Texas A&M Transportation Institute

Vehicle Telematics as a Platform for Road Use Fees

Final report

PRC 14-20 F

TRANSPORTATION
Policy Research CENTER

Vehicle Telematics as Platform for Road Use Fees

Texas A&M Transportation Institute

PRC 14-20 F

November 2016

Authors

Maarit Moran

Trey Baker

Table of Contents

List of Tables

Executive Summary

Vehicle telematics systems are composed of various onboard communications, positioning technologies, and computing technologies. Much of the data generated and/or gathered by these systems can be used to determine travel. These systems enable a range of new approaches to transportation policy; of immediate interest is their use in state road user charges (RUCs) that some states are evaluating as a replacement or counterpart to the motor fuels tax. The State of Oregon in 2015 implemented the nation's first distance-based RUC system for passenger vehicles.

This report briefly overviews the technologies supporting the vehicle telematics industry and discusses how vehicle telematics are currently being used to levy RUCs and how they may be used in the future, particularly in support of future transportation funding options. This report examines the challenges associated with road user charging implementation and shows how different telematics technologies might be used to address those challenges.

There are five primary vehicle telematics applications:

- **Blackbox—**These applications require the hard installation of an in-vehicle device to the chassis of a vehicle, which typically requires the services of a professional installation technician. Blackbox applications provide very detailed and reliable data, but they are relatively difficult to install and are not expected to be a significant telematics-based technology services platform in the long term.

- **OBD-II Dongles—**These applications generally take the form of a dongle that is self-installed by the driver through the vehicular onboard diagnostic (OBD) port. The dongle then receives and stores vehicular data through this connection.

- **Smartphones—**Smartphones are primarily a communication medium, but they are used by consumers for numerous non-communication-related applications, including the provision of in-vehicle services. Smartphone apps enjoy significant utilization, primarily due to the popularity of smartphones. Location data gathered from apps tend to be less accurate, and devices can be turned off or removed from the vehicle, lowering the reliability of any data gathered in terms of accurately assessing distance traveled.

- **Embedded Telematics—**These types of applications use factory-installed components, systems, and interfaces that are wholly contained in the vehicle and accessible to users through an in-dashboard display. In the long term, it is anticipated that embedded systems will dominate the telematics market since they are an increasingly common feature in newer-model vehicles. They also provide very reliable and accurate data and are difficult to tamper with.

- **Hybrid Approaches—**Hybrid applications occur when two different technologies are combined to provide vehicle telematics-based services. Smartphones are a component of most hybrid approaches because they can be coupled to both embedded and OBD-II-based technologies. The challenges of smartphone applications can be addressed in hybrid systems; for example, OBD-based devices can maintain logs of vehicle starts and stops, which can be paired with smartphone data to identify gaps in usage data.

Privacy concerns are significant in the use of telematics for levying RUCs. Many technologies and applications rely on the coupling of location data with personally identifiable information to provide services, which increases the risk of data breaches and privacy violations. Consumers are generally unable to prevent the use or retention of their data, and telematics companies do not allow consumers to delete collected location data. Methods used by private firms to de-identify sensitive information are often inconsistent. One method for addressing this in the near term is for states to place the burden of collecting and maintaining data on the private sector and allow consumers a choice in the types of devices and services they choose to use, as the State of Oregon is doing. Although telematics service providers are not entirely transparent, allowing consumers to choose the providers they are most comfortable with could help alleviate some of the public's privacy concerns. Governments play an important role in setting privacy protections regarding the coupling of location and transaction information in embedded telematics for public policy purposes.

Introduction: Telematics Technologies and Road User Charging

The fuel tax, which supplies the majority of funding for state and federal transportation programs, is facing threats to its long-term sustainability. It is levied on a per-gallon basis, meaning that it loses purchasing power over time if not periodically raised. Furthermore, it returns less and less revenue per mile driven as vehicular fuel efficiency increases. What makes this particularly problematic is that recent high gas prices are making highly fuel efficient and alternative fuel vehicles more attractive to consumers, and various state and federal incentives and mandates are encouraging auto manufacturers to make more of these vehicles available to consumers. There is the potential for significant reductions in long-term gasoline and diesel fuel consumption by the transportation sector and an accompanying drop in associated fuel tax revenues.

One potential funding alternative is to levy fees based on actual travel, not fuel consumption. These RUCs would address one of the primary deficiencies of the fuel tax by returning revenue in direct proportion to road usage. Under an RUC system, drivers who travel more would pay more, regardless of the fuel efficiency of their vehicle. The RUC concept has been pilot tested by several states and been shown to be a viable funding option. In fact, distance-based RUCs are already levied on heavy commercial vehicles in some states, and Oregon recently implemented the nation's first RUC system for passenger vehicles in summer 2015. However, despite the concept's advancement in recent years, there are issues with its application. From a technical perspective, three of the most challenging are:

- **Determining distance traveled—**Distance traveled is much more difficult to obtain than fuel consumption, which is routinely determined in a point-of-sale environment whenever drivers refuel their vehicle. Odometer readings can be taken, but that requires additional effort for the driver and additional administrative and enforcement effort by the public sector to verify. Odometer readings are also not generally collected on a routine or periodic basis, so the information is not readily available from other sources.
- **Differentiating travel—**It might not be desirable to charge for all travel. For example, an implementing entity might desire to not charge drivers for out-of-state travel or mileage accrued on private roadways. A simple odometer reading does not allow for the assessment of travel based on where it occurs, unless travel is self-reported. However, self-reporting of mileage creates a need for audit and enforcement.
- **Alleviating relatively high administrative costs—**The relative complexity of determining distance traveled versus fuel consumption means that RUCs are likely to be more complex and therefore costlier to administer than fuel taxes. Potentially high administrative costs are exacerbated by the potential number of collection points for an RUC. Fuel taxes, while ultimately paid by the consumer, are initially collected high in the

> fuel supply chain from a relatively limited number of fuel suppliers. Taxes are essentially assessed and collected at a wholesale level, with drivers reimbursing service station owners, who in turn reimburse fuel suppliers for the cost of the tax embedded in the wholesale price of the fuel. There are thus few collection points for the state/federal government relative to the total number of drivers paying the tax. However, a transition to an RUC might require collection of fees directly from individual drivers, which would significantly increase the number of collection points for the implementing entity, be it the state or federal government.

One potential option to address these issues is to us in-vehicle technologies for the metering of road usage and to rely on private-sector parties to collect and manage data. This could include the assessment and collection of the RUC. Since the 1980s, vehicle manufacturers have been incorporating an ever-evolving blend of electronic sensor and monitoring systems, commonly known as vehicle telematics systems, in their new-model vehicles. This practice has been accompanied by extensive growth in telecommunications and networking technologies in recent decades. Modern vehicle telematics systems incorporate any number of onboard communications, positioning systems, and computing technologies (*1*). This means that not only are more data being generated within vehicles, but the options for accessing, processing, and transmitting those data have become much easier. Much of the data gathered or generated by these systems can be used to determine distance traveled and differentiate that travel by location—basic requirements for the assessment of an RUC. Furthermore, because these systems are developed, operated, and administered by private-sector entities, the potential cost to the state or federal government of obtaining and maintaining the data for use in a charging system could be significantly reduced.

The purpose of this report is to provide an overview of the vehicle telematics industry and the technology components supporting it. The report begins with a discussion on the role of government in the historical development of these technologies, and it provides insight on how the policy focus has shifted as these technologies develop. Next is a review of basic vehicle telematics technology applications, followed by a discussion of how telematics and similar technologies are currently being used domestically and internationally to collect transportation-related fees and taxes. The report closes with a discussion on the challenges associated with the use of vehicle telematics technologies for levying RUCs here in Texas.

Historic Public-Sector Role in Telematics Development

In the 1980s, automobile manufacturers began incorporating electric sensors in their new-model vehicles to allow for better identification of system malfunctions. The State of California was the first to recognize the potential for these systems to help achieve public policy goals and understood that a certain level of standardization would be necessary to achieve those goals. Initially, these monitoring and sensor systems and the information they provided varied significantly between manufacturers. This made it difficult for independent service stations to diagnose problems from vehicle to vehicle.

In response to statewide concerns regarding air quality, the State of California worked to establish basic standards for in-vehicle monitoring systems and issued onboard diagnostic standards (OBD-I) in 1985. The State of California subsequently required that 1988 and subsequent model year vehicles conform to these standards if they were to be operated in California. One of the OBD-I's requirements was that onboard electronic units report emissions malfunctions to the driver through a malfunction indicator light on the dashboard, signaled with the phrase "check engine" or "service engine soon" (*2*). Since California was (and is) such a significant vehicle market, automotive manufacturers conformed to the standards for all their vehicles in order to not have to produce vehicles for one specific state's standards. These new standards made it easier for drivers to be aware of system malfunctions impacting emissions and made it easier for technicians to diagnose the issue because standardized OBD readers could be employed to check system sensors and indicators.

