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ASSESSING OUT-OF-STATE DRIVERS IN A RUC SYSTEM: PHASE 2 FINAL REPORT

Western Road Usage Charge Consortium // December 2016

WA **RUC**

Western Road Usage Charge Consortium

Assessing Out-of-State Drivers in a Road Usage Charge System: Phase 2

Final Report

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Definitions & Abbreviations

TERM/ABBREVIATION	DEFINITION/DESCRIPTION	REMARKS
AADT	Average Annual Daily Traffic	
Clearinghouse	an entity that calculates reconciliation and, optionally, handles reconciliation payments among two or more jurisdictions.	
GPS	Global Positioning System	
HPMS	Highway Performance Monitoring System	
Home Jurisdiction	the jurisdiction in which a vehicle is registered. Jurisdictions can adopt bilateral or multilateral approaches for data reporting, road charge collection, and revenue reconciliation.	
Host Jurisdiction	jurisdiction in which a visitor travels. Jurisdictions can adopt bilateral or multilateral approaches for data reporting, charge collection, and revenue reconciliation.	
MPG or MPGe	Miles per gallon or miles per gallon equivalent	MPGe is used in lieu of MPG for vehicles that derive some or all motive power from a fuel source other than gasoline or diesel, such as electricity.
MRD	Mileage reporting device	
Reconcile	▶ process of balancing two accounts, including calculation and payment of charges or refunds. In the Phase 1 final report we discussed two types of reconciliation: > *Individuals* reconcile the amount of charges paid with the amount of charges owed to all jurisdictions (home and hosts). Home jurisdictions or private account managers handle payments and refunds. > *Jurisdictions* reconcile the amount of charges collected from motorists with the amount owed by motorists. Additional payments or refunds are handled directly with other jurisdictions or through a clearinghouse. In this report we concentrate on methods of reconciliation by jurisdictions.	

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RUC	Road usage charge or road usage charging
Shadow Charge	a charge on one entity that is paid by another entity.
Visitor	registered owner or lessee of vehicle(s) traveling outside their home jurisdiction.
VMT	Vehicle Miles of Travel

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Executive Summary

This report summarizes the work performed under Phase 2 of the study of *Out-of-state Drivers in a Road Usage Charge (RUC) system*. It identifies and discusses key characteristics of interjurisdictional RUC, estimates the costs and revenue potential associated with assessing RUC on visitors, discusses interjurisdictional RUC assessment in an international context, and proposes a sequence of activities that WRUCC states can undertake to plan, develop and execute an interjurisdictional demonstration or pilot (hereafter referred to as pilot). The report focuses on states within the western region of the U.S. although the analysis and principles can be equally applied to other states outside the western region, the federal government, and jurisdictions bordering the U.S.

A principal topic of interest in a multi-state RUC context is methods of collecting and reconciling revenues among states when RUC is assessed on out-of-state visitors. Although states remain free to adopt various RUC operational concepts such as time permits (in which visitors pay RUC directly to host states), in a mature RUC system automated mileage reporting methods with location-aware devices are likely to be widespread. In this future, it is probable that a motorist will remit all charges to either their account manager or an agency in their home state, regardless of where miles were driven, and it will be necessary for jurisdictions to reconcile RUC collected among themselves. However, the low probability of a GPS mandate for any RUC system in the U.S. means that clear identification of where RUC is due is complex.

After estimating the proportion of RUC a state could expect to be generated by visitors (relative to residents), this report examines interjurisdictional RUC assessment and reconciliation costs under three policy bases developed for Phase 1 of the study: distance-based charge, shadow-charge, and combination of distance-based and fuel-based charges. It finds that distance-based charges are efficient only if everyone adopts a location-aware RUC reporting method and agrees to share location data (aggregated to the jurisdiction level) with their home state's RUC agency. In the near-term, a combination of distance-based and fuel-based user-fee assessment conveniently captures visitors, if they purchase fuel while in-state. Over the longer-term, as vehicles shift away from fossil fuels as a power source, less and less visitor road use will be "captured" via motor fuel tax payment. At that point, shadow charges are likely to be the most efficient method of capturing visitor travel to RUC states. Significant work remains to be done in terms of establishing agreed methodologies for determining shadow charges, particularly with states that do not assess any RUC at all.

Next, the report identifies characteristics of a successful interjurisdictional pilot, which include identification of clear policy questions in common across participating states, development of pilot objectives that address policy questions, clear definition of pilot scope, and definitions of organizational structure and business rules for implementing a pilot.

WRUCC may wish to adopt one of three different configurations for a regional or interjurisdictional pilot. Each of the three configurations offers opportunities to test unique RUC

elements, such as using block chain accounting for revenue reconciliation, testing the ability of commercial account managers to serve the reconciliation function, and testing the deployment of open, common standards in an operational environment.

Finally, steps that WRUCC might follow to plan and develop an interjurisdictional pilot test include ascertaining level of interest among states to participate in a pilot, formalize an organizational structure for pilot planning and development, establish pilot goals and objectives, define the scope, identify key issues and risks, estimate costs, identify funding sources, and create a detailed action plan to deliver the pilot.

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Chapter 1: Introduction

In 2014, the Western Road Usage Charge Consortium (WRUCC) carried out Phase 1 of a study addressing charging out-of-state drivers in a RUC system on behalf of member state departments of transportation, including the Washington State Department of Transportation (WSDOT) as the lead participant and the state DOTs of Arizona, California, Colorado, Idaho, Montana, Oregon, Nevada, and Texas as joint funding partners. In 2016, WRUCC, now RUC-West, launched Phase 2 to accomplish the following:

> ► Estimate costs and revenues of interjurisdictional RUC (Chapter 2)
> ► Examine RUC opportunities across international borders (Chapter 3)
> ► Develop elements of a regional, interjurisdictional RUC demonstration (Chapter 4)

This report presents the research conducted under Phase 2. It estimates the costs and revenues of interjurisdictional RUC, including costs associated with financial reconciliation, examines legal and regulatory issues related to RUC opportunities across international borders, and identifies and discusses key elements of interjurisdictional RUC, proposing a sequence of activities that RUC-West states can undertake to implement an interjurisdictional demonstration or pilot (hereafter referred to as pilot). This report focuses on RUC-West states. although the analysis and principles can be equally applied to other states outside the western region, the federal government, and jurisdictions bordering the U.S.

1.1.   Context

Under the current fuel tax system, passenger vehicles using liquid, carbon based fuel for travel on public roads pay the federal motor fuel tax, regardless of where the driver lives or where in the U.S. the fuel is purchased. Further, all states levy some amount of state fuel tax, and in many states other jurisdictions such as counties or cities levy additional local fuel taxes. In all cases, state fuel taxes are remitted to the state in which the fuel is purchased, not necessarily where it is consumed – fuel purchased on the California side of Lake Tahoe may be used to drive in Nevada, but the tax remains in California. Despite this, and perhaps because fuel taxes are both invisible and long-standing, it has been generally deemed acceptable that revenue remains in the jurisdiction where the fuel was purchased. However, a commonly voiced concern, both by motorists and officials, is that visitors to a state with a RUC might not be charged for using the host-state's roadways. Some members of the public have expressed questions about the fairness, or lack thereof, of only state residents contributing to road maintenance funding, even when out-of-state visitors are using the roads, while others perceive (correctly or not) that a very large share of the cars on the road are from out of state, and not including them in a road charging system amounts to the state voluntarily foregoing an important revenue stream.

Heavy vehicles (over 26,000 pounds), by contrast, consume relatively greater amounts of fuel and travel more frequently across jurisdiction borders. These vehicles are required reconcile fuel taxes paid to the mileage driven by jurisdiction through the International Fuel Tax

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Agreement (IFTA). IFTA serves as a model of a multi-jurisdictional framework for mileage (and fuel) reporting and reconciliation payments by drivers to 58 individual jurisdictions (48 lower U.S. states plus 10 Canadian provinces), as well as revenue reporting and reconciliation among the jurisdictions.

Transitioning from an invisible gas tax to RUC awakens a consciousness among officials and constituents alike that motorists are paying their state agencies for the miles they drive. It is not clear whether visitors, on the other hand, would be subject to charges for using the host-state's roadways absent a gas tax. Some members of the public have expressed questions about the fairness, or lack thereof, of only state residents contributing to road maintenance funding, even when out-of-state visitors are using the roads, while others perceive (correctly or not) that a very large share of the cars on the road are from out of state, and not including them in a road charging system amounts to the state voluntarily foregoing an important revenue stream.

In 2014, WRUCC sponsored Phase 1 of this study, which examined multi-jurisdictional policy and operational alternatives. That study developed and analyzed approaches that jurisdictions can consider for charging motorists from other jurisdictions for road usage, both along and in cooperation with other jurisdictions. The study examined a wide range of policy alternatives and suggested corresponding operational concepts for charging visitors, and established a basis for multi-state collaboration in reporting visitor data, collecting charges, and reconciling revenues.

RUC-West undertook this Phase 2 study to further extend the conceptual work completed in Phase 1 by defining cost and revenue estimates associated with various approaches to interjurisdictional RUC assessment, exploring specific issues that arise at international crossings, and exploring operational concepts for a multistate demonstration.

1.2. Review of Relevant Discussion from Phase 1

Several different policy bases for assessing RUC on a visitor were developed in Phase 1, including the option of not levying any tax or fee on visitors. These are listed in Appendix A. Some options, such as continuing to collect motor fuel taxes at the pump, require no reconciliation between jurisdictions – the tax remains in the state where the fuel was purchased. Many of the policy bases, however, require some sort of revenue reconciliation between states or countries.

1.2.1. Policy bases included in the analysis

Of the various policy bases explored in Phase 1 of this research, the following three were selected for closer examination during Phase 2:

► **Distance-based Charge**. Under a distance-based charge, motorists are assessed a charge based on the number of miles driven in a given jurisdiction. This requires direct measurement of miles driven in each jurisdiction and reporting of those mileage to either a state-managed RUC agency or a RUC account manager.

Methods of measurement are wide-ranging and include (but are not necessarily limit to):

> Automated methods such as a location-enabled OBDII dongle or smartphone app,

> Manual methods such as:

- Requiring motorists to report their vehicle information and odometer reading upon entering and leaving a jurisdiction, with subsequent invoicing and RUC collection
- Manual inspection of odometers at border crossing stations, with subsequent invoicing and RUC collection
- Sale of mileage permits

Under a distance-based charge, jurisdictions could assess RUC directly on visitors; that is to say an Oregon resident traveling in Washington would receive an invoice from and make payment to Washington. Alternatively, all mileage driven by a motorist could be invoiced by the home jurisdiction, and the various states could reconcile RUC amongst themselves.

The costs of these options varies widely, as does the reporting burden placed on the individual motorist.

► **Shadow Charge**. Under a shadow charge, states would not directly levy road usage charges on visitors. Rather, states would reconcile funds based on some estimate of the amount of visitor-generated vehicle miles traveled. The shadow charge can reduce costs associated with assessing and enforcing the RUC itself because each jurisdiction is concerned only with managing a RUC program for its own residents. However, the data required to adequately estimate not just VMT but also state of origin of visiting vehicles can be quite costly to collect. Over time and if an adequate number of jurisdictions implement location-aware mileage meters, data collected from RUC programs may be sufficient to calculate shadow charges.

► **Distance-based and fuel-based, with or without shadow charges.** Under this policy scenario, jurisdictions retain their motor fuel tax and, assuming a revenue-neutral RUC environment, refund fuel taxes paid to motorists.

Descriptions of the policy bases developed in Phase 1 but not included in Phase 2 can be found in Appendix A.

1.2.2.   Reconciliation methods

As jurisdictions adopt RUC and make the decision to impose it on non-residents driving in the jurisdiction, it becomes necessary for them to enter into agreements for reconciling distance charges with other jurisdictions.

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Bilateral/Multilateral Road Usage Charging

There are two general methods for such multilateral reporting, reconciliation, and financial clearing. The first is for more than two jurisdictions to report and reconcile distance charges in multiple bilateral agreements. This is the "mesh" approach used in some interoperability tolling environments for light vehicles like E-ZPass in the Northeast United States and Liber-t in France. This approach requires many links among agencies. This is illustrated in Figure 1, which depicts five agencies comprising ten links, four for each agency.

Figure 1. Bilateral reconciliation model

As the number of states entering into road charge agreements grows, it becomes more efficient to adopt a "star" approach whereby there is a single agreement among multiple jurisdictions and a single clearinghouse that handles multilateral reporting, reconciliation, and financial clearing. This approach reduces the number of links for each agency to one and the total number of links in the network to N. The star approach is illustrated in Figure 2, depicting five agencies, each with one link, for a total of five links. This is similar to the arrangement IFTA uses.

The states participating in the study opted to further develop the multilateral (clearinghouse) reconciliation model. Other revenue reconciliation methods are briefly described below.

Distributed account reconciliation

Figure 2. Clearinghouse reconciliation model

A third, emerging alternative not discussed in Phase 1 is for states participating in an interjurisdictional RUC is to employ block chain accounting, in which each state is a node in a reconciliation system. A block chain database uses advanced cryptography and a distributed messaging protocol to create shared ledgers. Put simply, a blockchain is a record of events that is virtually impossible to change. Every node has a copy of the complete block chain, thereby eliminating the need for bilateral agreements or a centralized third party to manage reconciliation activities. For an interjurisdictional RUC application, blockchains provide three things that could revolutionize a multi-state, regional or national system:

- ► A shared, replicated, and transparent ledger for all RUC transactions
- ► A secure, unified register of customers, VIN numbers, and RUC technology employed on the vehicle

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> ► A method for any customer to transact directly with any state agency

A RUC block chain system would be scalable to any number of customers and states. This accounting model eliminates the need for bilateral/multilateral agreements or clearinghouse architectures. A RUC interjurisdictional pilot built on block chain technology and distributed applications opens the door to all of these ideas.

This puts the driver or RUC customer back in the center of the picture. By using a shared block chain architecture, every volunteer in a RUC interjurisdictional pilot has direct access to the data they need. The need for state-to-state data transfers and agency-to-agency financial exchanges for interoperable transactions are eliminated. Every driver can transact directly with either the home or host agency if location services automatic reporting of odometer readings are employed.
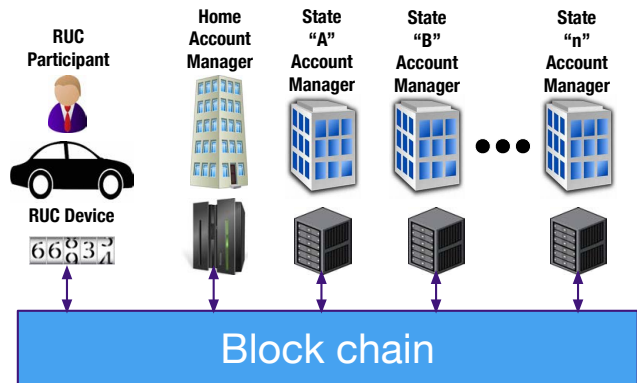
Figure 3. Block chain Model

While this technology was invented by and for Bitcoin, banks and other capital markets in the U.S., Europe, and Australia have begun to explore block chain technologies as a way of increasing efficiency and improving regulatory control. The built-in benefits of the RUC block chain model can improve interjurisdictional operations in ground-breaking ways by simplifying processes and reducing operating costs.

Additional information about block chains is located in Appendix C.

<u>**Shared Account-Manager-Based Reconciliation**</u>

A fourth alternative is for states to form an account manager certification compact, and then select commercial account management services from vendors approved by that compact. If a small number of account managers provide RUC services for all jurisdictions, they can collect RUC due from motorists and (assuming location-aware reporting technology) remit funds directly to the jurisdictions to which they are due. This system potentially eliminates the need for a clearinghouse, but also potentially limits competition and could, in time, raise operational costs.

Chapter 2: Interjurisdictional RUC

2.1.   Objectives of this Chapter

The objectives of this chapter are to extend work performed under Phase 1 of the Interjurisdictional RUC Policy Study carried out for WRUCC in 2014 by defining the following:

► Amount of cross-border traffic in the various jurisdictions
► Cost and revenue estimates associated with various approaches to interjurisdictional RUC assessment
► Cost and effort estimates associated with enforcement of interjurisdictional RUC

2.1.1.   States included in the analysis

Following from discussions during the project kick-off meeting, it was determined that Arizona, California, Colorado, Idaho, and Washington would be the states examined in this project. They present a diversity of geography, economic bases, population distribution, long-distance travel generators, and proximity to international borders.

Figure 4. States in Study Region

Nationally, there has been a trend of increasing household vehicle miles traveled (VMT) over the last five decades, especially for commute-to-work and recreation (Figure 6). The five states included in this analysis share the overall trend of increasing VMT (Figure 5) and increasing distance traveled by trip type.

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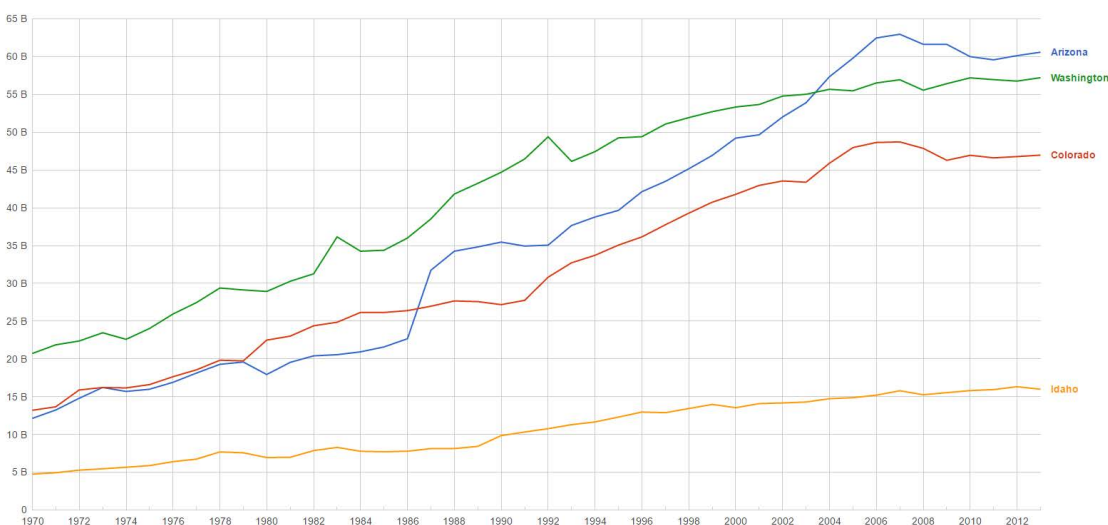
Figure 5. VMT, 1970-2013, for Arizona, Colorado, Idaho, and Washington

2.1.2.   Vehicles Included in the analysis

The cost and revenue estimates undertaken in this study focus on the impacts of visiting passenger vehicles. Large trucks used primarily for freight movements are not included in this study, since interstate motor carriers operating between any of the 48 contiguous states and 10 Canadian provinces already participate in the International Fuel Tax Agreement (IFTA) and provide the following information on a quarterly basis:

- ► Total miles, taxable and nontaxable, traveled by the licensee's qualified motor vehicles in all jurisdictions, IFTA and non-IFTA, including trip permit miles
- ► Total gallons of fuel consumed, taxable and nontaxable, by the licensee's qualified motor vehicles in all jurisdictions, IFTA and non-IFTA
- ► Total miles and taxable miles traveled in each member jurisdiction
- ► Taxable gallons consumed in each member jurisdiction
- ► Tax-paid gallons purchased in each member jurisdiction, and
- ► Current tax rates for each member jurisdiction

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Figure 6. Average Annual VMT Per Household

This allows the IFTA clearinghouse to distribute motor fuel taxes to the jurisdiction in which a motor carrier operated. Because interstate motor carriers already have a tax revenue reconciliation process in place, they are not considered in this study.

Further, rental-car fleets are not included as a separate entity when assessing the costs and revenues associated with assessing RUC on visitors. It is assumed that because rental cars are registered in the state where they are based, the bulk of "visitor" driving will be accounted for as part of any in-state process. In instances where drivers rent a car in one jurisdiction and then drive it into another jurisdiction, the vehicle would be treated as any other passenger vehicle driving outside its home jurisdiction.

