Washington Metropolitan Area Transit Authority). 2014a. "About Metro." Accessed August 2014. http://www.wmata.com/about_metro/.

——. 2014b. "Metrorail Average Weekday Passenger Boardings." Accessed August 2014. http://www.wmata.com/pdfs/planning/FY12_Historical_Ridership_By_Station.pdf.

——. 2014c. "FY 12 Metrobus Weekday Average Ridership." Accessed August 2014. https://www.wmata.com/pdfs/planning/FY12_Bus_Ridership_By_Line.pdf.

Zipcar. "Zipcar Mobile Apps." Accessed August 2014. http://www.zipcar.com/mobile.

Zuehlke, K., and Guensler, R. 2007. "Employer Perceptions and Implementation of Commute Alternative Strategies." *Journal of Public Transportation* 10(4): 171-194.