The federal government soon followed California's lead, and in the interest of maintaining national uniformity while addressing air quality passed the federal OBD-II requirements in 1990 through the Clean Air Act. Through that legislation, all new 1996 and later year passenger and light-duty vehicle models where required to meet the OBD-II standards, and all model year 2004 and later medium-duty vehicles up to 14,000 lb had to comply with the standards as well. The OBD-II standards were built upon OBD-I but improved those standards by focusing on the monitoring of components related to vehicle emissions and the storing of malfunction codes to help repair technicians assess vehicular issues more accurately. As a result of these measures, almost all new vehicles manufactured since 1996 and operating on the nation's roadways have a near-standard OBD-II port that allows technicians to access vehicular data.

A new international standard is now used: the controller area network (CAN) protocol. CAN is an International Standardization Organization defined communications and wireless protocol that facilitates the coordination and storage of data from up to 70 vehicular systems, such as the powertrain and braking systems (*3*). Most vehicles of model year 2008 or later conform to the CAN standards.

Federal legislation affecting in-vehicle telematics, namely the Clean Air Act, was born primarily out of concern for vehicle emissions and did not exclusively address issues of security and privacy in the nascent convergence of telecommunications and information technology in vehicles. (These issues are discussed in more detail in subsequent sections of this report.) Outside of certain California statutes, there has been minimal intervention by local and state governments regarding consumer privacy. Federal legislation regulating consumer privacy has not been passed by Congress since the 1980s, although there are bills currently under consideration. A summary of federal statutes affecting the vehicle telematics industry, including the Federal Trade Act of 1914, the Communications Act of 1934, the Privacy Act of 1974, and the Electronic Communications Privacy Act of 1986 and its Patriot Act Amendment, is provided in the appendix of this report.

Overview of Current Telematics Technologies

In recent decades, vehicle telematics systems have grown in their popularity and complexity. They are increasingly used by consumers to access and use any number of different applications, and the number of vehicle telematics-based systems on the roadway is expected to triple by 2016 (*4*). Owners of newer-model vehicles can monitor their vehicle's fuel consumption without needing to write down their fuel purchases and mileage. They can use in-dash displays to access music stored in a cloud server or find a nearby restaurant. In the event of a vehicular malfunction, a driver can contact a third party that will remotely diagnose the problem and send help if needed, all without having to step out of the vehicle. These services are supported by the sensing and communications technologies that make up modern telematics systems.

There are currently five general technology platforms supporting in-vehicle telematics systems. These include:

- **Blackbox—**These applications require the hard installation of an in-vehicle device to the chassis of a vehicle, which typically requires the services of a professional installation technician. They are very difficult to tamper with and receive information from their own sensors and other external sources rather than the vehicle itself and its electrical systems. This means that these devices are less capable of generating detailed data about the functioning of the vehicle itself, but they can provide very accurate data on speed, heading, distance, and location.

- **OBD-II Dongles—**These applications generally take the form of a dongle that is self-installed by the driver through the vehicular OBD port. The dongle receives and stores vehicular data through this connection and can be configured to receive global positioning system (GPS) location data. Furthermore, dongles can be configured to communicate with other devices over wireless channels. These types of telematics applications are relatively cheap and provide very reliable data. However, the necessary internal connection ports are not present in all pre-1996 vehicles, and devices can be removed, reducing the quality of the data they provide.

- **Embedded Telematics**—These types of applications use factory-installed components, systems, and interfaces that are wholly contained in the vehicle. Embedded systems are provided by the vehicle manufacturer without the need for aftermarket devices like a dongle or blackbox. Users of these systems generally access their services through an in-dashboard display. They are increasingly common in newer-model vehicles, and it is believed that embedded systems will begin dominating the vehicle telematics industry within the next few years.

- **Smartphones—**Smartphones are primarily a communication medium, but they are used by consumers for any number of non-communication-related applications, including the provision of in-vehicle services. These services generally take the form of an installed app. Like blackbox applications, a smartphone-based telematics app would not provide good data on how a vehicle is functioning, but it could provide data for use in assessing an RUC, such as distance traveled and location of travel. Due to widespread utilization of smartphones, these telematics-related services are among the most popular on the market.
- **Hybrid Approaches—**Hybrid applications occur when two different technologies are combined to provide a more robust vehicle telematics-based service. Smartphones are generally the most common component of a hybrid approach because they can be coupled to both embedded and OBD-II-based devices. In these cases, the smartphone can act as a transmission medium or provide supplemental data such as location.

Each technology application has several advantages and disadvantages in terms of its potential application under an RUC system. These technologies are discussed in more detail later in this section, and a table summarizing the advantages and disadvantages of each is provided in the appendix of this report.

The current market for telematics-based services is dominated by aftermarket (non-embedded) application packages that connect to vehicles through onboard diagnostic ports. Such technologies include smartphone-based applications and aftermarket devices such as dedicated personal navigation systems. Smartphone applications are continually evolving and can provide services regardless of the make and model of a vehicle. Relative to other telematics platforms, smartphone data formats are easy to modify to suit other consumer needs.

However, it appears that in the long term, embedded systems or systems that use embedded services will see the strongest penetration in domestic vehicle fleets. Recent consumer preference studies indicate that there is a growing desire to integrate embedded systems with smartphones to offer more personalization of in-vehicle interfaces and experiences (*5*). Furthermore, embedded telematics systems are likely to gain wider utilization because they are increasingly pervasive in new-model automobiles. For example, it is expected that embedded systems will soon support 59 percent of the usage-based insurance (UBI) market. UBI is similar to an RUC in that both must record the distance a vehicle travels, and there are multiple technology platforms and different technology providers available for each.

The technology configurations that could potentially be used for road user charging are very similar to those that are projected to support UBI policies, which could replace traditional flat insurance policies. Under a traditional policy, drivers pay a fixed rate for coverage over a set period regardless of the amount they drive. Under UBI, drivers only pay for insurance when they drive, with individual rates varying by any number of factors including total miles driven. UBI policies are seen as a breakthrough in risk assessment by the insurance industry because they offer a potentially more cost-effective model to American insurers with low profit margins relative to their European counterparts (*4*). The insurance industry is thus seeking to shift from proxy-based rating models that use reflective history patterns to models based on actual driving behavior since using actual driving behavior helps insurers better assess risk and assign insurance premiums. Vehicle telematics systems provide some of the best data on driving behavior, and the insurance industry will face similar challenges in using those data for insurance provision as a state will for RUCs.

OBD-based solutions are currently the preferred hardware application for the provision of UBI insurance policies because they are low cost and reliable (*4*). There are currently an estimated 2 million OBD-II devices in use in the United States and Europe providing insurance services. However, there is strong sentiment within the insurance industry that these types of applications will soon start losing market share to other applications, such as smartphones and embedded telematics solutions. Table 1 shows estimated technology market share over time in the UBI market by technology type. As the table illustrates, insurance industry experts anticipate a significant increase in market share for embedded telematics systems over the next two to five years. Industry experts expect that embedded systems will account for 59 percent of the UBI market within the next two to five years.

Table 1. Industry Estimates for Telematics Hardware Market Share within the UBI Industry.

Time Period	Blackbox	Smartphone	OBD-II	Embedded	Hybrid	Unsure
Next 6 months	22.9%	35.4%	56.3%	6.3%	8.3%	17.4%
6 months to 2 years	12.5%	47.2%	41.7%	21.5%	19.4%	16.7%
2 years to 5 years	6.9%	38.9%	16.7%	59.0%	23.6%	22.9%

Note: Multiple answers were allowed on the survey. Rows do not sum to 100 percent.
Source: (4).

The following sections summarize some of the issues associated with different vehicle telematics technologies and their application within the UBI industry and potential application within an RUC system.

Blackbox

Blackbox applications require the hard installation of an in-vehicle device to the chassis of a vehicle. Many vehicles already contain blackbox devices, which are used primarily as event data recorders for uses such as crash analysis, but aftermarket blackbox applications are also available. These types of applications are widely used in Europe since they are difficult to tamper with. Due to their hard installation, blackbox solutions offer significant value in markets with high rates of car theft and a high incidence of fraudulent insurance claims because it is difficult to remove the devices themselves from the vehicle. Blackbox applications are also valuable for forensic crash reconstruction.

Blackbox applications are reliable and among the most proven of telematics technologies. They can be configured to automatically record and transmit data once the ignition is turned on. Furthermore, the data they produce tend to be of very high quality, providing some of the most in-depth information available on driving behavior and location. However, blackbox applications are also among the most expensive vehicle telematics-based solutions on the market. One of the biggest drawbacks to these applications and their potential for supporting an RUC is that many in the industry see other technology applications as being much more popular among consumers in the near future.

Onboard Diagnostic Dongles

Almost all vehicles manufactured after 1996 have some form of OBD technology based on the OBD-II or CAN standards. OBD-based technologies are the most prevalent of vehicle telematics systems. OBD data are routinely read as part of safety and emissions inspections, and OBD scanning tools can be purchased to identify potential vehicle malfunctions at home.

OBD-based vehicle telematics technology applications generally take the form of dongles that the driver self-installs. These units are relatively inexpensive in comparison to other telematics devices due to their self-installation and reliance on common standards. They also are reliable and deliver data on vehicular performance and driving behavior since they obtain data directly from the vehicle. OBD-II dongles can be configured to receive and store GPS-based location data, and they can communicate with other technologies such as cellphones through a cellular, wireless, or Bluetooth® connection.