2.2. Organization

This chapter is organized as follows:

- ► Section 3 describes the methodology used to identify the number of vehicles crossing state borders each day, estimate visitor travel, and estimate the revenue implications of that travel.
- ► Section 4 describes unique issues in each of the participating states that influence visitor travel, and the impact of that travel on potential road user charge revenues.
- ► Section 5 identifies the amount of cross-border travel in each of the participating states, and characterizes that travel.
- ► Section 6 discusses the revenue implications of visitor travel for each of the participating states

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► Section 7 identifies the costs associated with assessing road user charges on visitors under the three policy bases examined in this study, and estimates the costs associated with operating a multilateral clearinghouse for revenue reconciliation
► Section 8 identifies issues associated with enforcing RUC on visitors, and identifies factors that could influence the effectiveness of enforcement, as well as the cost of enforcement efforts.

2.3. Methodology

To explore the revenue implications of charging, or not charging, visitors for road use, we developed a parametric model of visitor traffic volume in each of the participating states. Traditional travel models typically describe travel as either internal/internal, internal/external (or external/internal), and external-external, as illustrated in Figure 7. For the purposes of this project, internal/internal travel – that is to say travel originating and taking place entirely within the home jurisdiction– is not examined. The model assumes the bulk of interstate travel is external/internal, with only a small percentage of passenger vehicles driving through entire states and thereby creating external/external travel. Further, it assumes most travel is round-trip, meaning that each vehicle that enters a host jurisdiction returns to its home jurisdiction by the same or similar route. As a result, total external VMT is likely over-estimated. However, without significant additional detailed survey data, the model cannot be further calibrated.

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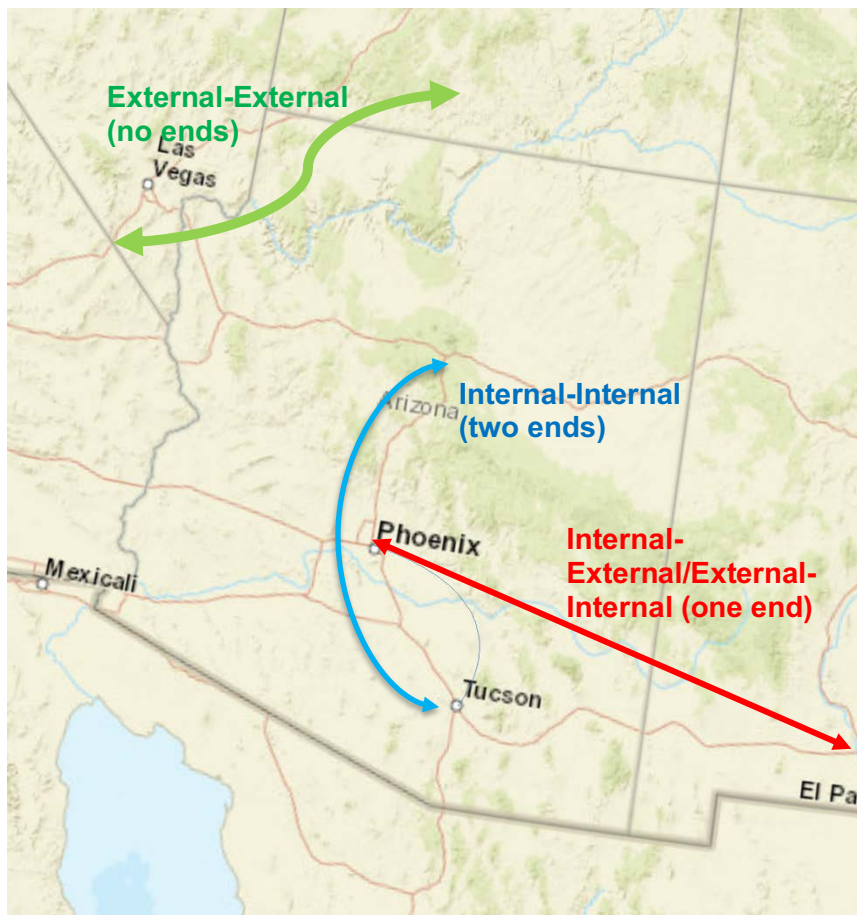
Figure 7. Model Travel Types

The model estimates external/internal travel within each of the participating states – that is to say it estimates the amount of travel that occurs inside a state that originates outside the state. Inputs to the model included the long-distance trip table from the 2001 National Household Travel Survey (NHTS), traffic volumes from the states' 2013 Highway Performance Monitoring System (HPMS) reports, and data about major long-distance trip generators and trip tables produced by statewide models, when available. Because varying data is available for each state, the NHTS and HPMS data form the core of the model, with refinements made to each state based on additional information available for that state. The specific data sources used for each state are discussed later in this chapter.

The analysis of revenue and cost implications for assessing RUC on visitors is limited to passenger vehicles and light trucks. Nearly all long-haul heavy trucks, and certainly those that operate across state lines, already report mileage by jurisdiction to IFTA, which has a revenue reconciliation and audit system in place.

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2.3.1. Estimating Visitor Travel

The model divides external/internal travel into two distinct types – short-distance and long-distance. Short-distance travel is the type encountered when metropolitan areas straddle state boundaries, or when two metropolitan areas are found on either side of the border, in relatively close proximity as illustrated in Figure 8. In these locations, vehicles make frequent, short trips across state lines. This type of interstate travel occurs in the Lake Tahoe area, Portland, Oregon-Vancouver, Washington, and Coeur D'Alene, Idaho-Spokane, Washington, among others. Commuting to work and travel to conduct personal business such as shopping, attending school, and medical appointments are the primary reasons people undertake short-distance interstate travel.

2.3.1.1. Short-Distance External/Internal Travel

Short-distance interstate travel is typically already modeled to some degree by the various Metropolitan Planning Organization (MPO) travel demand models, although they do not generally assign a state of origin to all road use. Most multi-state MPOs have agreements in place for allocating federal construction and maintenance funding from each state to projects in the MPO. Some MPOs have adopted a formula-based method that takes into account population and VMT in each jurisdiction for allocating funding.

The model developed for this analysis assumes that 90-95% of passenger vehicles crossing state borders in one of these short-distance travel zones is local travel. The estimate is on the lower end for the Lake Tahoe region, due to it being a regional tourism and recreation destination and the higher end of that range for the remaining cross-border local traffic.
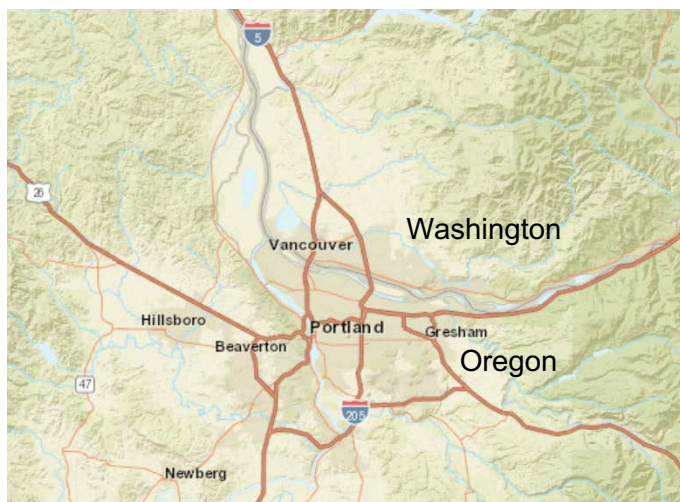
Figure 8. Example of short-distance external/internal travel zone: Portland, Oregon -- Vancouver, Washington

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2.3.1.2.   Long-Distance External/Internal Travel

Long-distance travel is also challenging. For this study, "long-distance" is defined as trips originating outside the state visited, and not inside one of the short-distance border zones. Over the years, various distances have been used to define "long-distance" in travel surveys. For instance, the 2001 NHTS defined long-distance travel as a trip of at least 50 miles from home to the farthest destination reached, while the 1995 American Travel Survey (ATS) defined a long-distance trip as a trip of 100 miles or more. For the purposes of this report, long-distance travel is interstate travel with origin or destination points outside one of the border zones defined as "short-distance" interstate regions. Examples of long-distance travel would include Phoenix, Arizona to Los Angeles, California and Portland, Oregon to Seattle, Washington. The main categories of long-distance travel include:

- ► Pleasure trips
  - > Visiting friends/relatives
  - > Touring to experience scenic beauty, history and culture
  - > Camping, hunting, fishing, hiking, and boating
  - > Attending special events such as a fair, festival, or sporting event
  - > Casino
  - > Theme park
  - > Resort (ocean beach, inland or mountain resort)
  - > Skiing/snowboarding
  - > Golf
- ► Business trips, exclusive of commuting.
- ► Personal business
- ► Commute to work

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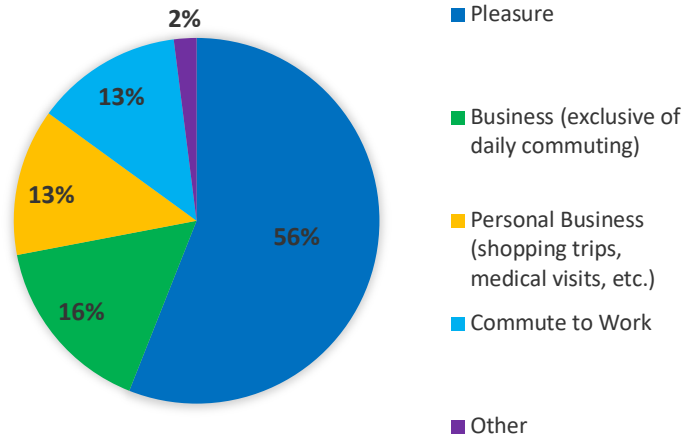
Figure 9. Purpose of Trips Longer than 100 Miles Round-Trip. Source: *The 2001 National Household Travel Survey, preliminary long distance file,* U.S. Department of Transportation.

Nationally, domestic long-distance travel (defined as a trip of more than 50 miles from home) has been increasing at a rate of about 2% per year since 2010. Growth has largely been in the area of leisure trips, while business trips have declined. Data from the 2001 NHTS indicates that for trips of less than 2000 miles (round-trip), people have tended to prefer personal vehicles, and personal vehicles are used for more than 89% of trips with a round-trip distance of at least 100 miles (Table 1). Air travel dominates on trips longer than 1000 miles (one-way).

Table 1. Percent of Long-Distance Travel by Mode and Distance in US

		Round Trip Distance (miles)					
		100-299	300-499	500-999	1000-1999	2000+	Total
Mode	Personal Vehicle	97.2	94.3	85.9	53.9	22.2	89.5%
	Air	0.2	1.5	10.3	42.4	74.8	7.4%
	Bus	1.6	3.4	3.2	2.6	1.4	2.1%
	Train	0.9	0.7	0.6	0.9	0.8	0.8%
	Other	0.2	0.1	0.0	0.1	0.8	0.2%

Source: *The 2001 National Household Travel Survey, preliminary long distance file*, U.S. Department of Transportation.

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At the same time, most long-distance trips (62%) also take place within the home state
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Figure 10). However, while a majority of long-distance trips occur entirely within the same state, they account for only about 27% of miles traveled (by all modes). An additional 24% of miles traveled are to a different state in the same census region. All of the states discussed in this report are located within the West Census Region.

Table 2. Distribution of Long Distance Trips in the Continental United States (all travel modes)

	Trips	Miles Traveled
Same State	62%	27%
Different State, Same Census Region	25%	24%
Different Census Region	11%	33%
International (outbound)	2%	16%
Total	100%	100%
SOURCE: *The 2001 National Household Travel Survey, preliminary long distance file*, U.S. Department of Transportation.		

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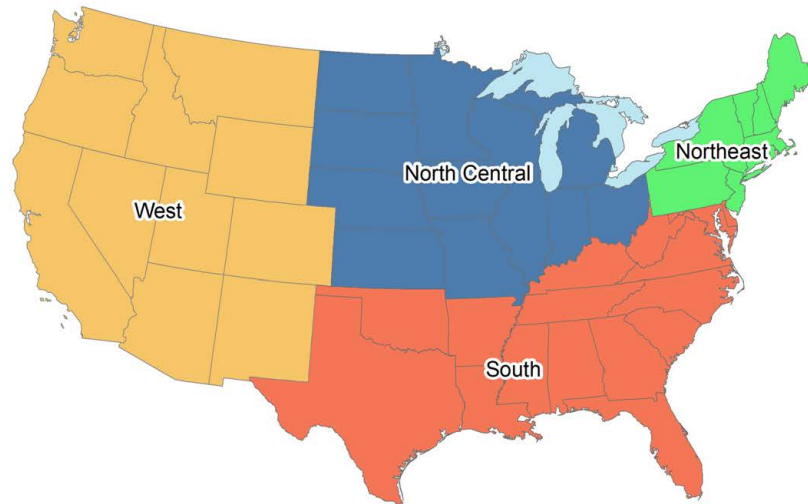
Figure 10. U.S. Census Regions

Altogether, these data suggest that up to one in four long-distance trips originating in the western states will have a destination in another western state, and that personal passenger vehicles are likely to be the primary travel mode in at least 85% of cases.

2.3.1.3. External-External Travel

External-External travel refers to those vehicles that drive through a state without stopping. While passenger vehicles make a significant number of external-external trips through the smaller states in New England, the longer distances involved with traversing states in the western U.S. significantly limits the amount of external-external passenger vehicle traffic in the region.

The model estimated external-internal and internal-external traffic at the state level using traffic volumes at state border crossings and applying a gravity model to assign incoming traffic to various locations along each major route. With a few notable exceptions, it assumes drivers covering the long distances typical of state-to-state travel in the western region of the United States primarily choose access-controlled or dual-carriageway facilities when they are available, for reasons of both safety and convenience. Therefore, routes included in the long-distance portion of this analysis are limited to those defined in the federal aid system as Interstate, Principal Arterial – Other Freeways and Expressways, and Principal Arterial – Other. These three categories of route encompass all Interstate highways, U.S. Highways, and most State Highways and other major thoroughfares.

2.3.2. Analysis Steps

2.3.2.1. Identify traffic volumes

This step accomplishes the first objective of the study in that is identifies the amount of cross-border traffic in the various jurisdictions. While the amount of cross-border traffic alone does not fully account for all visitor travel, it is a key parameter, since a basic assumption of this analysis is that the visitor-generated traffic of interest is generated by vehicles that drive into the host state from another state. Visitors who arrive in the host-state by a mode other than their personal vehicle (e.g. airplane, train, bus) and then rent a car are assumed to be operating under the same RUC system as residents. Therefore, any travel they undertake is not "visitor travel".

The primary data source for cross-border traffic counts is each of the states' 2013 HPMS reports. The traffic volumes reported in HPMS include truck volumes. For state-to-state travel where truck volumes are not available from either the Freight Analysis Framework (FAF) or a statewide model, trucks are assumed to be an average of 5% of cross-border travel. Specific exceptions to this assumption are noted in the discussion for each state. For international crossings, the proportion of trucks can be as high as 50% of all vehicles, depending on the point of entry. U.S. Customs and Border Patrol (CBP) reports annual passenger vehicle crossings separate from bus, train, and truck crossings. These figures were used to "true-up" total traffic volumes reported in HPMS. The overall impact of an assumed 5% truck volume in the absence of other data is a slight over-statement of the importance of passenger vehicles.

2.3.2.2. Identify key travel generators

Once the number of vehicles crossing into or out of a state is established, the next step is to identify likely destinations.

Short-distance interstate travel zones feature travel generators such as schools, churches, and workplaces typically found in traditional 4-step travel demand models. However, long-distance external-internal travel is more likely to be destined for special generators such as tourist and recreation destinations (Figure 11).

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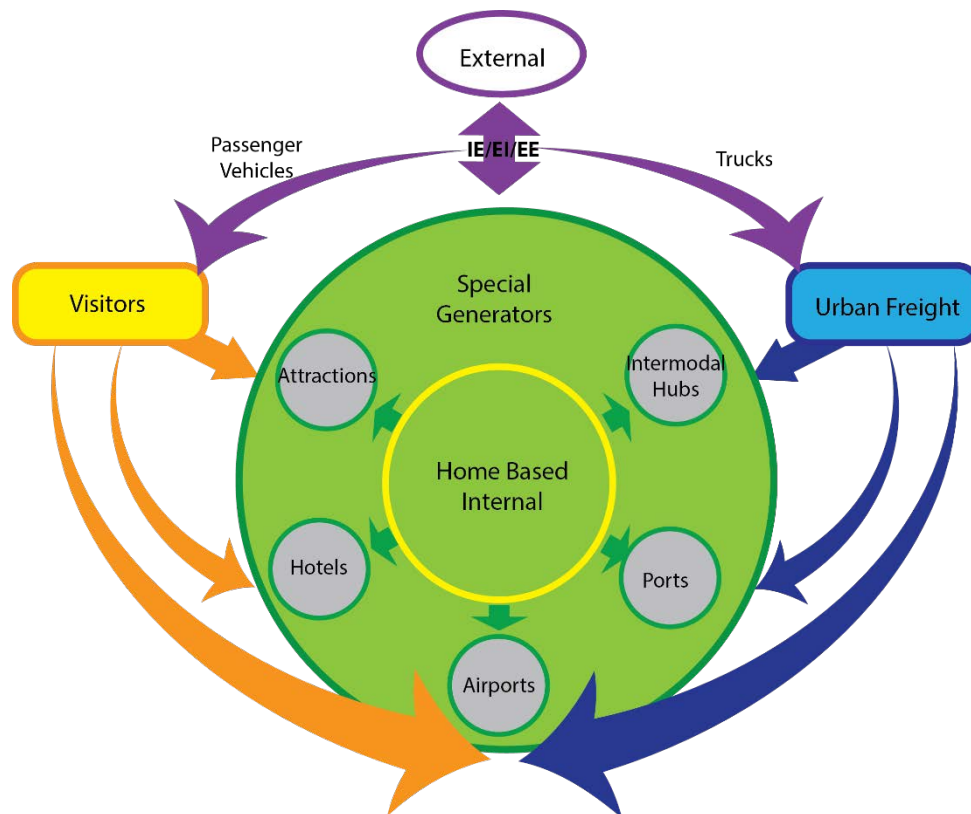
Figure 11. Vehicle Split and Special Generators in and IE/EI Travel Model

2.3.2.3.   Gravity Model

A simple gravity model was employed to conduct a parametric estimation of visitor travel within each participating state. Parameters driving the model include:

- ► Typology of each gateway
  - > Short-distance
  - > Long-distance
- ► AADT at each gateway
- ► Distance(s) to major travel generators
- ► Relative "pull" of travel generators across state lines
- ► Estimated decay rate of passenger vehicle travel

In the absence of detailed data about external/internal travel generated by specific generators (resorts, theme parks, etc.), the model assumes a linear distance decay function between gateways and destinations. Short-distance travel gateways are assumed to have a lower proportion of through-traffic than are long-distance gateways.

2.3.3.   Scenarios for Visitor Travel

While people travel for any number of reasons, there are a limited number of taxation or road charging scenarios under which motorists engage in interstate travel.

► ***Scenario 1:*** A visitor whose home state imposes motor fuel taxes, but not RUC, enters and drives in a neighboring RUC state, then returns to their home state
► ***Scenario 2:*** A visitor whose home state imposes RUC enters and drives in a neighboring RUC state, then returns to their home state
► ***Scenario 3:*** A visitor whose home state imposes motor fuel taxes, but not RUC, drives through multiple states, some of which impose RUC, some which do not
► ***Scenario 4:*** A visitor whose home state imposes a RUC drives through multiple states, some of which impose RUC, some which do not
► ***Scenario 5:*** A visitor drives into a RUC state from outside the U.S

These scenarios all generate slightly different assumptions about the costs and revenues associated with assessing RUC on visitors. For instance, in scenario 1 if a motorist fuels their vehicle in their home jurisdiction and immediately crosses into the host jurisdiction, drives 200 miles and returns home without paying a distance-based charge, the home jurisdiction receives all the revenue, even though roads in the host jurisdiction take all the wear (Figure 12). If, on the other hand, the visitor enters the host jurisdiction and then purchases fuel, under some RUC policy bases the loss to the host jurisdiction may be less because fuel tax is collected on the visitor in lieu of RUC.

Due to the variety of scenarios for visitor travel and variety of methods of assessing and collecting RUC under each policy basis, potential revenue from a visitor-generated RUC and costs associated with collecting it are estimated as ranges. At the lower-end of costs, and higher-end of revenues would be a situation where a visitor travels from one RUC jurisdiction into another, and has a location-aware mileage reporting device. Under a strictly distance-based charge the home jurisdiction simply issues an invoice on behalf of both itself and the host jurisdiction, and then remits any amount due to the host jurisdiction through one of the reconciliation methods described above. At the higher-end of costs, and lower-end of potential revenues would be a situation where a RUC state establishes a pre-paid distance permit for visitors. Such as system could require significant IT investment to develop a visitor permit database, and would likely have a high evasion rate and carry heavy enforcement costs.