One of the drawbacks of OBD-based solutions is that dongles can be easily removed. While in some cases this is advantageous (e.g., units can be removed and placed in other vehicles), it could complicate enforcement of an RUC system since units could be removed to prevent road usage assessment or potentially tampered with. Another disadvantage is that the devices can only be used in model year vehicles that are equipped with the requisite OBD connector port. There is also the potential for these devices to interfere with vehicular systems, and in some cases, they may void vehicular warranties. However, the data generated and provided by these systems are somewhat standardized, and in that respect, they may be better suited for the implementation of an RUC system relative to other applications.

Embedded Telematics

Embedded telematics systems are developed and installed by the automotive manufacturer and are available to the consumer upon purchase of the vehicle. They interface with and coordinate any number of in-vehicle systems and controls and can provide many services to the consumer using data generated by the vehicle and through external sources. Consumers typically access their embedded services through a display in the dashboard of the vehicle. Auto manufacturers are increasingly offering vehicle models with embedded systems, and they are anticipated to become the dominant technology in vehicle telematics services within the next two to five years. A listing of current embedded telematics systems is provided in the appendix of this report.

Embedded telematics systems offer quality data directly from the vehicle. They are very difficult to tamper with and provide great security features such as stolen vehicle tracking or roadside assistance. Thus, they would pose little challenge in terms of enforcing an RUC because it would be difficult for drivers to tamper with mileage assessments.

However, one disadvantage of embedded telematics is that the hardware and software are specific to the vehicle make and/or model, potentially limiting the implementation of an RUC system; more specifically, there could be significant variation between the embedded systems, which could complicate the mileage assessment and data transmission processes. Automotive manufacturers may desire to charge for usage of their data, and they may be wary of making changes in hardware and software design necessary to support a standardized RUC regime. However, there are currently companies whose business model is based on purchasing, standardizing, and then selling telematics (including embedded telematics) data for use in applications like UBI. Embedded telematics systems are also still a relatively narrow market since only some automobiles come with embedded telematics, but that is anticipated to change over time as the technology becomes more popular.

Smartphones

Smartphone-based telematics services typically take the form of an app that is downloaded to a smartphone. These apps generally rely on the phone's GPS components, accelerometer, and gyroscope to provide information on travel behavior. Smartphone usage is continually growing, and they provide users a real-time, feature-rich user interface that can be used for data feedback. Smartphones and their range of applications and services often compete with embedded systems, which are focused primarily on providing services within a single family of proprietary applications.

Smartphones offer reduced data handling and storage costs for telematics service providers relative to other applications. Furthermore, there is no need to provide hardware and arrange installation, further lowing costs to service providers. Data usage is already included in the consumer's data plan, and since smartphones are portable, the application can easily be taken to another vehicle.

One of the advantages of using a smartphone-based application for the levying of an RUC is that the device has already been purchased by the consumer. There is no cost associated with the device, its installation, or data connectivity that an implementing entity might be liable for outside of the cost to develop the app and manage the data. Furthermore, smartphones and their applications can be used in almost any vehicle, regardless of its age and onboard technology capabilities.

However, downsides to smartphones are that they are not universally owned by all drivers and they can be turned off, left behind, discharged, or lose data while circulating in areas lacking cellular coverage. They also do not provide the data necessary for some of the higher-value services that embedded systems provide, such as stolen vehicle recovery or remote vehicle diagnostics. The provision of these high-value services could be a potential mechanism for levying an RUC since service providers could use the data collected through the services to levy the fee and collect it as part of regular billing activities. Thus, relying on smartphones alone in an RUC system might not provide a strong enough business case for the private sector to get involved in RUC administration.

Hybrid Approaches

Hybrid telematics systems represent a middle ground between smartphone and embedded/OBD-based systems. They provide a wider array of services than OBD platforms while still allowing consumers to more easily personalize their vehicles and relying on the high-quality data provided through a direct, in-vehicle connection. Hybrid telematics approaches combine two or more of the technology systems already discussed, and because of their flexibility, smartphones are the most common element of a hybrid approach. They can be tethered to an OBD-II dongle or embedded telematics system through Bluetooth or other wireless technology. Merging these technologies can provide more detailed data than a smartphone alone, while the smartphone's processing power allows for more rapid data compression. Furthermore, hybrid approaches are generally simple to install for the user.

A shortcoming of hybrid approaches is that they are easier to tamper with since one of the technology components (such as the smartphone) is generally not hard-wired to the vehicle. Furthermore, hybrid solutions only work in vehicles with the requisite OBD-based technologies or embedded systems. There is also generally a cost associated with providing the OBD-II dongle to the user, if that approach is used. The use of a smartphone can also limit the range of these applications in terms of available cellular coverage.

In 2008, the Minnesota Department of Transportation (MnDOT) pilot tested a hybrid configuration for the levying of an RUC. The pilot used GPS-enabled Samsung Galaxy smartphones tethered to custom-made OBD-II dongles, which generated the data necessary for the calculation of distance traveled. The dongles determined distance traveled, while the smartphone app (in addition to other services) determined location and generated backup distance data. MnDOT concluded that the system was viable, but there were issues with the technology. Vehicle detection failures were encountered where the smartphone did not know if it was in the correct vehicle, resulting in lost trip data. Furthermore, the phones often encountered difficulty obtaining GPS signals. MnDOT concluded that it may be too early to rely on smartphone technologies to achieve the required level of accuracy that is expected for RUC fee systems (*6*).

Telematics Applications in Road User Charging

Most technology-dependent road user charging systems rely on technologies similar to those used in the tolling industry rather than telematics-based applications. These applications often rely on the use of in-vehicle transponders or tags that communicate with roadside equipment to determine road usage. Vehicles with the requisite equipment pass under a gantry equipped with a reader, and distance traveled is assessed by the successive passage of the vehicle through a series of these gantries. Communication between the in-vehicle device and the roadside equipment occurs through the dedicated short-range communications (DSRC) or similar radio frequency identification (RFID) spectrum, and relatively little information is exchanged. This helps to protect driver privacy since most tolling systems are only aware of the vehicle's iterative passage through the gantry network, meaning that the system does not have detailed travel data. The vehicle itself does not generate data for use by the pricing system; it is simply equipped with a basic in-vehicle device or tag that allows readers to determine its presence at discrete locations.

The tolling industry itself is also looking at the potential role of vehicle telematics in its operations. Many in the industry see a role for these technologies in the assessment and collection of tolls. Right now, most of the effort in utilizing the technology components discussed in this report has centered on the use of smartphones for toll collection since smartphones are increasingly being equipped with RFID technologies that could communicate with tolling equipment. There are currently several apps on the market that tout their ability to communicate with tolling protocols, but none have seen widespread adoption yet. Furthermore, many in the tolling industry acknowledge that embedded telematics systems will soon dominate the in-vehicle technology market, but again, little progress has been made thus far in enabling embedded systems to communicate with tolling equipment.

Embedded telematics pose a significant challenge for use with both tolling systems and RUC systems relative to other technologies. As previously noted, this is because embedded services are proprietary in nature and closely guarded by manufacturers. Systems would have to be adapted to communicate with the numerous tolling protocols currently on the market and would have to function within an RUC framework, but it is unclear if the automotive manufacturing industry is convinced of the business need for this. Aftermarket device providers, such as smartphone app developers and the makers of navigation units, have an incentive to develop interoperable products such that they work in a wide array of vehicular makes and models, making them better suited for RUC systems needing to collect standardized data to properly function. However, it appears that these will not be the dominant telematics applications in the long term.

Using technology approaches from the tolling industry would only work in an RUC implementation if there is a sufficiently robust network of gantries and readers to capture travel. This network could be significant in a large state like Texas. However, there are recent developments in the RUC area that could potentially increase the role of data generated in vehicle, as opposed to data collected by roadside infrastructure, and specifically vehicle telematics data. The next sections of this report provide a summary of some of these developments.

Oregon Road Usage Charge Program

In 2015, the State of Oregon implemented the nation's first distance-based road user charge system for passenger vehicles. The implementation of this system follows the completion of two successful pilots of the RUC concept and the passing of legislation by the Oregon Legislature implementing the new system. The program features an initial participant pool of 5,000 volunteer vehicle owners who will pay a 1.5 cent/mile road use charge instead of fuel taxes.

Various methods are used to determine fuel taxes paid, and participants will receive a credit against the assessed road usage charge for any fuel taxes paid (*7*).

The Oregon RUC system makes extensive use of private entities for administration, and some of these are expected to be telematics device and service providers. The Oregon Department of Transportation (ODOT) initially selected several account managers through a request for proposal (RFP) process, and subsequent RFPs for new account managers are possible depending on the success of the program. These account managers will be responsible for managing various aspects of the state's Road Usage Charge Program (RUCP) on behalf of ODOT and will serve as the primary account administrators for program participants. Access to mileage reading devices (MRDs) and numerous individual service providers will be managed through the account managers. Account managers will be required to develop systems that (*7*):

- Provide user choice of technology and service provider.
- Are auditable.
- Are cost effective.
- Collect RUCs from tax-liable users for travel in Oregon.
- Provide credits for Oregon fuel taxes paid.
- Do not charge for out-of-state travel for users who choose certain types of MRDs.
- Do not charge for travel off-road or on private lands for users who choose certain types of MRDs.
- Contain redundancy and backup information.
- Support interoperability.
- Are expandable and flexible for a greater number of users and revenue collection uses.
- Provide an open architecture that allows private companies to provide either technology or service components.

Through their account managers, participants will select a mileage reporting vendor (tested and certified by ODOT) and a mileage reporting device, and they will have a choice of various value-added service providers. These value-added service providers, including those providing in-vehicle services through telematics-based applications, will interface with program participants through the account manager and the account management systems they employ. Each account manager will be free to propose their own unique account management system but must fulfill the following responsibilities (*7*):

- Participant account registration.
- Participant account maintenance and support/customer relations management.

- Communication of program updates.
- Account handling.
- Change of service provider/MRD equipment.
- Configuration management.
- Help desk activities (handle inquiries and complaints).
- Modification, transfer, and closing of accounts.
- Data collection.
- Road usage charge calculation and levying.

ODOT has indicated through its procurement documents that four mileage reporting options will be supported, regardless of the account manager. These include:

- Basic.
- Advanced.
- Switchable.
- Telematics.

These mileage reporting options are still under development and refinement, but it is likely that several of these will resemble the mileage reporting plans used in Oregon's most recent pilot of the RUC concept. In that pilot, users of the basic plan used an in-vehicle device to record distance traveled, but location data were not collected. Under the advanced plan, participants used an in-vehicle device that recorded miles and basic location data, with mileage being allocated to the appropriate state. Under the switchable (smartphone) plan, participants used a GPS-enabled smartphone application that allowed them to choose whether they reported miles on a zone basis (as in the advanced plan) or reported all miles traveled (as in the basic plan). It is likely the telematics plan will use data from embedded or OBD-II-based telematics systems and will function in much the same way as the advanced and switchable plans did in the previous pilot. Verizon Telematics was recently announced as one of the three account managers that Oregon will rely on, in addition to Azuga and Sanef.

The fee system will be based on an open platform, defined in the authorizing legislation as "an integrated system based on common standards and an operating system that has been made public so that components performing the same function can be readily substituted or provided by multiple providers" (*8*). The platform is technology agnostic, meaning that any technology that meets the basic standards and specifications outlined by ODOT can be used to collect and transmit data for the system. This would include embedded systems. In its procurement documents, ODOT has identified the following standards and preferences to be used by system components (*7*):

- **Representational State Transfer—**An architectural style for distributed hypermedia systems (such as graphics, audio, and video) that can be applied to the development of web services (*9*).
- **JavaScript Object Notation (JSON)—**A data-interchange format based on JavaScript that is easy for humans to read and write and easy for machines to parse and generate. It uses many of the same conventions as other programming languages, such as C, C++, C#, Java, JavaScript, Perl, and Python, making it a useful data-interchange language (*10*).
- **Hypertext Transfer Protocol—**A common application protocol used in web-based applications for the exchange of data between clients and servers.
- **Transmission Control Protocol—**A well-established and highly reliable protocol for transmitting large amounts of data.
- **Internet Protocol—**The primary communications protocol for the modern internet.

This open platform is designed to be as flexible for evolving technologies as possible. By developing this standardized interface, devices from numerous technology providers can operate in conjunction with the various account managers, and multiple account managers can interface with ODOT (*7*). It is envisioned that the combination of the open platform, multiple account vendors, and multiple service providers will form the basis of a future road user charging market. This market will connect drivers with in-vehicle service providers while providing a means of generating transportation funding. Drivers will pay for various services and will be assessed an RUC through invoicing processes for these services (*7*).

Trucking Fees

As noted previously, Oregon's upcoming RUCP will be the nation's first road user charge on *passenger* vehicles. However, fees based on distance are already levied on commercial vehicles in several U.S. states. Furthermore, distance-based commercial vehicle fees are very popular in Europe, where there is a lot of cross-border highway-based goods movement. Many of these applications are dependent on telematics-based or similar technologies.

United States

The states of Kentucky, New Mexico, and New York all levy a distance-based highway use tax on heavy vehicles using roadways within those states. These systems are mostly paper based in that operators are required to maintain and submit logs documenting travel. They are similar in their administration to other interstate commercial vehicle fee systems such as the International Fuel Tax Agreement.

The State of Oregon also levies a distance-based heavy vehicle charge but is working on expanding potential reporting options such that in-vehicle data can be used to assess travel in lieu of maintaining and submitting paper logs. Under Oregon's current weight-mile tax (WMT) system, truck drivers are required to maintain log books to track hours of service, number of axles, truck combination, and trip odometer readings so that they can calculate their WMT. The miles traveled in Oregon for each axle combination are self-reported by companies that then pay their WMT on a monthly or quarterly basis. This process has proven to be very paperwork intensive (*11*).

To simplify WMT collection, ODOT implemented Oregon Trucking Online to allow payments to be received via the Internet, and since then approximately 25 percent of WMT payments have been made online (*11*). However, ODOT believed there were additional opportunities to reduce the resources and time required for WMT calculation, payment, and processing. As such, in February 2010, the ODOT Motor Carrier Transportation Division implemented the Truck Road Use Electronics (TRUE) pilot project.

The TRUE system took the form of a smartphone application enabled with a GPS component and microprocessor. The app was uploaded to phones used by truck operators. At the beginning of each trip, the driver entered the truck weight class, number of axles, and odometer information into the app. Other information was preloaded in the app. The app then recorded travel using the GPS component by taking latitude and longitude readings every five minutes. Data were collected in seven U.S. states and three Canadian regions as part of the study. Information collected by the app was sent electronically to ODOT, where the truck's WMT invoice was produced and made available for payment online. This automated process allowed the system to reduce the administrative burden on trucking firms as well as ODOT. The pilot program concluded in April 2012 (*11*).

Weigh-in-motion station records corresponding with the TRUE GPS data were collected for the pilot project vehicles. These data were similar to the TRUE GPS information and could be linked through mutual data points such as the vehicular license plate. This allowed for cross-checking of the two datasets, revealing inconsistencies in such elements as axle counts, commodity codes, vehicle weights, and overweight records (*11*). Such disparities indicate that there are issues with the accuracy and reliability of the driver/operator-input values in the TRUE dataset. They also highlight a problem with general road user charges that rely on some form of self-reporting—primarily, verifying that information as accurate.

The TRUE pilot project found that 95 percent of TRUE records included coordinates that were accurate within 53 feet of their actual location. There was a high degree of accuracy in smartphone GPS readings taken from interstate locations. Location accuracy was lower in Nevada, Utah, and west of Washington state (*11*).

Once ODOT concluded collection of the TRUE pilot project data in April 2012, a private company by the name of EROAD began a similar project in Oregon. EROAD is an in-vehicle services provider for the New Zealand commercial vehicle RUC, which will be discussed in the next section. EROAD negotiated a signed agreement with the Oregon Trucking Association that allows it to collaborate in Oregon on a pilot demonstration of the EROAD product as a potential mechanism for Oregon WMT assessment and payment (*11*).

International

There are numerous distance-based truck fee systems in operation in Europe and particularly in Central Europe. Some fee systems are simple vignettes, where truck operators purchase a sticker or similar permit that enables them to drive for a certain period on the nation's roadway network. Many of these vignette systems cover multiple countries.

Of more interest to this research are the European heavy vehicle fee systems that use in-vehicle devices for mileage assessment. All of these systems differ from the system Oregon is developing in that they use extensive networks of roadside equipment to either assess road usage, complement in-vehicle assessment technologies, or serve enforcement purposes. They tend to rely less on in-vehicle telematics capabilities than what is envisioned for RUCs in the United States, but their application is nonetheless informative for the domestic experience in terms of identifying barriers and opportunities for implementation.

Germany levies a heavy goods vehicle (HGV) fee that is among the most mature heavy vehicle fee systems in the world. Fees are levied on trucks weighing 12 metric tons or more for travel on the autobahn and other national highways. Since fees are levied only for travel on certain roadways, the system makes use of in-vehicle units that use GPS satellite signals to determine location. These units communicate with roadside-mounted DSRC equipment for enforcement purposes. Data are communicated from the units through a cellular network. Austria has the HGV tolling system, which is similar to the German system and relies on in-vehicle devices that communicate with roadside DSRC equipment but uses that information to calculate distance traveled and communicate charging information. Distance and location under the Austrian system are thus calculated based on the successive passage of a vehicle through a network-wide series of gantries, not GPS data. Similar systems are in use in the Czech Republic, Slovak Republic, and Poland.

Switzerland has a heavy vehicle fee but uses a unique combination of technologies to assess distance and levy the associated fee. The Swiss system relies on in-vehicle devices that actually connect to the vehicular diagnostic port, which allows for the calculation of distance traveled based on vehicular data, not GPS data or roadside equipment. Readers located at international borders are used to signal the in-vehicle device when the vehicle has left Switzerland and to cease charging. Charge information is forwarded to a back office on a chip from the in-vehicle device that must be sent in by the owner of the vehicle.