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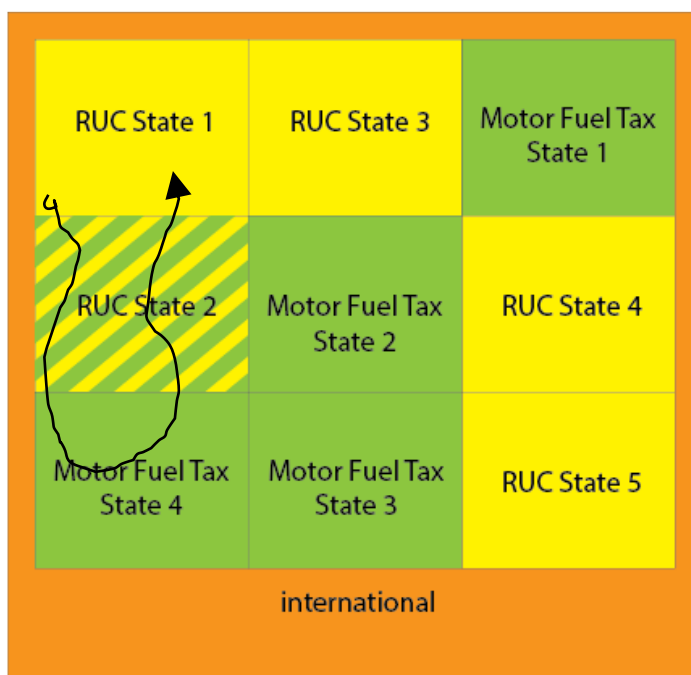
Figure 12. Scenario 1 Worst Case: Fuel Tax Arbitrage

2.3.4.　Estimating Revenue Implications

Because none of the states participating in this study have formally established per-mile rates for RUC, the evaluation of revenue implications of charging, or not charging, out-of-state drivers is done in terms of revenue that can be expected to be gained or lost relative to a state's in-state RUC revenue, estimated cost of collection, and estimated cost of enforcement. As such, the outputs of this portion of the model are dimensionless and presented as a range.

Revenue estimates also assume the state has an operational RUC system in place, and any revenue generated from visiting passenger vehicles represents a marginal increase over RUC generated by state residents.

2.3.5.　Estimating Costs Associated with Assessing RUC on Visitors

As with estimates of revenue implications, estimates of costs associated with assessing RUC on visitors assume each of the five states has an operational RUC system in place. The estimated costs associated with charging visitors are the marginal costs incurred by states to levy and collect RUC from visitors under various scenarios. Note that costs associated with cash-flow disruptions potentially arising from transition from motor fuel tax to RUC are not considered.

2.3.6. Estimating Costs Associated with Enforcement

Enforcement of RUC payment by visitors offers many challenges if motor fuel taxes are not in place. For methods that require direct payment of distance-based charges to the host jurisdiction, visitors may need to be required to register their vehicle in the host jurisdiction in order for most automated enforcement methods such as automatic license plate readers to be used. Cost estimates for enforcement efforts are presented as a range for each policy basis examined in this study, in order to account for the variations in reporting methods, account management, and the administration of RUC for visitors.

2.3.7. Data Sources for Long-Distance Travel

2.3.7.1. Traffic Volumes for All Participating States

To ensure consistency, baseline border traffic volumes were determined using Annual Average Daily Traffic volumes (AADT) reported by the states as part of their 2013 HPMS reports to the Federal Highway Administration (FHWA). Because this data item includes trucks, the figure was adjusted using truck volumes reported by the states.

In addition to the baseline traffic volumes for all states, we considered additional data sources such as statewide travel models and travel data collected from mobile phones by companies such as INRIX and AirSage. At this time, statewide travel models for the participating states lack sufficient information about external travel (specifically jurisdiction of origin) to be useful, although California's model was used to validate estimates derived from our model. Further, current services such as INRIX and cellular data aggregators do not typically provide origin-destination data for long-distance travel. To date, their services have evolved to support local or MPO-level travel demand models, which consider "external" to be external to the MPO planning area boundary, not external to the state.

2.3.7.1.1. Arizona

At the present time, Arizona's statewide travel model does not provide information about external travel behavior. Arizona is participating in the 2016 NHTS and plans to use the add-on element of the survey to improve information about long-distance trips.

2.3.7.1.2. California

This analysis used origin-destination (O-D) matrices for external travel from California's Statewide Travel Demand Model (CSTDM-V2). While California's statewide model does include travel modes such as Air and Rail, only passenger vehicles and light trucks were used to assess implications of assessing a road user charge on visiting vehicles. Limitations of the model include not capturing external-to-external (E-E) travel for passenger vehicles.

2.3.7.1.3. Colorado

Colorado has just begun the process of developing a statewide travel demand model. Data from the FAF was used to refine estimates of truck volumes.

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2.3.7.1.4. Idaho

Idaho is nearing the end of development of a statewide model that uses cell-phone data as a primary data source for developing O-D matrices.

2.3.7.1.5. Washington

Washington does not have a statewide model at this time.

2.3.7.2. General Limitations of the Data

AADT was pulled from the states' HPMS reports because they provide consistency across the region. However, the AADT reported has several limitations. Directionality (D-Factor) is not included in the publicly-available dataset, so, for purposes of modeling interstate passenger travel, all volumes are assumed to have a 50-50 split (50% inbound traffic, 50% outbound). While this assumption may not always hold for local traffic, for interstate traffic, particularly when measuring volumes of visitors to states, it is likely to hold. Every visitor that drives into a jurisdiction eventually drives out of it.

Another general limitation of the data is that the AADT represents *average* daily volumes over the course of a year, so it does not capture seasonal trends. And, the AADT reported in the publicly-available data set includes truck volumes.

Due to variations in the methods states use to collect traffic counts and calculate AADT, there are some (usually minor) inconsistencies in volumes reported along a route as it crosses state boundaries. In most cases the difference is less than 2% of the reported volume, but there are some instances where the traffic volumes reported at essentially the same location by two states is more noticeably different. In cases where there was obviously a data reporting error, the presumptively more correct value was used, as illustrated in Figure 13. The "450" reported by Jurisdiction A near the border with Jurisdiction B is likely an error, given that volumes along the rest of the route are consistent. In this case, the value of 4500 reported by Jurisdiction B is used to estimate traffic in Jurisdiction A.
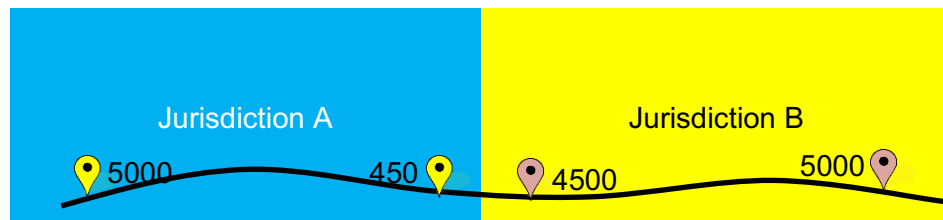
Figure 13. Illustration of AADT Correction

Finally, because external travel survey data and detailed electronic data (such as that supplied by INRIX) do not currently exist at a level of detail sufficient to identify state of origin of external travel, this analysis focuses on miles driven in the destination state but cannot identify jurisdictions of origin or estimate funds due to any external jurisdiction.

2.4. Unique Issues of Participating States

While common typologies exist, each of the participating states has unique characteristics and issues that influence visitor behavior. The number and nature of international points of entry, tourist destinations that function as travel generators, and presence of commuter-driven interstate travel vary by state and are described below.

2.4.1. Arizona

2.4.1.1. International Land Ports of Entry

► Douglas
► Lukeville
► Naco
► Nogales
► San Luis
► Sasabe

2.4.1.2. Tourist Destinations

► Grand Canyon
► Glen Canyon National Recreation Area
► Monument Valley (Arizona/Utah border)
► Hoover Dam (Arizona/Nevada border)
► Sedona

2.4.1.3. Other Unique Issues

Arizona DOT staff report that they are unable to conduct state-sponsored cordon surveys for the purpose of gathering data on travel behavior, including long-distance and interstate travel.

2.4.2. California

2.4.2.1. International Land Ports of Entry

There are six border ports of entry for passenger vehicles to California.

► San Ysidro
► Otay Mesa
► Tecate
► Calexico West
► Calexico East
► Andrade

2.4.2.2. Tourist Destinations

► Disneyland
► San Francisco Bay Area

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- ► San Diego-Tijuana
- ► Lake Tahoe
- ► Major Ski Resorts
  - › Squaw Valley, Heavenly Mountain, Mammoth Mountain
- ► National Parks

2.4.2.3.   Short-Distance I-E zones

- ► Lake Tahoe
- ► San Diego - Tijuana

2.4.3.   Colorado

External passenger vehicle travel to Colorado is driven primarily by tourism, although there is also significant business-related travel to the state.

2.4.3.1.   International Land Ports of Entry

Unlike the other states in this study, Colorado does not have any international land ports of entry.

2.4.3.2.   Tourist Destinations

- ► Denver is the largest tourist destination in the state, although a significant number of visitors arrive by air
- ► Pikes Peak region
- ► Mountain West resort area, which includes Eagle, Grand, Gunnison, and San Miguel, among others

2.4.3.3.   Short-Distance I-E zones

- ► Fort Collins, CO – Cheyenne/Laramie, WY

2.4.4.   Idaho

External travel to and from Idaho is driven largely by east-west freight movement (which is not considered here because it takes place on heavy vehicles) and tourism.

2.4.4.1.   International Land Ports of Entry

- ► Eastport (U.S. 95)
- ► Porthill (SH 1)

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2.4.4.2. Tourist Destinations

Tourism is the third largest industry in Idaho, behind agriculture and technology[1]. As with other states in this study, more overnight passenger trips originate from within Idaho than other states, followed by Washington, California, and Utah.

2.4.4.3. Short-Distance I-E zones

► Spokane, Washington – Coeur D'Alene, Idaho
► Lewiston, Idaho – Clarkson, Washington
► Moscow, Idaho – Pullman, Washington

2.4.5. Washington

2.4.5.1. International Land Ports of Entry

Washington has several border ports of entry, including:

► Point Roberts
► Blaine - Peace Arch
► Blaine - Pacific Highway
► Lynden
► Sumas
► Nighthawk
► Oroville
► Ferry
► Danville
► Laurier
► Frontier
► Boundary
► Metaline Falls
► North Cascades National Park

2.4.5.2. Tourist Destinations

Significant tourism destination in Seattle, with a number of both Canadian visitors stopping in Seattle.

► The I-5 corridor offers city-based touring and whale watching/wildlife tours
► Cascades
► Mount Hood
► Mount Rainier

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[1] The Idaho Tourism Effect, https://visitidaho.org/content/uploads/2016/11/Southwest-tourism-Impact-Infographic.pdf

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> ► Numerous National Forests

2.4.5.3.   Short-Distance I-E zones

> ► Portland, Oregon – Vancouver, Washington
> ► Spokane, Washington – Coeur D'Alene, Idaho
> ► Lewiston, Idaho – Clarkson, Washington
> ► Moscow, Idaho – Pullman, Washington
> ► Blaine-Bellingham, Washington – Surrey, British Columbia

2.5.   Estimates of Cross-Border Travel in Various Jurisdictions

Cross-border travel for the five participating states was calculated from the states' 2013 HPMS report, as well as detailed data on incoming passenger vehicles published by U.S. Bureau of Transportation Statistics[2]. Since this study is concerned only with light vehicles, the raw AADT reported in HPMS is downward-adjusted to remove heavy vehicle traffic. In cases where precise counts of passenger vehicles were available, those figures were used. Otherwise, it was assumed trucks account for 5% of total AADT.

2.5.1.   Arizona

Approximately 215,000 passenger vehicles enter or leave Arizona each day. Interstate 10 and Interstate 40 carry considerable east-west traffic through Phoenix and Flagstaff, respectively. Interstate 40 also carries a significant number of travelers on their way to visit Grand Canyon National Park.

Based on data from the 2001 NHTS, the states contributing the most long-distance travel to Arizona include Arizona, California, New Mexico, Texas, and Illinois.

In order to estimate VMT by visitors, 4 gateway zones were defined:

> ► Z1: Crossings from California to Arizona
> ► Z2: Nevada and Utah to Arizona (Grand Canyon routes)
> ► Z3: Nogales-area ports of entry
> ► Z4: New Mexico to Arizona

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[2] https://transborder.bts.gov/programs/international/transborder/TBDR_BC/TBDR_BCQ.html

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Zones 1, 3, and 4 are treated as long-distance external-to-internal crossings while zone 2 is examined as short-distance travel zones.

Figure 14. Traffic Flows, Arizona

Figure 15. Arizona Gateways

2.5.2. California

Nearly 385,000 passenger vehicles each day cross into or out of California each day. While this is a substantial number of crossings, it is a very small fraction (0.5%) when compared to the nearly 100 million daily passenger trips taken by California residents. Even when only long-distance travel is considered, most long-distance (destination greater than 50 miles from home) passenger vehicle travel in California is undertaken by California residents and both originates and terminates in the state. This number includes a significant number of super-commuters. Figure 17 identifies the primary states of origin for long-distance passenger vehicle travel to and in California. While Nevada and Arizona send a fair number of visitors, more than 86% of all long-distance passenger vehicle travel in California originates and ends in California.

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In order to estimate VMT by visitors, 7 gateway zones were defined:

- ▶ Z1: Crossings from Oregon to California
- ▶ Z2: Northern Nevada (to just north of Carson City) to California
- ▶ Z3: Lake Tahoe metropolitan area
- ▶ Z4: Southern Nevada to California
- ▶ Z5: Arizona to California
- ▶ Z6: Mexico to California
- ▶ Z7:Tijuana-San Diego metropolitan area

Zones 1, 2, 4, 5, and 6 are treated as long-distance external-to-internal crossings while zones 3 and 7 are examined as short-distance travel zones. These are illustrated in Figure 16.

Figure 16. California Gateway Zones

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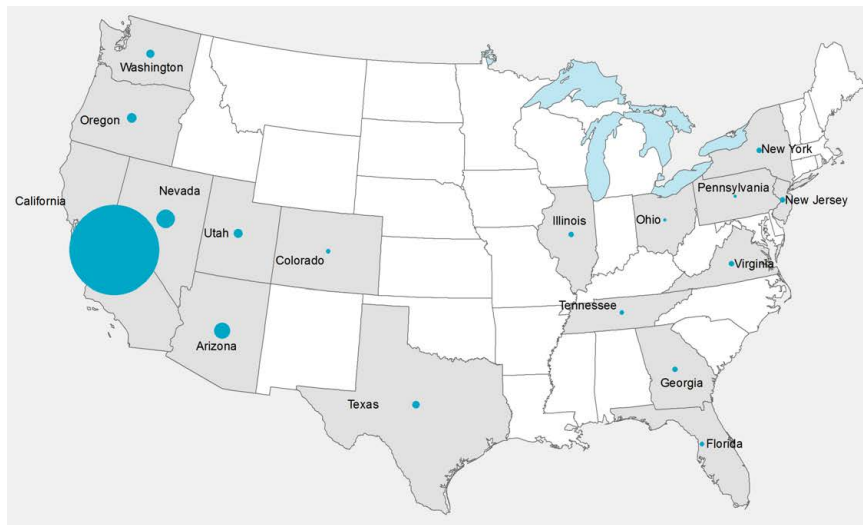
Figure 17. State of Origin for Long-Distance Driving Trips to California. *Source: Author's analysis of 2001 NHTS.*

Two regions in California have significant amounts of short-distance cross-border travel: the Lake Tahoe and San Diego-Tijuana areas.

2.5.3. Colorado

Approximately 75,000 passenger vehicles enter or leave Colorado each day at one of the 18 border crossings included in this study. Twelve of the crossings are low-volume facilities, with AADT less than 4,000 vehicles per day. Interstate 70 (Colorado-Kansas and Colorado-Utah) and Interstate 25 (Colorado-New Mexico and Colorado-Wyoming) account for 52% of vehicle movements into and out of Colorado. Volume is focused on Denver and Colorado Springs, and on the Interstate 70 and U.S. 40 routes to recreational areas. External-external travel is rare outside of heavy trucks.

In order to estimate VMT by visitors, 5 gateway zones were defined:

► Z1: Colorado Springs – Cheyenne/Laramie
► Z2: Utah to Colorado
► Z3: Northwest New Mexico to Southwest Colorado
► Z4: Eastern New Mexico to Eastern Colorado
► Z5: Kansas and Nebraska to Colorado

Zones 2, 3, 4, and 5 in Colorado are treated as long-distance external to internal gateways. Zone 1 is treated as a short-distance commuter region.

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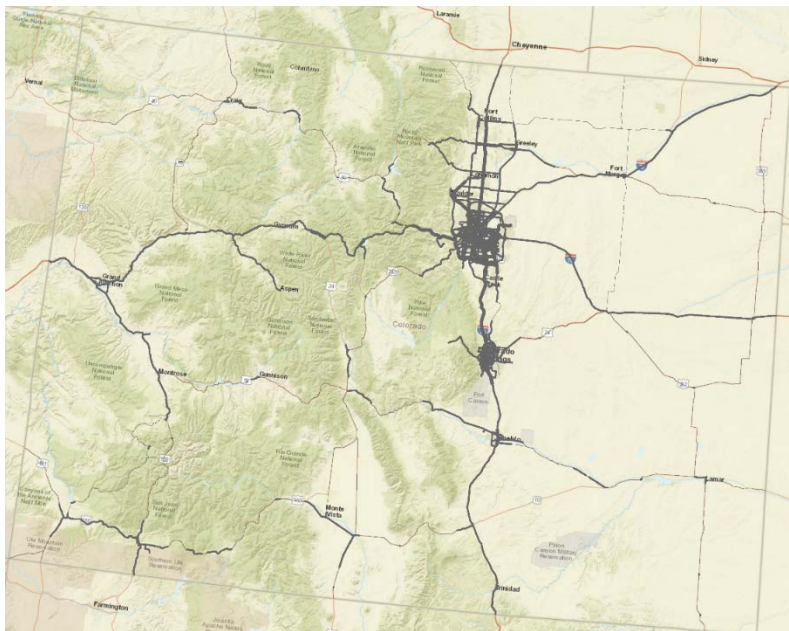
Figure 18. Traffic Flow Map, Colorado

Of overnight trips originating outside Colorado, about 52% of visitors travel in personal vehicles originating in another state.

2.5.4. Idaho

Approximately 179,000 passenger vehicles enter or leave Idaho each day. As described above, a majority of these are bound for recreational facilities. The exception is local travel in the Coeur d'Alene, ID – Spokane, WA and Lewiston, ID – Clarkson, WA areas.

In order to estimate VMT by visitors, 7 gateway zones were defined:

> ► Z1: Canada to Idaho
> ► Z2: Oregon to Idaho
> ► Z3: Nevada and Utah to Idaho
> ► Z4: Wyoming and Montana to Idaho
> ► Z5: Coeur d'Alene, ID – Spokane, WA
> ► Z6: Lewiston, ID – Clarkson, WA
> ► Z7: Washington to Idaho (exclusive of Spokane and Clarkson)

Zones 1, 2, 3, 4, and 7 are treated as predominantly long-distance external-to-internal crossings while zones 5 and 6 are examined as short-distance travel zones.

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Figure 19. Traffic Flow Map, Idaho

2.5.5. Washington

Approximately 469,000 passenger vehicles enter or leave Washington each day.

Figure 20. Traffic Flows, Washington

2.6. Revenue Implications of a Multi-Jurisdictional RUC

This section describes revenue *potential* for assessing RUC on visitors. It is important to note that the true revenue implications of a multi-jurisdictional RUC vary depending on the policy basis adopted and RUC methods used because administration costs and compliance are likely to vary widely.

2.6.1. Distance-Based Charge

If a jurisdiction opts to assess RUC on visitors strictly on a distance basis, the jurisdiction must have a system in place that can capture all visitor travel, or be willing to accept significant leakage. In the absence of a GPS mandate and national RUC program, distance-based charges for visitors are the most likely to lead to uncollected revenue for host jurisdictions, especially those that rely on manual distance methods for visitors.