One of the major issues facing these European systems is that each one requires a unique device, and devices are not interoperable. Truck operators who travel in multiple jurisdictions must have multiple devices and maintain multiple accounts. This is one of the primary concerns voiced by commercial vehicle operators in the United States in response to proposed RUC implementation. Commercial operators fear having to maintain devices and accounts for different states and would prefer to have one national system to operate under. Technology providers and automobile manufacturers have expressed similar concerns. They would like for the vehicles and in-vehicle devices they manufacture to work in all states and believe that a national system, as opposed to several state systems, would ensure interoperability.

New Zealand also charges a weight distance tax on heavy commercial vehicles, and its approach somewhat addresses the issue of technology interoperability by allowing operators to choose from an assortment of devices and plans. The New Zealand RUC is levied on heavy vehicles with a weight of 3.5 and varies based on the weight of the vehicle and the number of axles. Vehicles were originally required to have hubodometers, which attach to the exterior of the vehicle's wheel hub, to estimate distance traveled. However, New Zealand has recently transitioned to electronic collection of distance. Technology providers are required to collect certain information for the calculation of the RUC and collect the fee as part of the provision of other services such as fleet maintenance and logistics applications. Much like Oregon's soon-to-be-implemented passenger vehicle road usage charge and weight distance charge for trucks, device providers need only comply with basic government standards and business rules in order to participate in the fee system.

Barriers and Opportunities to Telematics Utilization in Road User Charging

Despite advancements in developing and implementing road user charging systems, there remain significant barriers to implementation of an RUC system. These include administrative costs, technological uncertainty, interoperability of technologies, lack of simple mileage estimation strategies, privacy concerns, and equity concerns. These concerns are particularly acute regarding the use of vehicle telematics systems for the levying of road user charges. However, recent success in the pilot testing of road user charges illustrate how these barriers might be overcome.

High Administrative Costs

Deploying and maintaining a system that determines road usage presents added costs and complexity to state institutions. By shifting fee collection from a relatively small number of payers (fuel suppliers) to many payers (road users), a state implementing a road user fee system would increase its total number of collection points by several orders of magnitude. In Texas, the Comptroller of Public Accounts collects fuel taxes from about 6,300 fuel tax license holders. At the same time, the Texas Department of Motor Vehicles (DMV) handles about 23 million vehicle registrations a year. Thus, a shift in how transportation fees are collected would significantly increase the number of collection points from the thousands to the tens-of-millions. Furthermore, a data-intensive road user charging system would likely require the state to maintain records on fee payers, thus incurring significant data storage and maintenance costs.

Administrative costs associated with road user fees were examined in pilots and studies conducted in Oregon, Minnesota, Nevada, and Washington. Each study concluded that administrative costs would be significant and recommended partnering with private entities to coordinate transaction and mileage data. For example, Oregon's road user charging concept includes an open-architecture design where government entities interface with private-sector account managers who collect the road usage charge information and provide account administration, compliance, and enforcement services. Motorists pay private-sector account managers, while the account manager sends standardized road usage data and any fees collected from the driver to the state. The role of the ODOT is primarily focused on certifying private-sector data handlers, establishing standards, and auditing, reducing overall costs to the state. Actual administrative costs from the Oregon system will not be available until well after the program is implemented in 2015.

Technological Development

The field of vehicle telematics and their underlying technologies is advancing rapidly. It is increasingly common for new-model vehicles to be equipped with embedded systems that use a wide array of in-vehicle sensing components while also communicating with exterior components such as smartphones or cloud-based services. One challenge for any road user fee system that seeks to leverage these developments will be simply keeping pace with them.

It is now generally accepted that government entities will play only a small role in the provision of any devices for use in a road user charging system. Early RUC pilots tested closed platforms that were limited to a specific technology application that was developed explicitly for the pilot. However, recent pilots have tested a range of private-sector-developed technology platforms, with the state only establishing basic business rules and technology standards. It is likely that this will be the primary role of states and the federal government if technology-based RUC systems are to see wider implementation. Oregon's RUCP is based on an open platform to be as flexible for evolving technologies as possible. The standardized interface allows for the utilization of multiple devices as part of road usage assessment and enables the private sector to take a more active role in system administration and customer management.

Standardization and Interoperability

Much of the federal government's initial role in the development of vehicle telematics technologies, and specifically OBD-based technologies, was in standardization. Standardization helps ensure that data collected for public uses, whether related to emissions control or potentially revenue generation, are consistent and can be processed and used with a lower compliance cost. Standardization also enables interoperability, wherein different technologies can all operate within the established policy system and the system itself can accommodate different types of technologies. Interoperability also means that devices will work in any state. Automobile manufacturers, technology providers, in-vehicle services providers, and the trucking industry have all expressed concerns about the potential for multiple state-level road user charging systems that are not interoperable. The fear is that states will be inconsistent in their technology approaches and account management practices. Technology and service providers, including automotive manufacturers with embedded systems, do not want to have to design their products, so they work under multiple state systems with differing requirements, standards, and/or specifications. Commercial trucking firms, and possibly interstate passenger vehicle travelers, do not want to have multiple devices and manage multiple accounts.

The effectiveness of OBD-based systems for assessing emissions was improved significantly with the development of industry standards related to vehicular data. Weak standards meant that it was difficult for emissions monitoring stations to read and assess data from vehicle to vehicle since different makes and models would provide different information. Even now, existing OBD standards might not be sufficient to levy an effective RUC, even though OBD-II is the most mature standard available. Pilots in Oregon and Minnesota showed that information retrieved through an OBD-II connection can still differ significantly from vehicle to vehicle, making the task of determining miles traveled on a vehicle-to-vehicle basis problematic. Pilot projects in both of these states had to restrict participation to certain vehicle classes that were at least somewhat consistent in the information their in-vehicle data systems provided.

The U.S. tolling industry has collected fees from road users for decades and has significant experience in the areas of standardization and interoperability that can inform the development of road user fee systems. In the past, toll road facilities in the United States accepted payment from users in the form of cash. Thus, for most of the tolling industry's existence, facilities have been interoperable in that as long as a driver had enough cash on hand, he or she was able to use any facility in the nation. However, with the advent of RFID and license plate recognition technology, electronic toll collection (ETC) and all-electronic tolling (AET) became increasingly popular options for toll entities because they do not require drivers to slow down or stop to pay.

Most electronic toll tags are based on 915 MHz RFID technologies. Tags contain identifying information used to extract tolls from an account without having to exchange hard currency. The tags are largely passive from the consumer's viewpoint—they are simply displayed in the vehicle and do not provide any active display or user interface. Even though the basic technology supporting ETC and AET is fairly consistent, there are several different communications protocols that may be used within the RFID family. As such, just because one type of RFID tag works on one toll road does not mean it will work on another toll road. Thus, not all AET and ETC toll roads are interoperable with one another. This can complicate enforcement of tolls from users who are not equipped with the right technology or do not have any type of toll tag technology at all.

Interoperability in tolling systems would allow road users seamless travel between toll service providers and permit them to reach their destinations without requiring multiple toll tags or onboard units. Tolling system operators have attempted to address this issue by forming regional partnerships that either use the same protocol or share information in order to facilitate collection practices. In the northeast, the E-Z Pass Interagency Group was formed by seven toll agencies in 1990 and now includes over 25 agencies. E-Z Pass currently operates within 15 states, with more than 14 million accounts and 24 million tags, and collects over $6 billion in electronic toll revenues (*12*). TxTag in Texas offers a similar approach, connecting all the state's systems through multiprotocol readers (i.e., technical interoperability)—EZ Tag (Houston), Toll Tag (Dallas–Fort Worth), Central Texas Regional Mobility Authority (Austin), and the Texas Department of Transportation's Central Texas Turnpike System.

As noted, tolling interoperability can generally be achieved in one of two ways: technical or institutional (*13*). Technical interoperability means that either the protocols used by one entity can be read by another or all entities use the same protocol. Institutional interoperability, on the other hand, involves the exchange of transaction data among toll operators in order to identify and charge viable accounts in other areas. An example of this would be a driver with a valid toll tag in one area using a toll road in another area that does not support that protocol. If the two toll entities are institutionally interoperable, the agency responsible for the facility that the driver just used would be able to charge the account maintained by the other entity by collecting the driver's license plate data with a specialized camera. A standardized format for these license plate databases serves as an institutional interoperability tool in the absence of standardized technology.

Oregon's approach does much to address standards and interoperability issues. The ODOT back office for its upcoming RUCP is designed to be as flexible as possible, with basic standards that accommodate numerous technologies, allowing it to remain interoperable across multiple technology platforms. However, there is still the potential that states will choose to develop their own systems, which may or may not be based on open principles. Such systems would require more specifically tailored technology applications and would likely necessitate the establishment of an account specific to that fee system. However, ODOT is currently working with other states to leverage its RUCP account management system for use in other state's road user charging efforts. In 2013, ODOT formed the Western Road User Charge Consortium (WRUCC) along with the states of Washington and Nevada. The WRUCC was formed for the purposes of developing road user charging expertise and facilitating resource sharing on the road user charging concept among member states. The goals of the WRUCC are to:

- Explore the technical and operational feasibility of a multijurisdictional system.
- Develop methods for remitting road use charges among multiple jurisdictions.
- Develop models for regional (and national) interoperability.
- Develop concepts for a multistate system.
- Engage automakers and the tech sector to offer mileage reporting capabilities.
- Identify and share public acceptance factors.
- Share policy and program experiences among members.

The organization hopes to expand its membership significantly in the coming years and could be a facilitator of multistate road user fee charging pilots. As of July 2014, WRUCC included its founding states as well as Texas, California, Arizona, Utah, and Colorado. The states of New Mexico, Wyoming, Montana, and North Dakota are also considering joining.

No Simple Telematics-Based Mileage Solution

There are issues with mileage assessment using telematics-based data. Blackbox applications provide very detailed and reliable data, but they are not expected to be a significant telematics-based technology services platform in the long term. Smartphone and hybrid applications enjoy significant utilization, but location data tend to be less accurate, and devices can be turned off or removed from the vehicle. OBD-based devices can be used to provide accurate and reliable data, but they too can be removed from a vehicle. Furthermore, not all vehicles manufactured prior to 1996 have the necessary connection ports for OBD access. Embedded systems are anticipated to dominate the telematics market since they offer reliable and accurate data and are difficult to tamper with, but they are not yet found in the majority of U.S. vehicles.

The challenge of mileage assessment is particularly difficult to address and is one of the central barriers facing RUC system implementation from an administrative cost perspective. However, Texas is uniquely positioned relative to other states on potential mileage assessment options, primarily because odometer readings are taken during state-mandated safety inspections. This practice does not occur in all states. Texas already has a database of periodic odometer readings for most of the vehicles registered in the state. However, these odometer readings are not verified or checked by any state entity as part of auditing or enforcement procedures. Therefore, the accuracy of the current database is in question. Furthermore, for any number of reasons, odometer readings are not always taken during the inspection process. They are required by rule, not statute. As a result of odometer reading data not being verified or checked, it is not possible at this time to determine the rate with which odometer readings are even taken.

Furthermore, the State of Texas already makes use of private vendors for the payment of transportation-related fees. Drivers in Texas can obtain their vehicle registration at any number of third-party locations, such as grocery stores, and private vendors can access certain registration data. The Texas DMV has websites and specialized web portals for such access.

Privacy and Security Issues

The current fuel-tax-based transportation funding system is anonymous in that taxpayers do not file a return and remit taxes directly to the collecting entity. Rather, they pay their fuel taxes within a retail environment, essentially reimbursing the supplier of the fuel for the taxes already paid when the fuel was distributed throughout the supply chain. Thus, there is no record of fuel taxes paid by individual taxpayers. However, a funding system based on road usage would require the collection of data related to travel, which in turn could lead to privacy concerns on the part of the motoring public.

In fact, privacy concerns by the public are perhaps the biggest non-technical challenge facing RUC implementation, and particularly RUC systems that incorporate a technology element. The metering of road usage can lead to perceptions of tracking by government entities, and strong opposition to RUC systems based on these concerns has been encountered. In Oregon, the American Civil Liberties Union attended legislative hearings and expressed opposition to the development of road user charging legislation due to privacy and data security concerns. Language was ultimately added that clarified data usage, disclosure, and destruction requirements as part of any pilot programs. Public studies on the RUC subject have shown that the public tends to have similar concerns about privacy and data security in RUC systems and may oppose charging efforts due to those concerns (*14*).

The U.S. Department of Transportation identifies two potential ways in which data breaches or data misuse might impact privacy in vehicle telematics systems: trip tracking and the release of personally identifiable information (PII). Trip tracking involves data being used to reconstruct a trip made by an individual vehicle. The collection of location data by vehicle telematics systems poses numerous opportunities for trip tracking and expands the potential for privacy violations. The U.S. Office of Management and Budget defines personally identifiable information as "information which can be used to distinguish or trace an individual's identity, such as their name, social security number, biometric records, etc. alone, or when combined with other personal or identifying information that is linked or linkable to a specific individual" (*15*). In addition, "non-PII data can become PII when additional information is made publicly available—in any medium and from any source—that, when combined with other available information, could be used to identify an individual" (*15*).

Although many devices and applications need only anonymous data, many telematics services, such as concierge services, roadside assistance, and voice recognition, require detailed location data, PII, or both. The coupling of location data with PII is particularly problematic from a consumer privacy standpoint, and the popularity of these services thus represents a potential area for public policy in terms of protecting driver privacy.

Privacy protection in the United States is guided by several laws as well as industry principles for the electronic marketplace. Regarding data that might be used by vehicle telematics systems, the Electronic Communications Privacy Act of 1986 prohibits the federal government and communications providers from "accessing and sharing the content of consumers' electronic communications, unless approved by a court or by consumer consent" and prohibits communications providers from "voluntarily disclosing customer records to government entities, with certain exceptions, but companies may disclose such records to a person other than a governmental entity" (*16*). The Government Accountability Office (GAO) has noted that the act does not distinguish if location data are considered content or part of consumers' records, and further noted that privacy groups are requesting the act be amended to address protecting consumer location data (*17*).

Consumer data, as opposed to location data, are governed by Fair Information Practice Principles (FIPPs) that grew out of the Privacy Act of 1974, which was established by the Federal Trade Commission and the Department of Homeland Security (*18*). FIPPs are non-enforceable recommendations on data collection practices aimed at protecting consumer privacy. FIPPs apply to telematics services only regarding the use of transaction data, common in tolling transactions, such as vehicle identification numbers and vehicle diagnostic information. FIPPs include the following eight principles (*18*):

- **Transparency**: Organizations should be transparent and notify individuals regarding collection, use, dissemination, and maintenance of PII.
- **Individual Participation**: Organizations should involve the individual in the process of using PII and, to the extent practicable, seek individual consent for the collection, use, dissemination, and maintenance of PII. Organizations should also provide mechanisms for appropriate access, correction, and redress regarding use of PII.

- **Purpose Specification**: Organizations should specifically articulate the authority that permits the collection of PII and specifically articulate the purpose or purposes for which the PII is intended to be used.
- **Data Minimization**: Organizations should only collect PII that is directly relevant and necessary to accomplish the specified purpose(s) and only retain PII for as long as is necessary to fulfill the specific purpose(s).
- **Use Limitation**: Organizations should use PII solely for the purpose(s) specified in the notice. Sharing PII should be for a purpose compatible with the purpose for which the PII was collected.
- **Data Quality and Integrity**: Organizations should, to the extent practicable, ensure that PII is accurate, relevant, timely, and complete.
- **Security**: Organizations should protect PII (in all media) through appropriate security safeguards against risks such as loss, unauthorized access or use, destruction, modification, or unintended or inappropriate disclosure.
- **Accountability and Auditing**: Organizations should be accountable for complying with these principles, providing training to all employees and contractors who use PII, and auditing the actual use of PII to demonstrate compliance with these principles and all applicable privacy protection requirements.

Current trends in the development of road user charging systems on the West Coast indicate that government entities will have a reduced role in the collection of these data from consumers because it would be difficult from an administrative and enforcement standpoint for governmental entities to develop the appropriate systems. This indicates a strong role for the private sector in the collection of data for RUC administration, which warrants an examination of current industry practices on the protection of driver privacy as part of vehicle telematics service provision and federal statutes influencing those practices.

Vehicle telematics companies also abide by informal industry-recommended practices concerning location data. In a recent report, GAO examined these practices and summarized them as follows (*17*):

- Disclosures should be provided to consumers about data collection, use, and sharing.
- Providing controls over location data for consumers.
- Data safeguards and explanations of retention practices for consumers.
- Accountability measures for protecting consumers' data.

GAO suggested these practices based on interviews with privacy advocates and groups representing the mobile industry, and, consequently, self-determined that these practices were applicable to companies providing vehicle telematics functions. GAO evaluated telematics companies based on their conformity to these practices as opposed to FIPPs, which lack specification on the use of location data. GAO found that most companies cite broadly worded reasons for collecting location data, which GAO concluded could potentially allow for unlimited data collection and use. For example, some companies will use data collected from drivers in order to help electric vehicle drivers locate recharging stations. Furthermore, GAO found that half of companies use data for unspecified purposes. All of the companies surveyed by GAO stated that they share consumer location data with third-party firms in order to improve services and/or serve law-enforcement purposes (*17*).

GAO concluded that consumers are unable to prevent the use or retention of their data, and that telematics companies do not allow consumers to delete location data collected. GAO found that companies do, in fact, obtain consumer consent to collect data in various ways but concluded that “without clear disclosures about the purposes, consumers may not be able to effectively judge whether the uses of their location data might violate their privacy” (*17*). GAO also found that data safeguarding does occur, but each firm tends to use different de-identification methods that can affect how and which consumers may be re-identified and exposed to privacy risks. Finally, and contrary to industry-recommended practices, GAO found that telematics companies generally do not disclose how they hold themselves and their employees accountable for the breakage of any consumer agreements and subsequent exposure of consumers to privacy risks.

It is anticipated that privacy concerns will ultimately be addressed by allowing a high level of consumer choice and increased transparency on data usage. It is unlikely that, in the near future, RUC systems will be implemented with a requirement that metering devices be used, particularly those that rely on location data. Choice is also likely to be offered in terms of simply participating in the road user fee system. While Oregon’s upcoming fee system does not appear to have a no-tech option, participation in the program itself is voluntary. Oregon drivers not wishing to use a device do not have to participate.