2.6.2. Shadow Charge

Shadow charges are likely to be an effective method of multijurisdictional RUC assessment, provided sufficient data are available to model both distance driven and home jurisdictions of drivers, and that all jurisdictions participate in a shadow charge system. The effectiveness of the shadow charge as a revenue generation method is highly dependent on the effectiveness of each jurisdiction in collecting RUC on all miles driven by its residents. Jurisdictions with a combination of (1) poor performance in measuring and collecting RUC for residents and (2) small proportion of visitor travel could possibly see net revenue loss compared with not assessing RUC on visitors at all.

2.6.3. Distance-Based and Fuel-Based, with or without Shadow Charges

Jurisdictions adopting a combination of distance-based and fuel-based RUC for visitors have the freedom to assess RUC directly only on those visitors that are already using a location-aware RUC reporting method in their home jurisdiction, while still collecting a RUC proxy for most visitors in the form of a gas tax. A key assumption, of course, is that visitors purchase gas in the host jurisdiction. For long-distance travel, leakage under this policy basis is similar to the current situation – sometimes residents purchase fuel outside the home jurisdiction, but sometimes visitors purchase fuel in the host jurisdiction. However, in cases where there is short-distance interjurisdictional travel and one jurisdiction does not charge a motor fuels tax, this policy basis could lead to all drivers purchasing fuel in the jurisdiction without a gas tax, thereby creating significant revenue leakage for the other jurisdiction. Particularly in this situation, a shadow charge may be necessary to ensure use taxes are ultimately remitted to the appropriate jurisdiction. This form of the shadow charge must take into account the fact that some RUC and gas tax revenue may have already been reconciled for those drivers using approved reporting methods in participating jurisdictions, or be calibrated some agreed methodology to account for those who paid RUC directly.

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For the states examined, potential revenue to be gained by assessing RUC on visitors ranges from about 1% to as high as 11% of RUC generated by residents. These estimates represent potential gross revenues, exclusive of costs of collection and enforcement.

2.6.4.   Arizona

As much as 11% of VMT driven in Arizona originates outside the state, with non-resident driving most likely accounting for between 5% and 8% of total annual VMT. Unlike the other states examined in this study, there is very little short-distance interjurisdictional travel in Arizona -- the high percent of externally-originating VMT is driven by a large number of outdoor tourist destinations such as the Grand Canyon, Prescott National Forest, and Lake Havasu.

2.6.5.   California

Visitor-generated VMT is estimated to be between 1.2% and 2.6% of statewide VMT on an annual basis.

2.6.5.1.   San Diego/Tijuana urban agglomeration

Included in that estimate is the San Diego/Tijuana urban agglomeration, which presents a unique case. Approximately 7.4 million crossings are made each year at the San Ysidro Port of Entry by U.S. citizens and legal residents in order to work, shop, or attend school in San Diego. Assuming they travel on weekdays within the greater San Diego area, this group could contribute as many as 200 million miles to San Diego's annual VMT. It is unknown how many of these daily commuters register their vehicles in California. For those that do, participation in the resident RUC program should ensure they are complying with any state RUC. However, some number of these daily commuters are likely to register their vehicles in Baja California. Because

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Tijuana is outside the US and Mexico does not currently participate in the IFTA Clearinghouse, it is unlikely a shadow charge could be collected by California. In this instance, direct distance charges levied on vehicles crossing the border may be the only mechanism for assessing RUC on residents of Mexico who commute daily. A pre-paid mileage permit could be sufficient to address the issue but would be challenging to enforce.

2.6.6. Colorado

Visitor-generated VMT is likely to be between 1.1% and 4.4% of statewide VMT on an annual basis.

2.6.7. Idaho

As much as 10% of Idaho's VMT may be generated by non-residents. Long-distance travel is estimated to account for approximately 5% to 7% of statewide VMT, while the cross-border short-distance traffic generates 1.5%-2.5% of statewide VMT.

2.6.8. Washington

Visitor-generated VMT is estimated to be between 5% and 8.6% of total VMT in the state. Short-distance local travel could be as much as 4% of all VMT in the state (50-80% of all visitor generated VMT) due to significant local cross-border traffic between Vancouver, BC -- Bellingham, WA, Portland, OR -- Vancouver, WA, and numerous smaller cities and towns along the Washington/Idaho border.

	minimum estimated visitor travel
	likely range of visitor travel
	maximum estimated visitor travel

2.7. Costs Associated with Multi-Jurisdictional RUC Reporting and Reconciliation

2.7.1. General Description of Costs

The cost model used to estimate costs associated with setting up and operating a multi-jurisdictional RUC reporting and reconciliation system considers four broad categories of costs: Operational, Account Management, Enforcement, and Audit. Because several states are included in this study, wage rates, transaction costs, IT costs, and various capital expenses are estimated based on prevailing *national* standards.

Also, operational costs presented here assume a fully-mature RUC system and do not factor in any transition period. Finally, all costs are presented as marginal costs beyond those already incurred by states managing a state-level RUC system for residents.

Operational Costs

Operational costs include items like administrative staffing, IT expenses, facilities maintenance, and communications costs. For the purposes of this study, start-up capital expenses are included in this category but are calculated and presented separately.

Administrative staffing

Administrative staffing encompasses all staffing support necessary to operate a program. Staffing may include program managers, project managers, and other administrative support staff. Administrative staff costs do not include specific staffing costs associated with database/IT maintenance, creation of reports about visitor travel for use by the clearinghouse, audit, or enforcement costs, all of which are covered in other categories. In the analysis of costs associated with assessing RUC on visitors, it is assumed each state already has an operational RUC system in place and administrative staffing costs shown represent only the marginal increase likely to be necessary to extend the program to include non-residents. Clearinghouse operations, on the other hand, are assumed to be independent of any state or provincial RUC program and are estimated as such.

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Database/IT maintenance

Regardless of the policy basis adopted or method of assessing RUC on visitors, RUC states may incur some IT requirements associated with multijurisdictional RUC that are beyond those required for a single-state RUC system. Examples range from storing aggregate mileage by jurisdiction to being able to interface with financial clearinghouse systems. Identifying these IT requirements early in the design of a RUC system is likely to significantly reduce the cost of including them. Modifying existing state or account manager systems to store and transmit multijurisdiction data has a different set of expenses and results in higher overall costs.

A clearinghouse will have separate IT costs, related to accepting, storing, and analyzing data from participating jurisdictions, and transferring funds to jurisdictions.

Facilities costs

Facilities costs include the costs of purchasing, constructing, or renting real property and facilities required to administer a RUC program or clearinghouse.

Electronic communications costs (only under some scenarios)

Electronic communications costs include both cellular communications (OBDII or smartphone mileage reporting technology to an account manager) and fixed network communications (transmittal of data between from account managers to states and between states and clearinghouse). These costs are represented as marginal increases above any costs incurred in the operation of a state-level RUC program.

Account Management Costs

Transaction Costs

Transaction costs include a range of expenses including bank and credit card fees and compensation to third parties that assist in collecting mileage data or reconciling collected funds (this includes transaction costs to states for services provided by a clearinghouse). Transaction costs are relatively static across various RUC policy bases since they are driven largely by external factors (e.g. credit card fees are set by the banking industry).

Collection and Administration Costs

Collection and administration costs include all costs required to collect RUC, exclusive of those captured under the administrative staffing and transaction costs categories. This includes any payments to commercial account managers, the costs of creating and mailing invoices, and expenses related to maintaining state oversight of RUC collection.

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As with other cost categories, the estimated cost of a multi-jurisdictional RUC is presented as the marginal increase of out-of-state RUC over costs incurred by an operational state-only system. Collection costs are relatively static across various RUC policy bases since they are driven largely by external factors (e.g. postage fees, prevailing wage rates).

Enforcement Costs

Enforcement costs include those costs associated with detecting and investigating non-compliance, issuing infraction notices, receiving responses to notices (either payment or dispute), supporting dispute adjudication, as well as collections costs. Costs can include both capital expenses (e.g., purchase and installation of roadside license plate readers) and ongoing operating expenses.

Due to the costs associated with enforcement, many similar programs such as state vehicle registration and toll operators assess various administrative fees and penalties on violators, both to encourage compliance and to recover costs associated with enforcement. Similar fees or penalties are not included here.

Audit Costs

Audit costs include those costs associated with conducting periodic audits of RUC programs, including clearinghouse activities. Costs estimated for state programs are limited to the marginal increase due to inclusion of out-of-state drivers or a financial clearinghouse in assumed program audit costs.

2.7.2.   Costs Associated with Assessing a Shadow Charge

Cost categories associated with assessing a shadow charge may include the following, above and beyond existing systems and costs incurred by states:

► Operational Costs
  > Creation of both statewide and regional travel models
  > Regular maintenance of travel models
  > Administrative support costs within each state
  > Database/IT costs
► Audit function costs within each state
► State-level costs associated with participating in a funds reconciliation clearinghouse (these are detailed in section 6.6 and not included in the totals presented in this section)

The largest cost associated with assessing a shadow charge is likely to be the development of statewide and regional travel models that are capable of determining long-distance passenger travel within each state based on vehicle origin, and regularly conducting the travel surveys

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necessary to generate sufficient data to input into the models. External activity-based travel surveys are relatively expensive to conduct (in recent years per-sample costs for one and two-day surveys have been as high as $200), and the typical single-day travel diary or survey used for MPO-level analysis is insufficient to gather meaningful data for long-distance out-of-state visitors who may be expected to drive long distances over several days.

Options for long-distance travel modeling for shadow charges

A range of options exists for developing the long-distance travel data required to operate a shadow charge. These included cooperative development of a new regional passenger travel-demand model, modification of the mathematical simulation-based long-distance framework recently developed under FHWA's Exploratory Advanced Research Program, and use of travel patterns from RUC participants with location-aware reporting devices as a sample from which to estimate travel by jurisdiction for the larger population. In addition, alternative sources of travel pattern data, such as cell phone data, were modeled.

Long-distance travel models

1. Traditional statewide or regional travel demand model. These models are typically traditional 4-step travel demand models, but recently there has been interest in the development of activity-based models. It is not uncommon for development costs for statewide models to run into the millions of dollars. Further, technical staff will be required to maintain and run the model. Importantly, these models may have other uses, so the costs would not be allocable strictly and fully to a RUC program.

2. USDOT recently completed a study titled *Foundational Knowledge to Support a Long-Distance Passenger Travel Demand Modeling Framework*[3] as part of its Exploratory Advanced Research Program which developed a preliminary mathematical model of long-distance passenger travel, which is essentially a simulation that anticipates travel behavior. For those states that participate in NHTS add-on surveys or already have a mature statewide model, an extension of the model developed in this study may be adequate for assessment of a shadow charge. This option carries significant additional development costs, although they are less than option 1, as well as technical staff to maintain and run the model.

3. Parametric model based on data collected for state-level RUC programs by location-aware mileage metering devices (OBDII dongles and mobile phone apps). Initial model development costs will be significantly less than option 1, however the data output will be suitable only for estimating interstate travel for RUC purposes. Technical staff will be

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[3] Available at http://www.fhwa.dot.gov/policy/modelframework/model_framework.pdf

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> required to maintain and run the model, although fewer than either option 1 or option 2
> because far less data are involved.

Long-distance travel data

1. Traditional travel surveys

2. Another option for procuring some of the necessary data on long-distance travel is for states to purchase cell-phone data, either individually or as a collective. Idaho Department of Transportation has actively pursued the use of cell phone data as a source of travel data inside the state as part of its statewide model development. While cell-phone generated trip data lacks several important elements required for detailed travel modeling (such as mode choice, trip purpose, or trip origin (for instance, cell phone data are unlikely to adequately capture a vehicle's home state), it can provide important information about the distances people drive once they cross the border into the host-state. This, used in combination with detailed travel surveys, could support shadow charging.

3. Data obtained from RUC participants using location-aware technologies.

Short-distance travel modeling for shadow charges

The analysis of mileage data collection costs and enforcement costs suggests that the shadow charge is the least costly method of assessing RUC on "visitor" in those metropolitan areas that span state lines and those with significant near-border generators[4]. However, those MPOs may find it necessary to incorporate additional model elements into their existing travel demand models to support shadow charging.

2.7.3. Summary of start-up and operational costs associated with assessing a shadow charge

Due to the wide variety of methods a group of states might adopt in order to assess a shadow charge, the cost of doing so is presented as a range, and start-up costs (assumed to be 1-time costs) are separated from ongoing operations. Start-up costs are estimated to be between $425,000 and $2.74 million, depending on the type of model used to assign external travel to both home and host jurisdictions. Start-up costs also include the costs incurred by a state to develop agreed standards and specifications with other states.

Ongoing operational costs are also influenced by the choice of model used to assign external travel since they have varying ongoing data requirements, hardware and software requirements,

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[4] This is true except for the San Diego-Tijuana urban agglomeration. See the more detailed discussion on page 32.

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and staff support requirements. Ongoing operations are estimated to range from $175,000 to $544,000 annually.
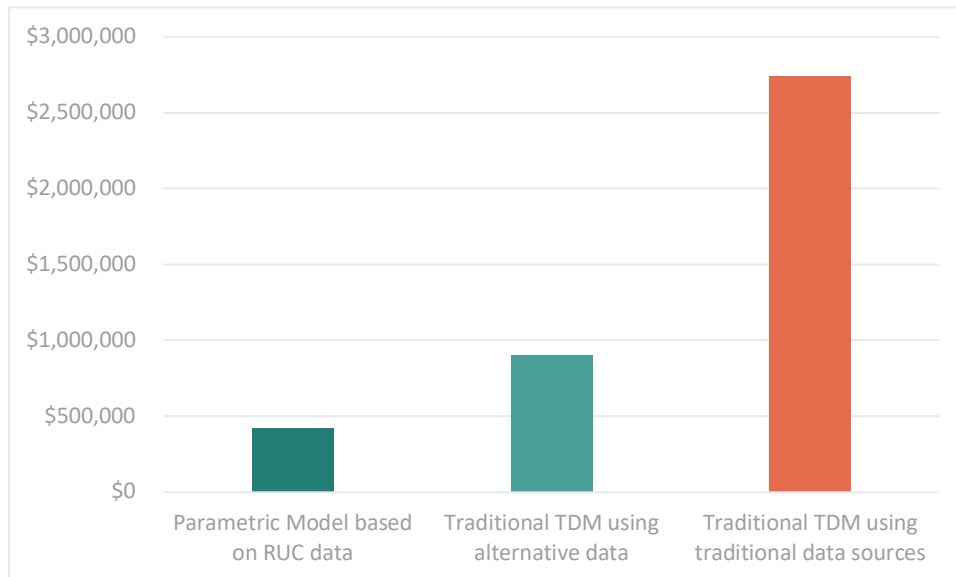
Figure 21. Estimated startup costs for shadow charges

2.7.4.   Costs Associated with Assessing a Distance-based Charge

Of the three policy bases examined, a pure distance-based charge on visitors is the most expensive to administer. Every visitor would have to either purchase a pre-paid mileage permit, valid for a set number of miles (for instance, 1,000 or 5,000), be assessed a RUC charge as they leave the state, which requires registration of odometer readings on entry and exit, or have a location-aware device that is known to the host jurisdiction. Cost categories associated with assessing a distance-based charge on visitors include the following:

► Operational costs
  > Administrative staffing
  > Database/IT maintenance
  > Transactional costs
  > Facilities costs (only under some scenarios)
  > Electronic communications costs (only under some scenarios)
► Account management costs
  > Transaction Costs
  > Collection and Administration Costs
► Enforcement costs
► Audit costs

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Scenario 1: No location-aware technology in vehicles and distance-based charges are assessed in real time directly by the state.

Under this scenario, it is necessary for the state to collect odometer readings for non-resident vehicles as they enter and leave the state, and to maintain these data in a database for some period of time. This would require states to establish physical facilities at gateways, staff those facilities, maintain a database of non-resident license-plate (or VIN) numbers and odometer readings, and maintain resources to collect either cash or credit-card payment. Cost estimates for a single facility could range into millions of dollars annually if several are required for each jurisdiction, so this scenario is considered cost prohibitive, to say nothing of the political challenges it could encounter.

Scenario 2: No location-aware technology in vehicles and distance-based charges are administered through a pre-paid mileage permit.

In this scenario, visitors to the state purchase a block of miles to "spend" while in the host-jurisdiction. This analysis assumes permits are purchased on-line and that the bulk of enforcement is performed via automated license plate readers. Fifty-five camera sites with 416 cameras were modeled; California will likely require more, Idaho fewer. The costs associated with this policy basis depend in large part on whether a state already offers a pre-paid distance permit to its residents. If it does, IT startup costs will be significantly lower.

Table 3. Multijurisdictional RUC using Mileage Permits

CATEGORY	START-UP COSTS (CAPEX)	OPERATIONAL EXPENSES (ANNUALIZED)
IT	$ 2,000,000 to $25,750,000	$ 5,266,000
Administrative Staffing		$ 1,400,000
Account Management		$ 8,075,000
Enforcement	$ 9,984,000	$ 220,520
Audit		$ 450,000
Totals	$ 35,734,000	$ 15,411,520

Scenario 3: Some drivers have a location-aware mileage reporting method and report mileage in host-jurisdiction to their home-jurisdiction while visitors without a location-aware mileage reporting method purchase a pre-paid mileage permit.

Costs are the same as Scenario 2.

Scenario 4: All drivers have a location-aware mileage reporting method in their vehicles are reporting mileage by jurisdiction to their home state or account manager.

Under this scenario, the only costs are those related to membership in a financial clearinghouse. However, this option requires a GPS mandate for all states, so is very unlikely to be implemented.

2.7.5. Costs Associated with Assessing a Combination of Distance-based and Fuel-based Charges

Under this policy basis, we assume the only motorists being assessed a distance-based charge are those already participating in their home state's RUC program with location-aware mileage meters and all other pay the motor fuel tax.

The cost model developed for this policy basis has the following assumptions:

1. All states continue to assess a motor-fuel tax that is paid when motorists fuel their vehicles.

2. States and account managers are already differentiating mileage by jurisdiction for those motorists with location-aware reporting technologies like OBDII dongles and mobile phone apps.

3. Visitors without a location-aware RUC reporting device pay the gas tax. Visitors with a location-aware RUC reporting device pay the gas tax but have that amount deducted from the RUC-due calculated by their account manager or home state. This does require each state and account manager maintain current tax rates for all jurisdictions in order to calculate out-of-state RUC.

4. All states report aggregate mileage by jurisdiction to the clearinghouse.

If these assumptions hold true and the state is a member of the financial clearinghouse, there are minimal additional costs other than those costs associated with participating in the clearinghouse (discussed in Section 6.6).

2.7.6. Costs Associated with Operating a Clearinghouse

Costs associated with operating a revenue clearinghouse include:

- ► Operational costs for the clearinghouse (external to state costs)
  - > Office rent or mortgage costs
  - > Transactional costs
  - > Database/IT maintenance
  - > Administrative staffing

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► Audit costs for the clearinghouse (external to state costs)
► Administrative support costs within each state
► Audit function costs within each state

Assumptions about the operations of the clearinghouse drove values input into the cost model. For instance, the assumed data and funds flow is:

| 1. Driver remits total RUC for all jurisdictions to Account Manager | 2. Account Manager(s) remit RUC to state, along with report of aggregate mileage by jurisdiction | 3. States forward out-of-jurisdiction RUC to Clearinghouse | 4. Clearinghouse forwards RUC funds to appropriate state |

Figure 22. Generalized Clearinghouse Process

A second model was also considered, and produced similar costs:

| 1. Driver remits total RUC for all jurisdictions to Account Manager | 2. Account Manager(s) remit RUC to Clearinghouse, along with report of aggregate mileage by jurisdiction | 3. Clearinghouse forwards RUC funds to appropriate state |

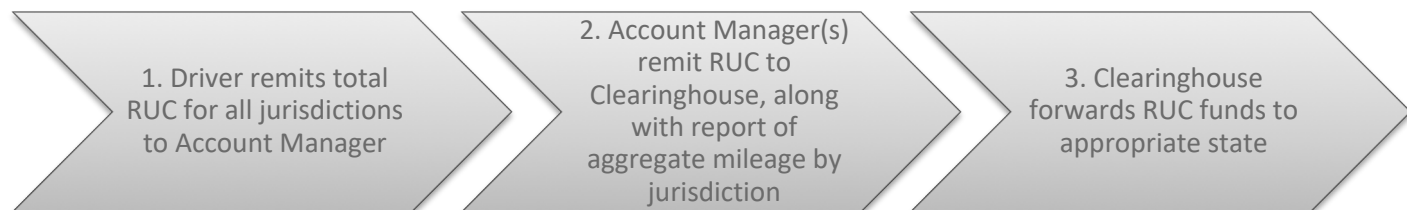**Figure 23. Alternative Clearinghouse Process**

Reduced transaction costs at the state level (caused by removing step 3 in the generalized process) were offset by an assumed increase in state-level audit costs.

It was also assumed the clearinghouse will operate independently from any state or provincial government. As such, it will require office space, staff, and will incur standard overhead expenses.

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Table 4. Costs Associated with Operating a Clearinghouse

Category	Startup Expenses	Ongoing Operating Expenses (annualized)
Clearinghouse Expenses		
Office Rent or Mortgage costs	$45,000	$62,000
Transactional costs		$139 per transaction per state[5]
Database/IT maintenance	$ 8,000,000[6]	$148,000
Administrative staffing		$700,000
Audit costs for the clearinghouse (external to state costs)		$10,000
Participating State Expenses (expenses apply to each participating jurisdiction)		
Administrative support costs within each state		$59,317.79
Database/IT maintenance within each state	$500,000 - $1,500,000	$8,400
Audit function costs within each state		$11,863.56

2.8. Enforcement of Multi-Jurisdictional RUC

Promotion of compliance should be a priority for any road usage charge system, as perceptions of ease in avoiding or defrauding the RUC will undermine revenue and be more expensive to address after a system has been introduced. Enforcement can be carried out with a mix of roadside infrastructure (identify chargeable vehicles and checking through communications and license plate recognition technology if such vehicles have active accounts or have registered or paid for road use) and mobile enforcement units (identifying on the charged network vehicles that may have not paid, and stopping them).

Enforcement should carefully segregate the issuing and pursuit of fine payment from the pursuit of charge debt. Typically, fines or other penalties for violations of the charging system become

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[5] Assumes financial transactions occur via EFT on a quarterly basis.
[6] Includes hardware and software procurement.

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part of general government revenue from fines. However, unpaid charge debt remains essentially a civil debt, which must be pursued separately (and once recovered forms part of the revenue of the RUC system). In toll systems in many states, administrative charges may be levied as part of unpaid toll debts. Road usage charge systems in other countries vary in their approach to levying additional charges for non-payment, such as "administrative charges", that *do not* comprise fines. Best practice would indicate having distinct systems and responsibilities for pursuing unpaid charge debts from the pursuit of penalty fines for offenders.

Likely methods of RUC evasion fall into four prominent categories:

- ► Failure to report miles driven
- ► Reporting false information
- ► Claiming improper exemptions, credits, or refunds
- ► Failing to pay assessed RUC

Multi-state cooperation in RUC collection is likely to improve the effectiveness of collection and enforcement efforts. The enforcement process is illustrated in Figure 24 and begins with violation detection (discussed above). Beyond the usual challenges of enforcing paying of a tax, in a multi-jurisdictional RUC context states (or provinces) must be able to collect that tax from non-residents.

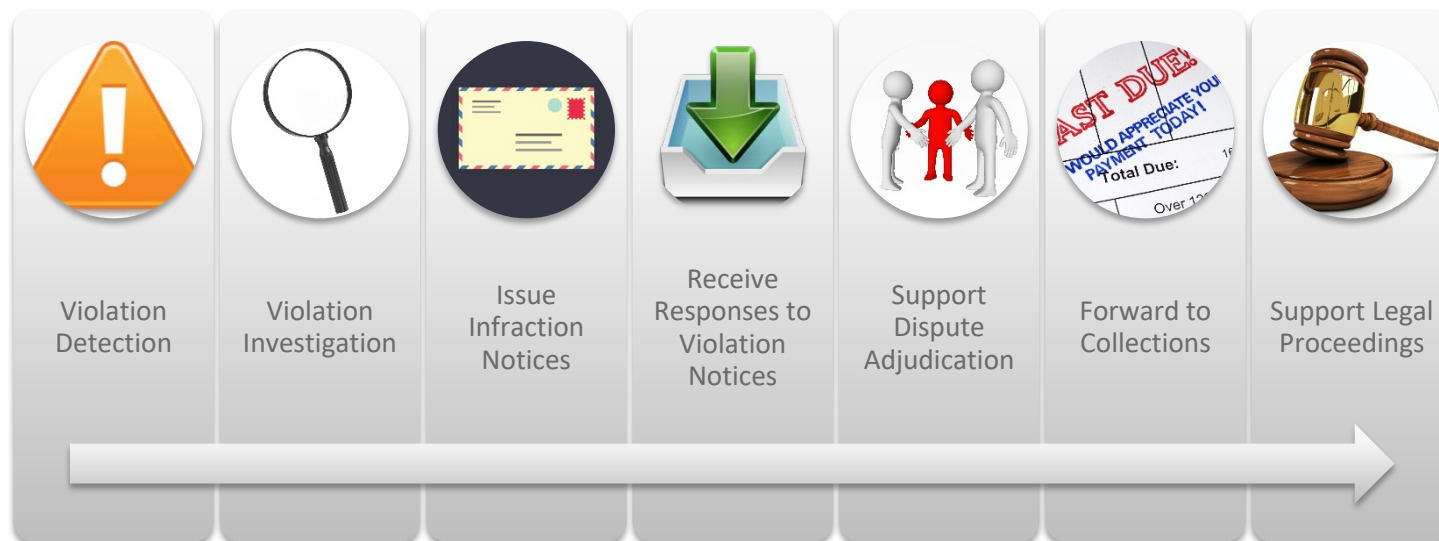| Violation Detection | Violation Investigation | Issue Infraction Notices | Receive Responses to Violation Notices | Support Dispute Adjudication | Forward to Collections | Support Legal Proceedings |

Figure 24. Simplified Enforcement Process

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2.8.1.   Enforcement Scenarios

There is a tremendous range of enforcement methods and activities jurisdictions can undertake to maximize visitor RUC collection. But regardless of the tools used, multi-jurisdictional enforcement efforts will fall into one of three categories.

2.8.1.1.   Universal retention of motor fuels taxes

By far the simplest method of "enforcement" is for all jurisdictions to continue to levy motor fuels taxes. This acts as a sort of deposit against future RUC due. When a driver reports and pays their RUC, they can be reimbursed for gas taxes paid. This scenario is not without some complications and in situations where jurisdictions charge significantly different motor fuel tax rates there is some potential for individuals to evade full payment (for instance, by purchasing all fuel in the low-tax state even when the bulk of their driving is in the high-tax state). It does, however, ensure all drivers (except PEVs) are paying something.

2.8.1.2.   State by state enforcement

Under this enforcement scenario, each state has responsibility for detecting violations, issuing infraction notices, and collecting RUC due, plus any administrative fees, fines, or other charges. A benefit of this scenario is that states' existing enforcement mechanisms are applied to visitors, likely with little or no additional cost. A major weakness of this approach, though, is that violators can only be engaged when they are physically present in the host jurisdiction. Demand letters can certainly be mailed to the violator's home address, but other penalties such as suspension of driver license, blocks on vehicle registration, and administrative penalties or fines are likely not enforceable.

2.8.1.3.   Multi-jurisdiction compact

State by state enforcement is only effective when the violator is present in the jurisdiction where RUC is due. Since multi-jurisdictional RUC systems, by definition, levy RUC on visitors (non-residents), pursuing payment outside the host-state could be problematic. The RUC administrative body in State A likely has no authority to take action against residents of State B, beyond straightforward collection of a debt. Other penalties, such as inability to renew driver licenses or motor vehicle registration would not be available. So, it is likely desirable that states engaging in multi-jurisdictional RUC form a multi-jurisdiction enforcement compact. The U.S. Driver License Compact provides one model.

In the past, states struggled with state-by-state enforcement of traffic fines and developed a system for sharing violation information so that violations by non-residents can be enforced in the home state.

According to the National Center for Interstate Compacts, the Driver License Compact "is an interstate compact used by States of the United States to exchange information concerning license suspensions and traffic violations of non-residents and forward them to the state where they are licensed known as the home state. Its theme is One Driver, One License, One Record.

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The home state would treat the offense as if it had been committed at home, applying home state laws to the out-of-state offense. The action taken would include, but not be limited to, points assessed on a minor offense such as speeding and suspension of license or a major violation such as DWI/DUI. It is not supposed to include non-moving violations like parking tickets, tinted windows, loud exhaust, etc."[7]

Within the U.S., this model is likely to be more effective than state by state enforcement, with only marginal additional cost to pre-existing enforcement activities to support a secure database of offenders. It should be noted, however, that such an agreement with either Canada or Mexico would likely require action by all involved national governments, and depending on the amount and type of information shared between jurisdictions, action by the U.S. Congress.

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[7] http://apps.csg.org/ncic/Compact.aspx?id=56

Chapter 3: Special Considerations for International RUC

3.1. Introduction

RUC-West and some of its member states have already begun to explore some of the issues related to assessing a RUC on international visitors through Interjurisdictional Study Phase 1 and Task 2 of this study, as well as its initial planning for a multistate regional RUC pilot project. This chapter expands the discussion in Chapter 2 to more closely examine RUC concepts at international borders. Because motorists from other countries are not likely to have any account-based relationships with either a US state or federal government agency (for example, property taxes, a US drivers' license or vehicle registration, a public utility connection, etc.), requiring these visitors to pay a RUC will likely require special mechanisms to facilitate proper payment. Providing these mechanisms will likely add additional start-up and operational costs to any RUC program. However, as was shown in Chapter 2, in some states there is significant travel by international visitors, who cause wear on roadways.

3.2. Objectives of this Chapter

The objective of this chapter is to identify issues that states in the US should consider in designing and implementing a RUC program capable of collecting revenue from motorists visiting from Canada or Mexico. This chapter in intended to inform the design of a future operational RUC system, rather than the design or operations of a pilot system.

3.3. Background

In Chapter 2 of this study, potential RUC revenues and costs were estimated for three different RUC policy bases:

► **Distance-based Charge**. Under a distance-based charge, motorists are assessed a charge based on the number of miles driven in a given jurisdiction. This requires direct measurement of miles driven in each jurisdiction and reporting of those mileage to either a state-managed RUC agency or a RUC account manager. Methods of measurement are wide-ranging and include (but are not necessarily limit to):
  > automated methods such as a location-enabled OBDII dongle or smartphone app,
  > manual methods such as:
   • requiring motorists to report their vehicle information and odometer reading upon entering and leaving a jurisdiction, with subsequent invoicing and RUC collection
   • manual inspection of odometers at border crossing stations, with subsequent invoicing and RUC collection
   • sale of mileage permits

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Under a distance-based charge, jurisdictions could assess RUC directly on visitors; that is to say an Oregon resident traveling in Washington would receive an invoice from and make payment to Washington. Alternatively, all mileage driven by a motorist could be invoiced by the home jurisdiction, and the various states could reconcile RUC amongst themselves.

The costs of these options varies widely, as does the reporting burden placed on the individual motorist.

► **Shadow Charge**. Under a shadow charge, states would not directly levy road usage charges on visitors. Rather, states would reconcile funds based on some estimate of the amount of visitor-generated vehicle miles traveled. The shadow charge can reduce costs associated with assessing and enforcing the RUC itself because each jurisdiction is concerned only with managing a RUC program for its own residents. However, the data required to adequately estimate not just VMT but also state of origin of visiting vehicles can be quite costly to collect. Over time and if an adequate number of jurisdictions implement location-aware mileage meters, data collected from RUC programs may be sufficient to calculate shadow charges.

► **Distance-based and fuel-based, with or without shadow charges.** Under this policy scenario, jurisdictions retain their motor fuel tax and, assuming a revenue-neutral RUC environment, refund fuel taxes paid to motorists.

Further, the chapter examined the costs associated with establishing a centralized clearinghouse model for interjurisdictional funds reconciliation.

While the basic policy scenarios described in Chapter 2 are valid for a variety of jurisdictional definitions (cities, counties, states, countries), there are some special characteristics of international RUC that deserve further consideration. Among these are questions about point of collection, enforceability of fines and penalties, currency conversion, and international acceptance of RUC measurement technologies.

3.3.1.   International RUC Systems Elsewhere in the World

Though studied extensively, both by academics and by practitioners, implementation of international multi-jurisdictional road usage charging has thus far been limited to Europe, and primarily to heavy vehicle (HV) charging.

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RUC systems in Europe can be described as either time-based (vignette systems, which allow foreign motorists access to motorways for a designated period of time) and distance based. Those jurisdictions with heavy vehicle charging/tax systems in Europe, based on distance, are[8]:

- ► Austria
- ► Czech Republic
- ► Germany
- ► Hungary
- ► Iceland
- ► Poland
- ► Russia
- ► Slovakia
- ► Switzerland

Systems in Austria, the Czech Republic and Poland use Dedicated Short Range Communication (DSRC, also known as tag and beacon) technology to measure distance by zone on major motorways. Germany, Hungary, Russia and Slovakia use location-aware technologies (such as GPS-like systems) to measure distance (Switzerland uses such technology to support its primary measurement of distance by the electronic tachograph).

Some of these RUC systems charge heavy vehicles on all roads, but others only charge on motorways/expressways and other major national roads. All systems charge heavy vehicles with a Gross Vehicle Weight of 12 tonnes and above, but many also charge vehicles 3.5-12 tonnes. Figure 25 provides an overview of the current HV charge systems in the European Union (EU).

While some elements of EU RUC systems are instructive (such as permit distribution and enforcement activities) in a US context, most EU states have a shared currency and a common set of regulations. This is not the case with Canada, Mexico, and the US. Further, EU RUC systems are based either on time or use GNSS or DSRC technology to measure distance. Since GPS (the American GNSS system) is unlikely to be mandated in US RUC systems, experiences of distance-based methods in Europe are not directly transferrable to the North American context.

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[8] This does not include countries that charge all vehicles by distance on a conventional tolled network such as in Belarus and Portugal.

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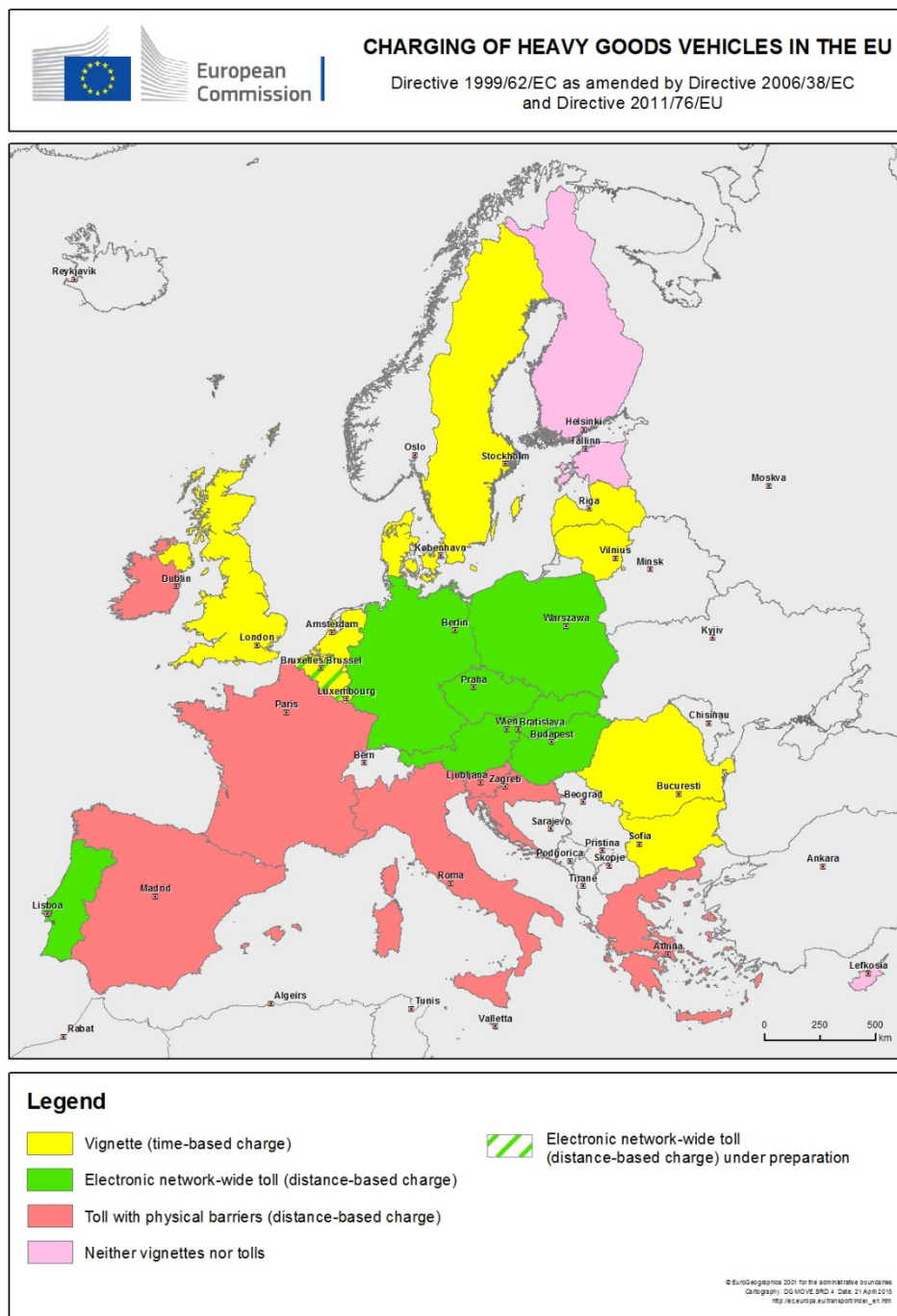

Figure 25: Heavy Vehicle Charging Systems in the European Union[9]

3.4. US Legal and Regulatory Issues Related to International Charging of RUC

The policy alternatives previously presented for charging out-of-state motorists included:

> ► Assess a shadow-charge
> ► Charge based on **distance**
> ► Charge using a **combination of fuel-based and distance-based methods**

Regardless of the policy basis adopted, it is likely US states that adopt RUC will need to form relationships with several other jurisdictions that may or may not have adopted a RUC – each of which will have its own operational concepts, rates, charging methods, and administrative structures – to facilitate revenue collection and create a rational tax environment for motorists. In pursuing and establishing these capabilities, foundational legal principles, existing statutes and regulations must be observed when creating this future tax system. This section attempts to highlight the most salient of these issues for consideration.

3.4.1. Characteristics of multijurisdictional travel

In simplest terms, three possible scenarios exist for international motorists traveling into a US state. First, a visitor entering from a country that imposes the gas tax (but not a RUC) drives on US roadways before returning home. Second, a visitor entering from a province or state that imposes a RUC drives on US roadways then returns home. And third, an international visitor travels through multiple states, some that impose RUC, some that have a combination RUC/fuel tax, and others that collect only fuel taxes.

3.4.2. Complications Arising from Interjurisdictional Travel Scenarios

For the purposes of this chapter, the long-range operational scenario is that a RUC would entirely replace the state's gasoline tax at least for passenger and light-duty vehicles. However, during a transitional phase of RUC implementation, it may be necessary or desirable to continue collecting the state's gas tax, crediting those taxes paid against a motorist's RUC invoice. In other words, for a period of time, the existing state gas tax acts as a pre-payment mechanism for the RUC. This approach is taken in Oregon's current RUC program, and is planned in Washington state's RUC pilot. In this transitional situation, the RUC collection agents or agencies need to know not only the miles traveled, but also the fuel consumed so that gas taxes paid can be calculated and credited back against the motorists' RUC account, thereby avoiding double-taxation for roadway use. In practical terms this means that under any sort of distance-based RUC, visitor vehicles would have to be "registered" with the US state or states they drive through. Sufficient vehicle information needs to be available (make/model/year) for fuel consumption estimates to be calculated as an offset to gas taxes paid.