Conclusions and Implications for Texas

Transportation infrastructure in the United States is funded primarily with the fuel tax, which is likely to see declines in purchasing power over time due to increases in average fuel efficiency and fuel consumption per vehicle. Road user charges are one potential funding mechanism that could address this issue since they are assessed based on distance traveled and not fuel consumption.

Vehicle telematics systems could provide an opportunity to assess distance traveled and levy a charge for that travel using data that are already being generated within the vehicle for use in other travel-related services. These systems are increasingly used by drivers to access any number of in-vehicle services, from safety features to navigation to concierge services. Vehicle telematics data also have the potential to be used as part of an RUC system since they can directly address several of the major challenges facing RUC implementation:

- **Determining distance traveled—**Determining distance traveled is more difficult than determining fuel consumption. Odometer readings can be taken, but doing so requires additional effort from the driver and the implementing entity. They may also be unreliable. Telematics systems generate high-quality data, often on a recurring basis, that can be used to determine distance traveled.
- **Differentiating travel—**An implementing entity might wish to discount certain types of travel, such as distance accrued out of state or on private roadways. Odometer readings do not allow for the differentiation of travel by location, but data from vehicle telematics, particularly those that are capable of using GPS data, can allow for mileage differentiation.
- **Alleviating relatively high administrative costs—**Road user charging systems would vastly expand the number of collection points relative to the fuel tax and would require the utilization of significant amounts of data relative to the fuel tax. An RUC system established on private-sector collection of data, including telematics data, could shift data collection, processing, and management costs away from the public sector and lower administrative costs to the state.

There are five basic vehicle telematics technology platforms, each with its own distinct advantages and disadvantages. Blackbox applications provide very detailed and reliable data, but they are relatively difficult to install and are not expected to be a significant telematics-based technology services platform in the long term. Smartphone and hybrid applications enjoy significant utilization, primarily due to the growing popularity of smartphones. However, there are issues with the use of these types of platforms, particularly for road user fees. Location data tend to be less accurate, and devices can be turned off or removed from the vehicle, lowering the reliability of any data gathered in terms of accurately assessing distance traveled. This issue can be addressed in hybrid systems; for example, OBD-based devices can maintain logs of vehicle starts and stops, which can be paired with smartphone data to identify gaps in usage data. However, OBD devices can also be removed from the vehicle, which reduces the reliability of the data. Embedded telematics systems reliably provide high-quality data and are difficult to tamper with. While embedded systems are limited to new-model cars, their utilization is expected to triple in the next few years.

Embedded telematics systems are not currently used as part of any domestic road user charging efforts, but they are anticipated to play a role in usage assessment as part of Oregon's upcoming RUCP. The success of the RUCP will be a strong indicator of the potential success of road user charging systems in addressing the implementation issues discussed in this report. The Oregon system will first validate whether open platforms are the best mechanism for accommodating and facilitating the development of multiple road user charge assessment technologies. The Oregon platform is set up to be technology agnostic, meaning that as long as a technology provider can meet certain basic standards and requirements, its technology application can be used for the assessment of road usage and the calculation of a charge. The extent to which multiple technology types are deployed in support of the pilot, and the ability of those technologies to evolve over time, will be primary indicators of the platform's success in remaining flexible.

Second, the RUCP will demonstrate the viability of the road user charging market, wherein multiple vendors manage customer accounts and facilitate services between drivers and service providers while collecting a fee. One aspect of this success that is most pertinent is the extent to which telematics and, in particular, embedded telematics providers participate in the system. High levels of participation will be indicative of industry willingness to participate in the development of these charging systems and to participate in the road user charging market. As noted earlier, Verizon Telematics was recently selected as one of the three initial account managers for the RUCP system.

Furthermore, should the RUCP pilot be successful, it could be an indication of the transportation technology industry's faith in the program to be leveraged for use outside of Oregon. Technology providers, including the developers of in-vehicle telematics services, have shown a strong preference for a national-level road user charging program in lieu of several distinct state-level programs. Strong participation in the new system could indicate either faith in the new system's leveragability or a desire to bolster the system's leveragability to make it the de facto national system.

Regardless of the RUCP's success, privacy concerns are likely to remain with regard to the use of telematics for levying RUCs. Many technologies and applications rely on the coupling of location data with personally identifiable information in order to provide services, which increases the risk of data breaches. Consumers are generally unable to prevent the use or retention of their data, and telematics companies do not allow consumers to delete collected location data. Methods used by private firms to de-identify sensitive information are often inconsistent. One method for addressing this in the near term is for states to simply place the burden of collecting and maintaining data on the private sector and allow consumers a choice in the types of devices and services they choose to use. While this report has shown that telematics service providers are not entirely transparent, allowing consumers to choose the providers they are most comfortable with could help alleviate some of the public's privacy concerns. In the longer term, governments may play an important role in setting privacy protections with regard to the coupling of location and transaction information in embedded telematics for public policy purposes.

The interoperability of different devices and technology systems across different jurisdictions is another potential barrier to implementation of a telematics-dependent RUC. The developers of aftermarket telematics systems such as smartphone applications and personal navigation devices have a strong incentive to develop their applications to be interoperable with as many vehicles and service applications as possible since doing so increases their potential market. However, vehicle manufacturers have a strong incentive to protect their proprietary systems and services from these competitors. As such, the embedded vehicle telematics market could pose a challenge for states seeking to leverage in-vehicle data for public policy objectives because it will be difficult to obtain standardized data given the proprietary nature of the system interfaces. However, there are currently companies that specialize in collecting telematics data and processing that data in a standard format for use by third-party service providers. Furthermore, lessons learned from tolling interoperability efforts suggest that interoperability may be achieved through back-office business practices.

References

1 Chen, M.-C., J.-L. Chen, and T.-W. Chang. Android/OSGi-Based Vehicular Network Management System. *Computer Communications*, Vol. 34, No. 2, 2011, pp. 169–183.

2 Baltusis, P. On Board Vehicle Diagnostics. Convergence Transportation Electronics Association, 2004. http://www.iatn.net/files/75280/on-board-vehicle-diagnostics-as-presented-by-paul-baltusis-2004-iatn-convention. Accessed Dec. 31, 2014.

3 Chen, H., and J. Tian. Research on the Controller Area Network. *Proc., 2009 International Conference on Computing, Networking and Communication*, 2009, pp. 251–254.

4 Telematics Update. Insurance Telematics Report. 2014. http://www.tu-auto.com/insurance-report/. Accessed Dec. 31, 2014.

5 Telematics Update. What UBI Do People Really Want? Sept. 5, 2014. http://analysis.telematicsupdate.com/insurance-telematics/what-ubi-do-people-really-want. Accessed Dec. 31, 2014.

6 Rephlo, J. A. *Connected Vehicles for Safety, Mobility and User Fees: Evaluation of the Minnesota Road Fee Test.* Minnesota Department of Transportation, Roseville, 2013.

7 Oregon Department of Transportation. *System Requirement Specifications for the Road Usage Charge Program, Version 1.3*. ODOT, Salem, Dec. 2014.

8 Oregon Senate Bill 810. 2013. https://olis.leg.state.or.us/liz/2013R1/Downloads/MeasureDocument/SB810/Enrolled.

9 Fielding, R. T. *Architectural Styles and the Design of Network-Based Software Architectures*. Doctoral dissertation. University of California, Irvine, 2000.

10 Introducing JSON. www.json.org. Accessed Dec. 31, 2014.

11 Bell, K. E., and M. A. Figliozzi. *Final Report: The Application of Smart Phone, Weight-Mile Truck Data to Support Freight-Modeling, Performance Measures and Planning.* Oregon Transportation Research and Education Consortium, Portland, Aug. 2013. http://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?article=1092&context=cengin_fac. Accessed November 10, 2016.

12 E-Z Pass Group. About Us: Overview. http://www.e-zpassiag.com/about-us/overview. Accessed Sept. 10, 2014.

13 Battelle and Texas Transportation Institute. *Tolling and Pricing Integration Opportunities: Assessment of System Integration Opportunities.* FHWA, U.S. Department of Transportation.

14 Baker, R. T., and V. D. Goodin. *Exploratory Study: Vehicle Mileage Fees in Texas*. Report FHWA 0-6660-1, Texas A&M Transportation Institute, College Station, Tex., Jan. 2011.

15 Office of Management and Budget. Memorandum for the Heads of Executive Departments and Agencies: Safeguarding Against and Responding to the Breach of Personally Identifiable Information. May 22, 2007. http://www.whitehouse.gov/sites/default/files/omb/memoranda/fy2007/m07-16.pdf. Accessed Aug. 28, 2014.

16 Electronic Privacy Act of 1986, 18 U.S.C. Section 2510-22. United States Department of Justice, Office of Justice Programs. https://www.justice.gov/jmd/electronic-communications-privacy-act-1986-pl-99-508. Accessed Dec. 31, 2014.

17 United States Government Accountability Office. *In-Car Location-Based Services: Companies Are Taking Steps to Protect Privacy, but Some Risks May Not Be Clear to Consumers.* U.S. Senate, Committee on the Judiciary, Subcommittee on Privacy, Technology and the Law, Washington, DC, 2013.

18 United States Department of Homeland Security, National Institute of Standards and Technology. Enhancing Online Privacy. 2008. https://www.nist.gov/pba/enhancing-online-privacy. Accessed Aug. 28, 2014.

Appendix: Supplemental Information

Federal Statutes Affecting Vehicle Telematics Systems

Federal Trade Act of 1914

The Federal Trade Commission (FTC) was created in 1914 to prevent unfair methods of competition in commerce. The commission was directed to administer a wide variety of consumer protection laws, including the Telemarketing Sales Rule, the Pay-Per-Call Rule, and the Equal Credit Opportunity Act. In 1975, Congress gave the FTC the authority to adopt industry-wide trade regulation rules (*1*). According to GAO, "The FTC could take action against a company if the FTC found the company was being unfair or deceptive by not adhering to the company's own privacy policies that describe how location data are collected, used and shared" (*2*).

The Communications Act of 1934

The Communications Act of 1934 is a federal law signed by President Franklin D. Roosevelt, codified as Chapter 5 of Title 47 of the United States Code, 47 U.S.C. § 151 et seq. The act replaced the Federal Radio Commission with the Federal Communications Commission (FCC). It also transferred regulation of interstate telephone services from the Interstate Commerce Commission to the FCC (*3*).

The purpose of the Communications Act is to:

> Regulate interstate and foreign commerce in communication by wire and radio so as to make available, so far as possible, to all the people of the United States a rapid, efficient, nationwide, and worldwide wire and radio communication service with adequate facilities at reasonable charges, for the purpose of the national defense, and for the purpose of securing a more effective execution of this policy by centralizing authority theretofore granted by law to several agencies and by granting additional authority with respect to interstate and foreign commerce in wire and radio communication.

On January 3, 1996, Congress amended sections of the Communications Act of 1934 with the Telecommunications Act of 1996. This law covers location data collected by telecommunication providers, not data collected by firms providing in-car location-based services (*2*). This law would not apply directly to telematics companies; it applies to third-party telecommunications companies collaborating with telematics, imposing requirements to protect customer proprietary network information and location of customers when calls are made (*3*).

Privacy Act of 1974

The Privacy Act of 1974 covers the collection, maintenance, use, and dissemination of personally identifiable information about persons maintained in government records, balanced with the government's need to ensure unwarranted invasions of individual privacy (*4*). The purpose for establishing the act was to deter illegal surveillance and investigation of individuals by federal agencies exposed to the Watergate scandal and the rising growth of technology within the government to store and retrieve personal data.

The act presented four policy objectives and was the precursor to FIPPs later codified by the FTC and the Department of Homeland Security (*4*): (a) to restrict disclosure of personally identifiable records maintained by the agencies; (b) to grant individuals increased rights of access to agency records maintained on themselves; (c) to grant individuals the right to seek amendment of agency records maintained on themselves upon a showing that the records are not accurate, relevant, timely, or complete; and (d) to establish a code of fair information practices, which requires agencies to comply with statutory norms for collection, maintenance, and dissemination of records.

Electronic Communications Privacy Act of 1986

The Electronic Communications Privacy Act of 1986 (ECPA; codified at 18 U.S.C. §§ 2510–2522) was enacted by Congress to extend government restrictions on wire taps from telephone calls to include transmissions of electronic data by computer. Specifically, ECPA was an amendment to Title III of the Omnibus Crime Control and Safe Streets Act of 1968 (the Wiretap Statute), which was primarily designed to prevent unauthorized government access to private electronic communications (*5*).

The ECPA also added new provisions prohibiting access to stored electronic communications (i.e., the Stored Communications Act, 18 U.S.C. §§ 2701-12). The ECPA further included pen/trap provisions that permit the tracing of telephone communications. The ECPA has been amended by the Communications Assistance to Law Enforcement Act (1994), the USA PATRIOT Act (2001), the USA PATRIOT reauthorization acts (2006), and the FISA Amendments Act (2008). Pertaining to telematics, GAO summarizes ECPA as (*2*):

> prohibiting the federal government and providers of electronic communications from accessing and sharing the content of consumers’ electronic communications, unless approved by a court or by consumer consent. The act also prohibits providers of electronic communications from voluntarily disclosing customer records to government entities, with certain exceptions, but companies may disclose such records to a person other than a governmental entity.

Advantages and Disadvantages of Vehicle Telematics Technology Platforms

Table 2 presents the advantages and disadvantages of the five primary vehicle telematics applications.

Table 2. Advantages and Disadvantages of Vehicle Telematics Technology Platforms.

Technology	Advantages	Disadvantages
Blackbox	Difficult to tamper with Receives vehicle information from external sources Valuable for forensic crash reconstruction Accurate driving behavior and location data	Expensive for motorists Requires installation by professional technicians Forecasted to lose popularity among consumers relative to other technology applications
OBD-II Dongle	Inexpensive for motorists Accurate driving behavior and location data Post-1996 vehicles mandated to carry an OBD-II port OBD scanning tools accessible for purchase for motorists Direct access to vehicle data Can obtain data from external sources as well (i.e., GPS) Can communicate with cellphones through cellular, wireless, or Bluetooth connections	Can be easily removed, complicating enforcement of road user charges Not universal in all vehicles, mainly pre-1996 vehicles Not suited for mileage reporting; primarily serves emission malfunctions Limited port space could block value-added services Mileage reporting can occur indirectly
Embedded	Prevalent in new vehicles Added security features for vehicle tracking Difficult to tamper with Easy to integrate with motorists' personal multimedia devices No additional hardware costs to motorists	Small share of vehicle fleet Limited to a specific vehicle, not a motorist
Smartphone	Low capital costs for governments Interoperable with aftermarket devices and embedded telematics Portable charging device Personalized interface for motorists Prevalence of smartphones	Constrained to cellular range Can be left behind, turned off, or discharged Limits some value-added services such as stolen vehicle recovery or remote vehicle diagnostics (unless connected to a wireless dongle or embedded system)
Hybrid	Leverages smartphone processing power with dongle data accuracies Not limited to a specific vehicle but can be used by a motorist on any vehicle	Time- and cost-intensive solution requiring smartphone and dongle connection Constrained to cellular range Pilot testing in Minnesota revealed vehicle detection failures and lost trip data Easy to tamper with Vehicle requires an OBD-II port connection

Source: (6).

Embedded Telematics Services and Providers

Table 3 lists the service features and corresponding providers of embedded telematics systems.

Table 3. Services Provided by Embedded Telematics.

Feature	OnStar (GM)	MBmbrace	BMW Assist	Lexus Enform	Toyota Safety Connect	Ford Sync	Hyundai BlueLink	Infiniti Connection
Automatic Collision Notification	X	X	X	X	X	X	X	X
Concierge		X	X	X				X
Dealer Service Contact		X	X				X	
Destination Download	X	X	X	X		X	X	X
Destination Guidance	X	X	X	X		X	X	X
Emergency Services	X	X	X	X	X		X	X
Fuel/Price Finder			X				X	
Hands-Free Calling	X		X					
Location Sharing		X					X	
Remote Door Lock		X					X	X
Remote Door Unlock		X	X				X	X
Remote Horn/Lights	X		X				X	
Roadside Assistance	X	X	X	X	X		X	X
Sports/News Information			X			X		X
Stock Information			X			X		X
Stolen Vehicle Tracking Assistance	X	X	X	X			X	X
Text Message/Memo Display						X	X	
Traffic Information		X	X			X	X	
Vehicle Diagnostics	X		X			X	X	X
Vehicle Locator	X	X	X					
Weather Information		X	X	X		X	X	

Source: (7).

References

1 Federal Trade Commission Act of 1914. Cornell University Law School, Legal Information Institute. https://www.law.cornell.edu/uscode/text/15/41. Accessed Dec. 31, 2014.

2 United States Government Accountability Office. *In-Car Location-Based Services: Companies Are Taking Steps to Protect Privacy, but Some Risks May Not Be Clear to Consumers.* U.S. Senate, Committee on the Judiciary, Subcommittee on Privacy, Technology and the Law, Washington, DC, 2013.

3 Communications Act of 1934, 47 U.S.C. Section 151. United States Department of Justice, Office of Justice Programs. https://it.ojp.gov/PrivacyLiberty/authorities/statutes/1288. Accessed Dec. 31, 2014.

4 Overview of the Privacy Act. United States Department of Justice, 2006. http://www.justice.gov/sites/default/files/opcl/docs/1974privacyact-2012.pdf. Accessed Dec. 31, 2014.

5 Electronic Communications Privacy Act of 1986, 18 U.S.C. Section 2510-22. United States Department of Justice, Office of Justice Programs. https://www.justice.gov/jmd/electronic-communications-privacy-act-1986-pl-99-508. Accessed Dec. 31, 2014.

6 Telematics Update. Insurance Telematics Report. 2014. http://www.tu-auto.com/insurance-report/. Accessed Dec. 31, 2014.

7 Edmunds. Telematics Chart. http://www.edmunds.com/car-technology/telematics.html. Accessed Dec. 31, 2014.