3.4.3. Standards for Assessing a RUC on International Visitors

3.4.3.1. Existing Authority for Collection of Transportation-Related Taxes and Fees from International Motorists

New laws, policies and operations are probably required to assess RUCs on motorists from outside the US. As a starting point for understanding the legal concept of tax nexus, below is a summary of current requirements for payment of transportation-related taxes and fees:

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Table 5. Existing Authority for Collecting Transportation-Related Taxes and Fees

Transportation Tax or Fee	Description	Basis of Taxation
State Gasoline Tax	Per-gallon tax collected at the fuel terminal rack (wholesale level). The tax is passed on to consumers by increasing the retail price of gasoline by an equivalent amount.	**Actual purchase in-state**: For motorists: purchase of gasoline within a US state, regardless of motorists' state or province of residency or where gasoline is used.
Toll Roads	Flat or variable-rate charge for motorists' travel on a specific lane, road or bridge. Toll exemptions vary by facility. Some toll bridges between the US and Canada are interoperable with US toll systems such as EZPass, and tolls may be paid in either US or Canadian dollars on either side of the border. Typically, however, tolls on either end of the bridges are collected by different companies. Some bridges have enacted a "currency parity policy", which allows for Canadian rates to be reviewed and adjusted twice each year to keep them in line with prevailing currency exchange rates. While many bridges on the US-Mexico border charge tolls (particularly on the Mexico side), there are no interoperable toll bridges between the two companies, and toll operations are completely separate.	**Actual use in-state**: All non-exempt vehicles using the tolled facility must pay, including international vehicles.
Vehicle Registration Fee	Flat annual fee for all vehicles required to be registered in a state. Typically this requirement extends to residents of a state, although some states require additional categories of vehicles to be registered.	**Presumptive use in state**: Generally, registration fees are owed if the vehicle is based in the state (i.e. the owner/lessee is a resident).

For RUC, the most analogous use case is toll roads: the tax basis for both a RUC and toll roads is actual use of a road facility by a non-exempt vehicle (international vehicles are not exempt). However, a key difference is that when an out-of-state motorist uses a toll facility, the amount of usage (and thus the amount owed) is easily determined, because the price is based on the vehicle's presence traveling on a precisely defined segment of roadway. By contrast, the amount of roadway used by an international vehicle traveling on a US state's roads is not easily discoverable without a pre-existing mileage-recording device and a RUC account. A further complication is that the state's RUC agency has no established taxpayer relationship or account with international drivers. Therefore, it is unlikely pre-existing toll crossings could be leveraged to support any of the three RUC policy bases being examined here. They could, possible,

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support a concept similar to a time permit, or generic use permit, if an additional fee were charged at the toll bridge/tunnel for road use beyond the border. However, because it would be assessed with no indication of actual miles driven, it would not be a mileage permit.

One other vehicle-related "fee" that all motorists pay is for car insurance. Canadian passenger vehicle insurance, including liability, is in full effect in the US – no additional coverage is required for vehicles entering the country. Mexican liability insurance, however, is not effective in the US. Mexican vehicles with Mexican license plates must purchase special liability policies in order to have required coverage in the US. That said, proof of liability insurance is not typically required when crossing the border.

3.4.4.   Legal Authorizations Required for Interjurisdictional Revenue Collection and Reconciliation

3.4.5.   Authorizations and Agreements for Multilateral RUC Collection

In a future scenario where there are multiple states that impose RUCs, the most efficient (and legally advantageous) structure is for a single, uniform agreement to be entered into by and between all states. Whether that agreement takes the form of an interstate compact (which confers greater legal power in the administration and enforcement of the agreement) or a multistate agreement (similar to a cooperative or association agreement) depends upon the powers conferred (for example, if enforcement actions are included), and any state-specific restrictions on entering into agreements with other states. If the RUC agencies from each state are comfortable having an agreement that spells out specific roles and duties, without any legal enforceability between the states, an interagency memorandum of understanding (MOU) may be sufficient. An MOU is typically non-binding, cancellable at the will of the parties, and usually entered into in an open-book, full cooperation manner. However, if a more durable agreement that allocates responsibilities, costs and obligations – including the obligation for unpaid accounts – is desired, a more formal agreement such as a bi-state compact may be required. Under the U.S. Constitution, bi-state (or interstate) compacts are subject to the approval or consent of Congress under Article I, Section 10, if the scope of the compact would result in any encroachment or diminution of federal authority. In the context of a RUC system, no impact on federal authority is envisioned, so Congressional approval of the compact would not be required. However, each state has its own requirements for state-level approval of bi-state or interstate compacts. Many states require compacts first to be approved by the state legislature before the compact can be forwarded for Congressional approval or, if Congressional approval is not required, before the compact can become effective.

This separation between state authority and federal authority is important. US states that adopt RUC cannot directly leverage US customs or immigration facilities to assess state RUC. They can, however, modify the activities of any state agents at or near those facilities (such as state agricultural inspectors) to collect additional information about incoming or outgoing visitors at international borders.

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Often one of the primary aims of multistate compacts is to create a legally empowered agency to administer the agreement for the benefit of all members collectively. This purpose is probably of greater interest when the number of states participating in a RUC system grows large.

The process for approval of multistate compacts is identical for bi-state compacts: Congressional consent is required if the compact in any way diminishes federal authority or power; and state legislative approval is required for all interstate compacts, with or without the Congressional consent requirement.

3.5. Distance-based charges

Distance-based charges can take several forms for international visitors.

3.5.1. Mileage Permit

Visitors entering the US from Canada and Mexico could be required to purchase a mileage permit – a block of miles they can consume on US roadways. In this case, RUC would be pre-paid directly to a host jurisdiction, with no financial reconciliation.

Enforcement of such a system would be challenging. In order to determine whether a permit is valid at any given time, there must be a record of the vehicles' odometer reading at the time it enters the US. There is also the question of whether a visitor must purchase a separate permit for each state it visits, which only increases both the visitor's reporting burden and the states' data management and enforcement burden. It is conceivable odometers could be read at entry and exit at state-run border inspection facilities at international points of entry, such as agricultural inspection points, but this added inspection burden could dramatically increase border wait times and RUC administration costs, and so is not likely to be palatable. Further, even if this proved feasible it does not address the problem of international visitors passing from one US state into another.

This options for assessing distance-based charges is likely to have very low compliance rates, particularly if the permitting system is seen by visitors as overly complex. Even when non-compliant visitors are caught and cited, collecting fines, penalties, and unpaid fees from another country may be quite difficult.

3.5.2. Location-aware automated reporting

A second option for distance-based RUC can be used by international visitors whose home state or province has a RUC program and who has installed a location-aware automated reporting system in their vehicle. If the home jurisdiction has entered into a RUC clearinghouse agreement with the US state(s) where the visitor travels, then mileage can be apportioned in a straightforward manner. This option has an advantage over the mileage permit in that RUC can be assessed for all miles driven by the home jurisdiction and distributed through a clearinghouse to the appropriate host jurisdiction(s). Evasion is still possible (simply not paying

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the RUC), but collections would occur in the evader's home jurisdiction. Still, this option is not without complications:

(1) All jurisdictions where travel took place must participate in the clearinghouse for full reconciliation of tax funds to occur

(2) there must be some agreement in place about how to handle currency conversions. For instance, does the clearinghouse use the prevailing exchange rate on the date travel took place, or the date reconciliation occurs? Or is an exchange rate set periodically (say, twice each year)?

(3) For enforcement purposes, host states must have some way of identifying "reporting" vehicles without stopping the vehicle on the road. In effect, this means developing an international database of RUC-enrolled vehicles, and differentiating them by mileage measurement method. There would likely be significant privacy concerns associated with this.

3.6.   Shadow Charge

More than any other RUC policy basis described in either Phase 1 or Phase 2 of this study, the shadow charge requires clear and detailed formal agreements between jurisdictions to describe the manner of calculating travel (and therefore RUC due) and the manner of reconciliation among jurisdictions. In an international context, at minimum an international MOU or multistate compact is necessary, with Congressional approval likely. The benefit of the shadow charge is that RUC is not collected on a location-specific basis; indeed, shadow charge scenarios can successfully include jurisdictions that do not charge any RUC at all. In this model, RUC for all miles driven is paid to the home jurisdiction, and the states or provinces reconcile funds due amongst themselves using an agreed-upon method of estimating visitor travel.

Numerous Canadian provinces and US states have been party to both International Registration Plan (IRP) and International Fuel Tax Agreement (IFTA) for several decades, so there is precedent for using a clearinghouse model for funds reconciliation. However, IFTA relies on detailed reporting by truck drivers to determine the distance driven in each jurisdiction, along with fuel tax paid. Such reporting would not be required by drivers under a passenger vehicle shadow charge. So, then, additional agreements would be required to detail how the shadow charge is assessed. And, as with distance charges, an agreement for handling currency conversions must be in place.

International agreements with Mexico have proven difficult to implement and sustain. For example, IFTA and IRP do not include Mexico, and neither has near- or medium-term plans to include Mexico. Likewise, programs to allow Mexican trucks to circulate in limited volumes in limited areas within the U.S. have likewise been controversial and slow to develop, and there are currently no cross-border interoperable tolling schemes. Given this background and other

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border issues, it is highly uncertain whether interoperable RUC based on a shadow charge with Mexico could be realistically achieved in the near future.

3.7.   Distance-based and fuel-based, with or without shadow charges.

In the near term, adopting a combination of distance-based and fuel-based user fees is likely to be the most straightforward option for charging international visitors for their use of US roadways. Visitors that cross the border and purchase fuel will pay the motor fuel tax. If they are already participants of a RUC program that (1) uses location-aware technology and (2) has an agreement with US states to reconcile RUC, they can have the fuel tax credited against any RUC due. If they do not pay a RUC, they will not be eligible for the fuel tax rebate.

This option not only captures revenue via a user fee proxy (albeit an increasingly poor proxy), it provides an environment that allows time for international agreements and revenue reconciliation systems to be developed while still generating revenues for host jurisdictions. Some interjurisdictional revenue reconciliation is necessary to account for those visitors with location-aware RUC reporting systems, but retaining the motor fuel tax means that all others pay their user fee directly to the host jurisdiction.

Once concern with this option is that motorists could choose to fuel in their home country and then drive in US states. However, fuel prices along the US/Mexico border tend to be similar, while those in Canada are significantly higher than in the US. This being the case, there is little incentive for people to show preference to their home jurisdictions. And, for long-distance travel, it is very likely visitors will have to refuel in at least one host jurisdiction.

3.8.   Special Considerations for an Operational International RUC Program

Any large-scale international RUC scheme is very likely to require the US to enter into either international compacts or treaties with Canada and Mexico. Looking ahead to potential policy and design decisions that must be made in order to implement an effective RUC system where international motorists are required to pay their fair share for use of US roadways, the following parameters are suggested:

► **There should be no discriminatory intent or design in collecting RUCs from international drivers**. For example, any charge must be levied for in-state, out-of-state, and international motorists traveling a jurisdiction's roadways. There should not be a special tax or fee that is applied only to international motorists ("tax exportation"). *An open question that requires additional legal research is the extent to which local tax preferences or similar accommodations are allowable*. In some instances, discounts for certain toll payers has been upheld, while in other cases exemptions for state residents have been found to be discriminatory. In Europe, the EU recently filed suit against Germany for allowing German residents to claim local fees paid against the national road usage charge, effectively lowering the rate for German residents compared to other road users.

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> ► **A RUC should reflect a fair approximation of the use of the facilities**.
> ► **The amount of a RUC should not be excessive in relation to the benefits conferred**.
> ► **Methods of reporting and fee collection should not unduly burden international drivers**.
> ► **Standards for precision and accuracy of mileage measurement methods should be agreed**.

In addition, there will need to be agreement on any regulations or specifications related to mileage measurement devices. How precise must they be, which types of devices are valid for measuring mileage, etc.

3.8.1. Regulations related to mileage measurement

Based on experiences in previous RUC pilots, vehicle owners seem most familiar and comfortable with the mileage totals displayed on their odometer. In other per-mile fee tests, participants have questioned the accuracy of the automated mileage metering devices, including those with GPS-enabled mapping for mileage calculation, because the GPS calculated mileage doesn't always match what is displayed on the vehicle's odometer. These discrepancies, no matter how small, may raise questions in the minds of the public about whether they are being "overcharged" for miles driven. There appears to be a built-in bias that the public is more likely to believe and accept the mileage shown on their odometers as most accurate than they are the mileage recorded by a new, unfamiliar device.

3.8.2. Global Positioning System (GPS) and Accuracy Standards

The regulation, standards and accuracy of the Global Positioning System (GPS) itself is within the domain of the U.S. federal government. The U.S. Department of Defense originally developed the GPS system in the 1970's to aid in military navigation. Although the system is maintained by the U.S., it is freely accessible to anyone with a GPS receiver.

The GPS system's accuracy for civilian uses (including mapping applications) is governed by the GPS Standard Positioning Service (SPS) Performance Standard, which is set by the Department of Defense. The current standard specifies that the lowest level of accuracy ("worst case" accuracy) is 7.8 meters at a 95% confidence level. Even higher levels of accuracy can be achieved when GPS is used in combination with other systems, enabling real-time positioning to within a few centimeters[10]. The accuracy of the GPS system itself is undisputed, certainly for purposes of measuring vehicle distances traveled on public roadways. In fact, GPS devices have been certified as revenue-grade use for measuring distances for truck fees in Oregon, and

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[10] See *Augmentation Systems*, internet based article provided by GPS.gov. Accessed June 27, 2016 at http://www.gps.gov/systems/augmentations/

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similar systems have been certified for revenue calculation purposes in New Zealand, Germany, and elsewhere.

The actual accuracy that users attain as measured on their GPS-enabled receivers, such as vehicle navigation devices, smart phones, etc., depends on factors outside of the GPS itself. Atmospheric effects, sky blockage (such as from tall trees or buildings), and quality of the receiver unit itself (in particular, the size, quality and location of the antenna) can affect accuracy. However, analysis conducted by the FAA shows that high-quality GPS receivers generally provide accuracy better than 3.5 meters.

A key difference between GPS mileage recording versus odometer mileage recording: to the extent there are minor discrepancies in actual versus recorded movement, with GPS those differences are only momentary, until the next signal plots the location along the roadway map. In this manner, any minor misreadings (for example, showing a vehicle traveling off the public roadway) are only momentary, until the next signal is received. By contrast, with odometer readings, very small variations in mileage are cumulative; if an odometer records very slightly more miles than actually traveled, these minor miscalculations are cumulative, continually recorded in the odometer reading, without the ability for correction. Such errors cause typical vehicle odometers to have inaccuracies ranging approximately +/- 2.5% or more; industry-developed targets for odometer accuracy are set at 4% margin of error.

3.9. Conclusions

International multijurisdictional RUC has similar challenges to multi-state RUC. These include:

  ► Being able to identify whether a "visiting" vehicle is registered for a valid RUC method in the host jurisdiction.
  ► Enforcing RUC on visitors
  ► Developing multi-jurisdiction frameworks for revenue collection and distribution

In addition, international RUC reconciliation requires agreement about how to manage currency conversion.

While RUC remains a state-level tax, states are unlikely to be able to leverage federal facilities at land ports of entry to collect data such as license plate numbers or odometer readings of RUC vehicles. Those states that maintain their own international border presence, such as agricultural inspection stations, could expand the functions of those facilities, but at a cost that is very likely to be prohibitive and have a negative impact on border wait times.

In the near term, for international visitors is seems the most cost effective and enforceable RUC policy is a combination of fuel-based and distance-based user fees. This scenario allows jurisdictions time to develop international partnerships and a robust financial clearinghouse model, and will be able to shift, over time, away from fuel-based fees to distance-based fees as the number of RUC states and provinces grows.

Chapter 4: Developing a Successful Interjurisdictional RUC Pilot

4.1.   Objectives of this chapter

The primary objectives of this chapter are the following:

- ► Identify characteristics of a successful regional, interjurisdictional RUC pilot related to interoperable travel reporting, RUC collection, and reconciliation across state boundaries
- ► Distinguish core activities of a regional interoperability test from activities common across individual state RUC pilots.
- ► Discuss steps for planning and executing an interjurisdictional RUC pilot

4.2.   Organization

This chapter begins with a brief review of key points from Phase 1 of this study. Next, it discusses the characteristics a successful interjurisdictional RUC pilot is likely to have. Then it proposes at a high level three different approaches to configuring a multi-state demonstration, each designed to support distinct pilot objectives, followed by key issues to consider for international participation in a multi-jurisdiction pilot. Finally, the chapter lays out a path to a pilot.

4.3.   Review of Relevant Discussion from Phase 1

Reconciliation methods and policy bases described in Phase 1 of this study are important background to many of the decisions described later in this chapter. That report is located at [URL] reference.

4.3.1.   Recap of Policy Bases Developed in Phase 1

The eight policy bases developed in Phase 1 are summarized in Appendix A. Each of these has different implications for an interjurisdictional pilot. All but the "no charge" option can be tested in an interjurisdictional pilot, but the choice must be harmonized with participating states' own policy goals. Another point to consider is that more than one of these policy bases can be tested in a single pilot; each state may adopt the basis that best supports its internal goals. Any arrangement with shadow charges requires consensus among participating states, but all other bases can be adopted by a state unilaterally (although not imposed on other states).

4.4.   Motivating Factors and Success Factors for an Interjurisdictional RUC Pilot

This section describes motivating factors and characteristics a regional, interoperability pilot should have to give it the best possible chance for success.

There are three primary motivating factors for undertaking a regional or multi-state pilot that set it apart from pilots already conducted or planned by individual states:

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► The first reason is to assess the feasibility and performance of interoperable RUC reporting, payment, and reconciliation methods for charges assessed on miles driven across jurisdictional boundaries, from the perspective of motorists and participating agencies. This has not been fully evaluated in any U.S. pilot to date. States are free to adopt a unilateral approach to charging out-of-state drivers (e.g., using time permits in which visitors pay RUC directly to the host state). However, in a mature RUC system where automated mileage reporting methods with location-aware devices are widespread, it is quite probable that a motorist will remit their full RUC to either their account manager or home state, regardless of where miles were driven. In this future, it will be necessary for jurisdictions to reconcile RUC collected among themselves.

► The second reason is to develop the governance model, standards (for products and services that are used across borders), procurement, and other operational issues of common or shared RUC systems versus individual state RUC systems. WRUCC has already begun some of this work through development of its charter and bylaws, launch of a communications task force, and initial design of a certification framework. However, these activities could be extended and enhanced as part of a multi-state pilot complementary to the participant-facing activities of an interoperable RUC pilot.

► A third potential reason to test interjurisdictional RUC is economies of scale. States can share developmental costs and reduce their marginal costs of participation in a pilot. However, this reason is secondary to the core reasons mentioned above (to offer a metaphor, a Baskin-Robbins Groupon is of little use if you are lactose intolerant). Moreover, meaningful economies of scale for RUC operations do not materialize until participation reaches the hundreds of thousands, well beyond the scope of most RUC pilots.[11] It is doubtful that even a large multi-state pilot would have enough volunteers to see evidence of economies of scale, and as such conducting a pilot to assess costs is not an effective use of limited pilot opportunities available to states.

Other goals, such as increasing public awareness of RUC, testing RUC technology and operations, and building in-state institutional RUC capabilities, can be part of a multistate pilot, but these goals do not differentiate a multi-state effort from those already conducted by individual states.

The next section enumerates fundamental characteristics necessary for successful pilot testing interoperability of RUC.

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[11] Although empirical data from U.S. RUC pilots are lacking, experience from light-vehicle RUC in New Zealand, weight-mile tax schemes in the U.S. and Europe, and IFTA suggest that the cost of collecting and reconciling RUC in a multi-jurisdictional environment can be competitive with fuel taxes at very large volumes

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4.5. Success Factors for an Interjurisdictional RUC Pilot

4.5.1. Ability to identify shared policy questions across participating states and funding agencies

The first key to success is to begin the process of designing an interjurisdictional pilot by articulating policy questions. Policy aims should be clearly established by legislative policy or a committee of stakeholders who provide legitimacy before any detailed pilot design or concept of operations is undertaken. Without policy-level questions and guidance, pilots are unlikely to produce information of value to decision makers. Moreover, if the goals for an interjurisdictional pilot conflict with the internal policy goals of participating states, the resulting tension could compromise the success of the pilot or set back a state's efforts for many years. For instance, if a state has adopted a policy stance stating that all RUC will be assessed using manual methods such as odometer readings, that state may not be a good fit for a multi-state pilot testing the ability of account managers to direct revenue to the correct jurisdiction using location-based operational concepts.

Clearly, not all states will have total alignment of RUC policy goals. However, a pilot can emerge from the policy questions that are held in common. Among WRUCC states actively studying RUC, the policy question of how to address visitors has arisen in Washington and Oregon, to a lesser extent in California, and hardly at all in Hawaii.

4.5.2. Ability to clearly translate policy objectives into pilot objectives shared by all participants

Common policy questions and objectives should drive pilot objectives, and the objectives should be driven by the questions the participating states wish to answer, along with activities that will further the goals of WRUCC over the mid- to long-term. Examples of objectives for an interjurisdictional pilot include the following:

► Work across state borders to highlight key issues not already resolved in single-state pilots, such as:
  > Interoperability of RUC collection methods across state boundaries, including improved functionality (reliability and ease of use) of multijurisdictional operational concepts such as automated mileage reporting with location-aware technologies and public acceptance of such options
  > Reconciliation of funds among jurisdictions, including assessment of feasibility of different methods of financial clearing or reconciliation and development of business rules that govern the exchange of funds
  > Establishing standards for common technology or operational elements, possibly to support shared procurement or certification of account managers.
  > Test the application of common specifications and standards for hardware, software, and account management in an operational environment
  > Test the flexibility of pre-existing "open" platforms and their ability to address local design preferences

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> > Test the use and functionality of interoperable RUC in the presence of varied jurisdictional rate structures
> > Test application of RUC to various population segments across participating jurisdiction at once
> ► Amplify issues already being address in single-state pilots such as:
> > Jointly conduct outreach with key stakeholders and policy makers to raise awareness about the need to study and test RUC
> > Increase public awareness of the challenges that surround declining gas tax revenues
> > Clearly position the gas tax as a user fee for road funding

Clearly, no single pilot can have all these objectives, and WRUCC may decide to adopt a different set of pilot objectives. However, those listed above are examples of objectives that can be evaluated.

4.5.3. Ability to define pilot scope that address policy questions and meets pilot objectives

Once policy questions have been identified and pilot objectives articulated, it is critical to resolve issues surrounding what to include and what to leave out of the pilot, as an early step the design process. The number of states to involve, the ability of states to enter over time, number of pilot participants to include, number and description of operational concepts and technologies to offer, description of interoperability features across various mixes of operational concepts (including fuel taxes), types of account management services to offer, types of public engagement activities to feature, length of the pilot, and type of reconciliation method (including business rules) to test should be decided, based on the policy objectives and questions that the pilot aims to address.

To the extent possible, attention should be paid to selecting an optimal combination of the policy bases and operational concepts developed in Phase 1 of this study on interjurisdictional RUC issues and to ensuring that test design and implementation options are developed that work for each individual state as well as the collective.

4.5.4. Ability to define organizational structure with clearly defined roles and responsibilities

The structure of an interjurisdictional pilot is heavily dependent on the overall scope, objectives, participating states, and technical, operational and administrative parameters for the project. It should be recognized that each participating state may have different organizational structures in place to report and reconcile RUC. In fact, many states may have different organizations or specially-designed organizational structures in place. As such, a multi-state or regional pilot may have a suite of organizations that may need to collaborate in agreeing to a set of defined roles and responsibilities as well as the business rules that govern them.

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> ► **Stakeholders**. As part of the pilot design process, participating jurisdictions should identify possible participants, stakeholders, and other interested parties and determine whether or not their interests can or should be incorporated in the pilot. To the extent stakeholders are included in the pilot, their role should be made clear early in the planning process (advisory, observational, etc.).

> ► **Administrative parameters**. A multi-state, interjurisdictional pilot is bound to be a complex undertaking. Each participating state is likely to have different procurement rules, budgetary processes, relationships with stakeholders, and groupings of agencies involved with assessing, collecting, and distributing RUC. As such, it is critical that the pilot project have a well-defined organizational structure. The importance of establishing and formalizing this structure is discussed in Section 6.2.

4.6. Interjurisdictional Pilot Configuration

There are several different forms a multistate RUC pilot might take. The examples provided in this section are not exhaustive. WRUCC may identify and desire to pursue something altogether different, but this list provides a starting framework for configuring a pilot that incorporates several states:

1. Extend current RUC systems and pilots to additional states

2. Extend the specification of the current "open architecture" used by some WRUCC states to develop a pilot that uses commercial account managers to manage revenue reconciliation activities

3. Layer the collection of federal motor fuel tax to test reconciliation models that correctly allocate state and federal taxes to the correct jurisdiction, based on federal funding allocation formulas for the federal portion of the taxes collected.

4.6.1. Extension of current state-level RUC systems and pilots

Among the RUC-West states, Oregon currently has an operational RUC program, and California is undertaking a pilot. Other states are addressing possible pilot tests. Thus far, Oregon and California have adopted open system architectures for their RUC systems, and Washington's RUC Steering Committee has endorsed the concept, to encourage continuous innovation in mileage reporting technologies. Extending this open system architecture to additional states provides opportunities for:

> ► Additional public engagement and outreach to increase public awareness of declining gas tax revenues

> ► Testing a variety of methods of assessing RUC on out-of-state drivers, including time permits and shadow charges

► Testing any of the three methods of reconciling RUC fees collected among the participating states

► Demonstrating to participating states the freedom of selecting RUC measurement and reporting methods that best support the state's policy objectives and political climate

4.6.2.   Create an account manager-based reconciliation system

Another option for an interjurisdictional pilot is for a group of jurisdictions (cities, states, provinces, etc.) to adopt a common specification that allows the jurisdiction(s) to enter into an arrangement with one or more commercial account managers to provide the full range of RUC account services, including mileage measurement, reporting, invoicing, transaction processing, funds transfers, and distribution of RUC to the relevant jurisdiction(s). Under this model, account managers calculate the RUC due to each state and remit the funds directly to the states on a periodic basis. This option provides opportunities for:

► Additional public engagement and outreach to increase public awareness of declining gas tax revenues,

► Use of independent and third-party vendors to collect fees, operate the system, and reconcile revenues,

► Ability of audit functions to effectively monitor the revenue reconciliation process,

► Testing the feasibility of assessing shadow charges on motorists that do not choose a location-based mileage reporting method

4.6.3.   Integration with federal gas tax

A third path to a pilot is for a group of states to band together to investigate the feasibility of states collecting, reconciling, and redistributing a federal RUC in addition to the state's road charge. Under the current model, federal taxes are assessed "at the rack" – upon removal from bulk storage terminals – and paid to the Internal Revenue Service (IRS). The revenue is deposited into the Highway Trust Fund. Most (83-87%) of the revenue is deposited into the Highway Account for redistribution back to states for road construction and maintenance. Under this pilot configuration, states could test the feasibility of collecting a "federal RUC" in addition to the state charge and redistributing it to participating state accounts using existing federal apportionment formulas, but without sending it to the IRS. States would still be subject to federal program approval to spend the funds, and would still be subject to audit by the IRS, but such a model, if it proves feasible, could eliminate much of the federal cost of collection and redistribution. Under this model, a block chain accounting model is likely to be most efficient. This option provides opportunities for:

► Additional public engagement and outreach to increase public awareness of declining gas tax revenues,

► Testing methods of streamlining the federal gas tax collection/dispersal process under a RUC

► Determining the feasibility of block-chain accounting for multi-jurisdictional RUC

4.6.4.   Considerations for an International Demonstration Project

Expansion of a regional pilot to include jurisdictions in either Canada or Mexico requires special consideration. While some metropolitan areas in Washington, California, Arizona, and Texas see significant amounts of daily cross-border passenger vehicle traffic, in most areas the amount of passenger traffic generated by vehicles originating outside the U.S. is quite small. The potential revenue to be gained by assessing RUC on these vehicles should be balanced against the challenges of the following:

- ▶ Informing international visitors of RUC rules and requirements
- ▶ Gaining compliance with each state's RUC
- ▶ Enforcing RUC across international borders

A detailed analysis of the costs and revenues associated with levying RUC on international visitors is presented in Chapter 3.

4.7.   Steps for Developing an Interjurisdictional RUC Pilot

The sections above describe considerations and possible starting points for an interjurisdictional pilot. This section walks through the concrete steps WRUCC states can follow to develop an interjurisdictional RUC pilot. While these "steps" are listed sequentially, in reality some may be addressed concurrently.

4.7.1.   Ascertain State Interest in and Readiness for Participating in a Pilot

Given that the states comprising WRUCC are all at different stages of RUC policy development and operational readiness, not all may be willing or able to participate in a multi-state pilot. In the context of developing a pilot, the concept of "interest" includes political openness to state participation, likely availability of funding, and willingness to allocate knowledgeable staff to participate in pilot project development and management. "Readiness" suggests that the state has formulated a basic policy objective for RUC (typically it is to create a sustainable transportation revenue source) and can articulate specific objectives for a pilot. It is not necessary for a state that wishes to participate to have already undertaken its own RUC pilot, but it is critical to have some direction, even if just questions, from engaged policy makers.

4.7.2.   Formalize an Organizational Structure to Oversee Pilot Planning and Development

The planning and development of a pilot project requires significant organization and dedication of resources. One strategy the WRUCC can adopt is to create a committee charged with leading pilot planning and development efforts. Members of the committee would be charged with overseeing pilot development, keeping the WRUCC Board of Directors informed of pilot progress, and serving as liaisons between various agencies within their states (DOTs, Commissions, DMVs, etc.) and WRUCC. An alternate strategy is for WRUCC, or a WRUCC pilot management committee, to hire a project manager specifically for the project, who would

be charged with updating the WRUCC membership and Board and managing the relationships with vendors and state agencies.

Regardless of the model WRUCC chooses for overseeing pilot planning and development, there are several key questions that must be answered at this point:

- ► Who leads the discussions and the project? A key element of any collection of states or organizations requires a single point of management or focus to harmonize the efforts and manage the group to a consensus. As discussed above, the project could be managed by a WRUCC committee, a project manager hired by WRUCC specifically for this project, or an employee of one of the participating DOTs.
- ► Which state manages or administers the project and ensures that any state or federal reporting requirements are met? Is this the responsibility of the WRUCC Administrator or another state to take the lead?
- ► Who contracts necessary services? Will each state enter into separate contracts for services to be provided in that state, or will WRUCC contract vendors for the project as a whole? Do the participating states have the ability to enter into a compact or contractual agreement with one another to facilitate procurement activities?
- ► Is the contracting entity the same entity that serves as the project's primary point of contact with contractors?
- ► How are agreements between states executed and documented? Who has the authority to enter into such agreements? It is very likely that the need to pool funds or share procurements will require some formal agreements between states. These can take several forms, including Memorandums of Understanding, contracts, and Letters of Commitment.

4.7.3. Establish pilot goals and objectives

Regardless of the funding source, pilot goals and objectives should be established that respect the context and policy objectives of the funding agencies, and deliver value to longer-term RUC development. That said, chances of securing funding increase if WRUCC is able to identify objectives that align with those of funding entities.

A number of possible objectives are listed in Section 3.3 above. As a starting point for narrowing that list or developing new pilot goals and objectives, the following questions may be helpful:

- ► What still-untested element(s) of RUC can be demonstrated and evaluated that will generate the most useful results for WRUCC?
- ► What still-untested element(s) of RUC can be demonstrated and evaluated that will generate the most useful results for funding agencies (state legislatures, FHWA, USDOT, Congress, etc.)?
- ► What are the key policy objectives of participating WRUCC states? What is the key policy objective of WRUCC as a collective?

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> ► How do WRUCC's policy objectives align with those of the funding agencies? How can a regional pilot further those objectives?

4.7.4.   Define project scope

Once the pilot's goals and objectives are defined, the next step is to create an initial definition of the project scope. The scope may be revised based on feedback from stakeholders, participating agencies outside WRUCC (for instance, a participating state's DMV or equivalent), and funding entities. However, a clear scope definition is necessary before the next steps can occur.

The scope should contain a list of all activities necessary to deliver on a regional pilot, including design and initiation activities as well as volunteer recruitment, vendor procurement, communications and media activities, pilot operations, and evaluation of outcomes.

4.7.5.   Identify key issues and risks

As the pilot's scope takes shape and objectives are established, it is a good practice to begin to identify issues that the states are likely to encounter during the pilot lifecycle (planning, developing, implementing, operating, and evaluating) and develop initial mitigation measures. Issues and risks may be administrative (for example, different procurement rules in participating states make it difficult to procure required services, state treasury rules prohibit use of a clearing house for revenue reconciliation), operational (state IT rules may make it difficult to connect to a 3rd party clearinghouse), budgetary (limitations on the use of funds allocated to a state DOT might make it difficult for a group of states to meet funding match requirements), or schedule-related (a state that wishes to participate cannot guarantee funding until its legislature meets in 2017). Early identification of possible issues and risks may impact the pilot project's ultimate scope – it may be that the most effective mitigation measure for some issues is to adjust the project scope to avoid the issue entirely.

Risk identification and management are activities that should be conducted throughout the pilot project.

4.7.6.   Develop cost estimates for an interjurisdictional pilot

Once the project scope is defined, the next step is to develop a high-level cost estimate for the pilot, and indicate each participating state's share of the costs. All elements of the project should be included in this estimate, including any costs associated with project management, public engagement, recruiting, vendor procurement, evaluation, financial reconciliation, and stakeholder management. These cost estimates will be important when seeking funding for the project.

4.7.7.   Identify funding sources

Funding is obviously a critical element of any pilot, and sources of funding must be identified early in the pilot development process. RUC pilots in the U.S. have been funded through direct

state legislative appropriation, under research programs funded by USDOT, or some combination of the two. In Fixing America's Surface Transportation (FAST) Act (Pub.L. No. 114-94), Congress made available $95 million to provide grants to states to demonstrate user-based alternative revenue mechanisms that utilize a user-fee structure. This grant program requires a fifty-percent, non-federal match from participating states, and so in most cases will require an appropriation from state legislatures or state generated soft match contributions.

While funding is typically not actively sought until after a general project scope is defined, understanding the objectives of the various funding entities will aid in aligning the pilot's goals with those of the funding sources, thereby increasing the likelihood of the pilot being funded.

4.7.8. Create and Implement an Action Plan to Deliver an Interjurisdictional Pilot

Finally, the organization (WRUCC subcommittee) or project manager overseeing pilot planning and development should create and implement an action plan to deliver the pilot. It should also determine which activities in the action plan should be conducted by state staff versus consultant staff. Elements of this action plan include but are not limited to:

- ▶ Request funding from state legislatures
- ▶ Seek any necessary legislative authorization to conduct the pilot
- ▶ Seek any available federal funding
- ▶ Procure any required support to finalize project planning and begin pilot delivery, including but not limited to:
  - › Creation of communications plans
  - › Creation of participant recruitment plans
  - › Stakeholder management
  - › Creation of any necessary technical documents, including Concept of Operations and system specifications
  - › Support for vendor procurement (commercial account managers, technology providers, and revenue reconciliation services)
- ▶ Establish pilot evaluation criteria
- ▶ Procure required vendors
- ▶ Recruit pilot participants
- ▶ Risk analysis to identify impediments to implementation and potential issues and mitigation measures in the overall approach

4.8. Summary

This chapter outlines key steps to consider in planning an interjurisdictional RUC demonstration, and suggests objectives for such a pilot. It also suggests three starting points for pilot planning and development (extend the Oregon and California system, test a multi-state system based on

common specifications, and test a system that reconciles both federal and state RUC using block chain ledgers), and describes the characteristics of a successful interjurisdictional pilot.

Chapter 5: Summary and Conclusions

This report extends the work undertaken in Phase 1 of "Assessing Out-of-State Drivers in A Road Charge Usage System" by estimating possible revenue impacts of charging or not charging RUC on visitors to a state with a RUC system under three different RUC policy bases: distance-based charge, shadow charge, and combination distance-based/fuel-based charging. The estimates of revenue implications included costs associated with assessing and enforcing RUC on visitors, as well as costs associated with participating in a revenue reconciliation clearinghouse. In a situation where all jurisdictions charge a RUC and all jurisdictions continue to assess a motor fuel tax at the pump, a combination distance-based/fuel-based charge is the least costly in the short-term. However, as the proportion of plug-in electric vehicles increases over time, the effectiveness of the fuel-tax as a user fee for visitors will decline. In the longer term, shadow charges are likely to be more efficient to collect than attempting to identify all visitors and enforce RUC payment, but there is a significant amount of work to do to develop models of visitor travel to support such as system.

This report also identified special considerations related to assessing RUC on international visitors, with special attention to legal and regulatory issues and a discussion of the types of agreements that may be used to establish international RUC relationships with jurisdictions outside the U.S.

Finally, the report lays out considerations for developing a successful interjurisdictional RUC pilot, including considerations for an international demonstration.

Appendix A. Recap of Policy Bases Developed in Phase 1

The eight policy bases developed in Phase 1 are summarized in Table 6. Each of these has different implications for an interjurisdictional pilot. All but the "no charge" option can be tested in an interjurisdictional pilot, but the choice must be harmonized with participating states' own policy goals. Another point to consider is that more than one of these policy bases can be tested in a single pilot; each state may adopt the basis that best supports its internal goals. Any arrangement with shadow charges requires consensus among participating states, but all other bases can be adopted by a state (although not imposed on other states) unilaterally.

Table 6. Summary of Policy Bases Developed in Phase 1

Policy Basis	Description of Policy Basis
1. No charge	The host jurisdiction does not charge visitors for road usage.
2. Shadow charge	The host jurisdiction does not charge visitors for road usage, but measures or estimates their usage as the basis for a reconciliation of funds collected by the visitor's home jurisdiction. For example, this could apply for visitors with a manual (e.g., odometer-based) RUC reporting option in their home jurisdiction. It could also work in conjunction with a fuel-based charge.
3. Charge based on fuel consumption	The host jurisdiction imposes a tax on fuel purchased by visitors. The tax may or may not also apply to residents.
4. Charge based on time	The host jurisdiction imposes a charge on visitors based on the amount of time they access the host roadway network.
5. Charge based on distance	The host jurisdiction imposes a charge on visitors based on the distance they travel on the host roadway network.
6. Distance-based, with shadow charges	The host jurisdiction imposes a distance-based charge on vehicles equipped with electronic distance- and location-reporting capabilities (including fuel tax offsets), but uses shadow charging for vehicles that opted for manual or non-location-based distance reporting in their home jurisdictions.
7. Distance-based and fuel-based, with or without shadow charges	The host jurisdiction imposes a distance-based charge on vehicles equipped with electronic distance- and location-reporting capabilities (including fuel tax offsets), but uses fuel taxes for all other visitors.

8. Distance-based and time-based	The host jurisdiction imposes a distance-based charge on vehicles equipped with electronic distance- and location-reporting capabilities (including fuel tax offsets) and time-based charging for all other visitors.

Appendix B. The Great Chain of Being Sure About Things

Source: The Economist.com,
http://www.economist.com/news/briefing/21677228-technology-behind-bitcoin-lets-people-who-do-not-know-or-trust-each-other-build-dependable

Blockchains

The great chain of being sure about things

The technology behind bitcoin lets people who do not know or trust each other build a dependable ledger. This has implications far beyond the cryptocurrency

Oct 31st 2015

David Parkins

WHEN the Honduran police came to evict her in 2009 Mariana Catalina Izaguirre had lived in her lowly house for three decades. Unlike many of her neighbours in Tegucigalpa, the country's capital, she even had an official title to the land on which it stood. But the records at the country's Property Institute showed another person registered as its owner, too—and that person convinced a judge to sign an eviction order. By the time the legal confusion was finally sorted out, Ms Izaguirre's house had been demolished.

It is the sort of thing that happens every day in places where land registries are badly kept, mismanaged and/or

corrupt—which is to say across much of the world. This lack of secure property rights is an endemic source of insecurity and injustice. It also makes it harder to use a house or a piece of land as collateral, stymying investment and job creation.

Such problems seem worlds away from bitcoin, a currency based on clever cryptography which has a devoted following among mostly well-off, often anti-government and sometimes criminal geeks. But the cryptographic technology that underlies bitcoin, called the "blockchain", has applications well beyond cash and currency. It offers a way for people who do not know or trust each other to create a record of who owns what that will compel the assent of everyone concerned. It is a way of making and preserving truths.
That is why politicians seeking to clean up the Property Institute in Honduras have asked Factom, an American startup, to provide a prototype of a blockchain-based land registry. Interest in the idea has also been expressed in Greece, which has no proper land registry and where only 7% of the territory is adequately mapped.

A place in the past
Other applications for blockchain and similar "distributed ledgers" range from thwarting diamond thieves to streamlining stockmarkets: the NASDAQ exchange will soon start using a blockchain-based system to record trades in privately held companies. The Bank of England, not known for technological flights of fancy, seems electrified: distributed ledgers, it concluded in a research note late last year, are a "significant innovation" that could have "far-reaching implications" in the financial industry.

The politically minded see the blockchain reaching further than that. When co-operatives and left-wingers gathered for this year's OuiShare Fest in Paris to discuss ways that grass-roots organisations could undermine giant repositories of data like Facebook, the blockchain made it into almost every speech. Libertarians dream of a world where more and more state regulations are replaced with private contracts between individuals— contracts which blockchain-based programming would make self-enforcing.

The blockchain began life in the mind of Satoshi Nakamoto, the brilliant, pseudonymous and so far unidentified creator of bitcoin—a "purely peer-to-peer version of electronic cash", as he put it in a paper published in 2008. To work as cash, bitcoin had to be able to change hands without being diverted into the wrong account and to be incapable of being spent twice by the same person. To fulfil Mr Nakamoto's dream of a decentralised system the avoidance of such abuses had to be achieved without recourse to any trusted third party, such as the banks which stand behind conventional payment systems.

It is the blockchain that replaces this trusted third party. A database that contains the payment history of every bitcoin in circulation, the blockchain provides proof of who owns what at any given juncture. This distributed ledger is replicated on thousands of computers—bitcoin's "nodes"—around the world and is publicly available. But for all its openness it is also trustworthy and secure. This is guaranteed by the mixture of mathematical subtlety and computational brute force built into its "consensus mechanism"—the process by which the nodes agree on how to update the blockchain in the light of bitcoin transfers from one person to another.

Let us say that Alice wants to pay Bob for services rendered. Both have bitcoin "wallets"—software which accesses the blockchain rather as a browser accesses the web, but does not identify the user to the system. The transaction starts with Alice's wallet proposing that the blockchain be changed so as to show Alice's wallet a little emptier and Bob's a little fuller.
The network goes through a number of steps to confirm this change. As the proposal propagates over the network the various nodes check, by inspecting the ledger, whether Alice actually has the bitcoin she now wants to spend. If everything looks kosher, specialised nodes called miners will bundle Alice's proposal with other similarly reputable transactions to create a new block for the blockchain.

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This entails repeatedly feeding the data through a cryptographic "hash" function which boils the block down into a string of digits of a given length (see diagram). Like a lot of cryptography, this hashing is a one-way street. It is easy to go from the data to their hash; impossible to go from the hash back to the data. But though the hash does not contain the data, it is still unique to them. Change what goes into the block in any way—alter a transaction by a single digit—and the hash would be different.

Making a hash of it

INPUT

Transaction A

Any length of data

OUTPUT #A

#DFCD 24D9 AEFE 93B9

Unique hash value of fixed length

Each transaction in the set that makes up a block is fed through a program that creates an encrypted code known as the hash value.

Hash values are further combined in a system known as a Merkle Tree.

The result of all this hashing goes into the block's header, along with a hash of the previous block's header and a timestamp.

The header then becomes part of a cryptographic puzzle solved by manipulating a number called the nonce.

Once a solution is found the new block is added to the blockchain.

Transaction A → Hash value #A
Transaction B → Hash value #B
Transaction C → Hash value #C
Transaction D → Hash value #D

MERKLE TREE

Hash value #AB
Hash value #CD

Block 10 # + Combined hash value #ABCD + Timestamp / Nonce

Block 11
Block 10
Block 09
Block 08

Economist.com

Running in the shadows

That hash is put, along with some other data, into the header of the proposed block. This header then becomes the basis for an exacting mathematical puzzle which involves using the hash function yet again. This puzzle can only be solved by trial and error. Across the network, miners grind through trillions and trillions of possibilities looking for the answer. When a miner finally comes up with a solution other nodes quickly check it (that's the one-way street again: solving is hard but checking is easy), and each node that confirms the solution updates the blockchain accordingly. The hash of the header becomes the new block's identifying string, and that block is now part of the ledger. Alice's payment to Bob, and all the other transactions the block contains, are confirmed.

Assessing Out-of-State Drivers in a Road Usage Charge System: Phase 2

This puzzle stage introduces three things that add hugely to bitcoin's security. One is chance. You cannot predict which miner will solve a puzzle, and so you cannot predict who will get to update the blockchain at any given time, except in so far as it has to be one of the hard working miners, not some random interloper. This makes cheating hard.

The second addition is history. Each new header contains a hash of the previous block's header, which in turn contains a hash of the header before that, and so on and so on all the way back to the beginning. It is this concatenation that makes the blocks into a chain. Starting from all the data in the ledger it is trivial to reproduce the header for the latest block. Make a change anywhere, though—even back in one of the earliest blocks—and that changed block's header will come out different. This means that so will the next block's, and all the subsequent ones. The ledger will no longer match the latest block's identifier, and will be rejected.

Is there a way round this? Imagine that Alice changes her mind about paying Bob and tries to rewrite history so that her bitcoin stays in her wallet. If she were a competent miner she could solve the requisite puzzle and produce a new version of the blockchain. But in the time it took her to do so, the rest of the network would have lengthened the original blockchain. And nodes always work on the longest version of the blockchain there is. This rule stops the occasions when two miners find the solution almost simultaneously from causing anything more than a temporary fork in the chain. It also stops cheating. To force the system to accept her new version Alice would need to lengthen it faster than the rest of the system was lengthening the original. Short of controlling more than half the computers—known in the jargon as a "51% attack"—that should not be possible.

Dreams are sometimes catching
Leaving aside the difficulties of trying to subvert the network, there is a deeper question: why bother to be part of it at all? Because the third thing the puzzle-solving step adds is an incentive. Forging a new block creates new bitcoin. The winning miner earns 25 bitcoin, worth about $7,500 at current prices.
All this cleverness does not, in itself, make bitcoin a particularly attractive currency. Its value is unstable and unpredictable (see chart), and the total amount in circulation is deliberately limited. But the blockchain mechanism works very well. According to blockchain.info, a website that tracks such things, on an average day more than 120,000 transactions are added to the blockchain, representing about $75m exchanged. There are now 380,000 blocks; the ledger weighs in at nearly 45 gigabytes.

Bit player

Bitcoin price, $

Hash rate
Billions of hashes per second
Log scale

Source: Blockchain.info
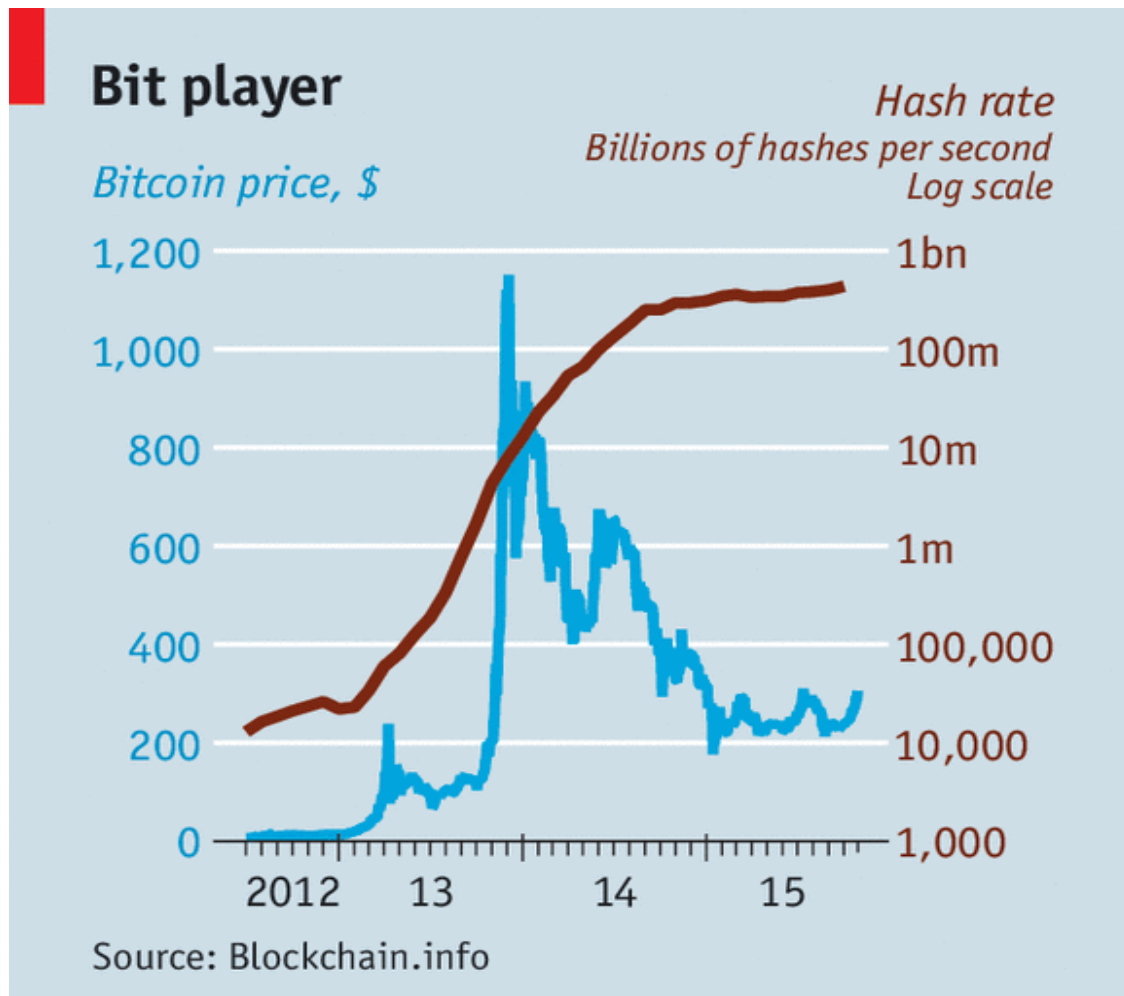
Economist.com

Most of the data in the blockchain are about bitcoin. But they do not have to be. Mr Nakamoto has built what geeks call an "open platform"—a distributed system the workings of which are open to examination and elaboration. The paragon of such platforms is the internet itself; other examples include operating systems like Android or Windows. Applications that depend on basic features of the blockchain can thus be developed without asking anybody for permission or paying anyone for the privilege. "The internet finally has a public data base," says Chris Dixon of Andreessen Horowitz, a venture-capital firm which has financed several bitcoin start-ups, including Coinbase, which provides wallets, and 21, which makes bitcoin-mining hardware for the masses.

For now blockchain-based offerings fall in three buckets. The first takes advantage of the fact that any type of asset can be transferred using the blockchain. One of the startups betting on this idea is Colu. It has developed a mechanism to "dye" very small bitcoin transactions (called "bitcoin dust") by adding extra data to them so that they can represent bonds, shares or units of precious metals.

Protecting land titles is an example of the second bucket: applications that use the blockchain as a truth machine. Bitcoin transactions can be combined with snippets of additional information which then also become embedded in the ledger. It can thus be a registry of anything worth tracking closely. Everledger uses the blockchain to protect luxury goods; for example it will stick on to the blockchain data about a stone's

distinguishing attributes, providing unchallengeable proof of its identity should it be stolen. Onename stores personal information in a way that is meant to do away with the need for passwords; CoinSpark acts as a notary. Note, though, that for these applications, unlike for pure bitcoin transactions, a certain amount of trust is required; you have to believe the intermediary will store the data accurately.

It is the third bucket that contains the most ambitious applications: "smart contracts" that execute themselves automatically under the right circumstances. Bitcoin can be "programmed" so that it only becomes available under certain conditions. One use of this ability is to defer the payment miners get for solving a puzzle until 99 more blocks have been added—which provides another incentive to keep the blockchain in good shape. Lighthouse, a project started by Mike Hearn, one of bitcoin's leading programmers, is a decentralised crowdfunding service that uses these principles. If enough money is pledged to a project it all goes through; if the target is never reached, none does. Mr Hearn says his scheme will both be cheaper than non-bitcoin competitors and also more independent, as governments will be unable to pull the plug on a project they don't like.

Energy is contagious

The advent of distributed ledgers opens up an "entirely new quadrant of possibilities", in the words of Albert Wenger of USV, a New York venture firm that has invested in startups such as OpenBazaar, a middleman-free peer-to-peer marketplace. But for all that the blockchain is open and exciting, sceptics argue that its security may yet be fallible and its procedures may not scale. What works for bitcoin and a few niche applications may be unable to support thousands of different services with millions of users.

Though Mr Nakamoto's subtle design has so far proved impregnable, academic researchers have identified tactics that might allow a sneaky and well financed miner to compromise the block chain without direct control of 51% of it. And getting control of an appreciable fraction of the network's resources looks less unlikely than it used to. Once the purview of hobbyists, bitcoin mining is now dominated by large "pools", in which small miners share their efforts and rewards, and the operators of big data centres, many based in areas of China, such as Inner Mongolia, where electricity is cheap.

Another worry is the impact on the environment. With no other way to establish the bona fides of miners, the bitcoin architecture forces them to do a lot of hard computing; this "proof of work", without which there can be no reward, insures that all concerned have skin in the game. But it adds up to a lot of otherwise pointless computing. According to blockchain.info the network's miners are now trying 450 thousand trillion solutions per second. And every calculation takes energy.

Because miners keep details of their hardware secret, nobody really knows how much power the network consumes. If everyone were using the most efficient hardware, its annual electricity usage might be about two terawatt-hours—a bit more than the amount used by the 150,000 inhabitants of King's County in California's Central Valley. Make really pessimistic assumptions about the miners' efficiency, though, and you can get the figure up to 40 terawatt-hours, almost two-thirds of what the 10m people in Los Angeles County get through. That surely overstates the problem; still, the more widely people use bitcoin, the worse the waste could get.

Yet for all this profligacy bitcoin remains limited. Because Mr Nakamoto decided to cap the size of a block at one megabyte, or about 1,400 transactions, it can handle only around seven transactions per second, compared to the 1,736 a second Visa handles in America. Blocks could be made bigger; but bigger blocks would take longer to propagate through the network, worsening the risks of forking.

Earlier platforms have surmounted similar problems. When millions went online after the invention of the web browser in the 1990s pundits predicted the internet would grind to a standstill: *eppur si muove*. Similarly, the bitcoin system is not standing still. Specialised mining computers can be very energy efficient, and less energy-hungry alternatives to the proof-of-work mechanism have been proposed. Developers are also working on an

add-on called "Lightning" which would handle large numbers of smaller transactions outside the blockchain. Faster connections will let bigger blocks propagate as quickly as small ones used to.

The problem is not so much a lack of fixes. It is that the network's "bitcoin improvement process" makes it hard to choose one. Change requires community-wide agreement, and these are not people to whom consensus comes easily. Consider the civil war being waged over the size of blocks. One camp frets that quickly increasing the block size will lead to further concentration in the mining industry and turn bitcoin into more of a conventional payment processor. The other side argues that the system could crash as early as next year if nothing is done, with transactions taking hours.

A break in the battle

Mr Hearn and Gavin Andresen, another bitcoin grandee, are leaders of the big-block camp. They have called on mining firms to install a new version of bitcoin which supports a much bigger block size. Some miners who do, though, appear to be suffering cyber-attacks. And in what seems a concerted effort to show the need for, or the dangers of, such an upgrade, the system is being driven to its limits by vast numbers of tiny transactions. This has all given new momentum to efforts to build an alternative to the bitcoin blockchain, one that might be optimised for the storing of distributed ledgers rather than for the running of a cryptocurrency. MultiChain, a build-your-own-blockchain platform offered by Coin Sciences, another startup, demonstrates what is possible. As well as offering the wherewithal to build a public blockchain like bitcoin's, it can also be used to build private chains open only to vetted users. If all the users start off trusted the need for mining and proof-of-work is reduced or eliminated, and a currency attached to the ledger becomes an optional extra.

The first industry to adopt such sons of blockchain may well be the one whose failings originally inspired Mr Nakamoto: finance. In recent months there has been a rush of bankerly enthusiasm for private blockchains as a way of keeping tamper-proof ledgers. One of the reasons, irony of ironies, is that this technology born of anti-government libertarianism could make it easier for the banks to comply with regulatory requirements on knowing their customers and anti-money-laundering rules. But there is a deeper appeal.

Industrial historians point out that new powers often become available long before the processes that best use them are developed. When electric motors were first developed they were deployed like the big hulking steam engines that came before them. It took decades for manufacturers to see that lots of decentralised electric motors could reorganise every aspect of the way they made things. In its report on digital currencies, the Bank of England sees something similar afoot in the financial sector. Thanks to cheap computing financial firms have digitised their inner workings; but they have not yet changed their organisations to match. Payment systems are mostly still centralised: transfers are cleared through the central bank. When financial firms do business with each other, the hard work of synchronising their internal ledgers can take several days, which ties up capital and increases risk.

Distributed ledgers that settle transactions in minutes or seconds could go a long way to solving such problems and fulfilling the greater promise of digitised banking. They could also save banks a lot of money: according to Santander, a bank, by 2022 such ledgers could cut the industry's bills by up to $20 billion a year. Vendors still need to prove that they could deal with the far-higher-than-bitcoin transaction rates that would be involved; but big banks are already pushing for standards to shape the emerging technology. One of them, UBS, has proposed the creation of a standard "settlement coin". The first order of business for R3 CEV, a blockchain startup in which UBS has invested alongside Goldman Sachs, JPMorgan and 22 other banks, is to develop a standardised architecture for private ledgers.

The banks' problems are not unique. All sorts of companies and public bodies suffer from hard-to-maintain and often incompatible databases and the high transaction costs of getting them to talk to each other. This is the

problem Ethereum, arguably the most ambitious distributed-ledger project, wants to solve. The brainchild of Vitalik Buterin, a 21-year-old Canadian programming prodigy, Ethereum's distributed ledger can deal with more data than bitcoin's can. And it comes with a programming language that allows users to write more sophisticated smart contracts, thus creating invoices that pay themselves when a shipment arrives or share certificates which automatically send their owners dividends if profits reach a certain level. Such cleverness, Mr Buterin hopes, will allow the formation of "decentralised autonomous organisations"—virtual companies that are basically just sets of rules running on Ethereum's blockchain.

David Parkins

One of the areas where such ideas could have radical effects is in the "internet of things"—a network of billions of previously mute everyday objects such as fridges, doorstops and lawn sprinklers. A recent report from IBM entitled "Device Democracy" argues that it would be impossible to keep track of and manage these billions of devices centrally, and unwise to to try; such attempts would make them vulnerable to hacking attacks and government surveillance. Distributed registers seem a good alternative.

The sort of programmability Ethereum offers does not just allow people's property to be tracked and registered. It allows it to be used in new sorts of ways. Thus a car-key embedded in the Ethereum blockchain could be sold or rented out in all manner of rule-based ways, enabling new peer-to-peer schemes for renting or sharing cars. Further out, some talk of using the technology to make by-then-self-driving cars self-owning, to boot. Such vehicles could stash away some of the digital money they make from renting out their keys to pay for fuel, repairs and parking spaces, all according to preprogrammed rules.

What would Rousseau have said?
Unsurprisingly, some think such schemes overly ambitious. Ethereum's first ("genesis") block was only mined in August and, though there is a little ecosystem of start-ups clustered around it, Mr Buterin admitted in a recent blog post that it is somewhat short of cash. But the details of which particular blockchains end up flourishing matter much less than the broad enthusiasm for distributed ledgers that is leading both start-ups and giant incumbents to examine their potential. Despite society's inexhaustible ability to laugh at accountants, the workings of ledgers really do matter.

Today's world is deeply dependent on double-entry book-keeping. Its standardised system of recording debits and credits is central to any attempt to understand a company's financial position. Whether modern capitalism absolutely required such book-keeping in order to develop, as Werner Sombart, a German sociologist, claimed

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in the early 20th century, is open to question. Though the system began among the merchants of renaissance Italy, which offers an interesting coincidence of timing, it spread round the world much more slowly than capitalism did, becoming widely used only in the late 19th century. But there is no question that the technique is of fundamental importance not just as a record of what a company does, but as a way of defining what one can be.

Ledgers that no longer need to be maintained by a company—or a government—may in time spur new changes in how companies and governments work, in what is expected of them and in what can be done without them. A realisation that systems without centralised record-keeping can be just as trustworthy as those that have them may bring radical change.

Such ideas can expect some eye-rolling—blockchains are still a novelty applicable only in a few niches, and the doubts as to how far they can spread and scale up may prove well founded. They can also expect resistance. Some of bitcoin's critics have always seen it as the latest techy attempt to spread a "Californian ideology" which promises salvation through technology-induced decentralisation while ignoring and obfuscating the realities of power—and happily concentrating vast wealth in the hands of an elite. The idea of making trust a matter of coding, rather than of democratic politics, legitimacy and accountability, is not necessarily an appealing or empowering one.

At the same time, a world with record-keeping mathematically immune to manipulation would have many benefits. Evicted Ms Izaguirre would be better off; so would many others in many other settings. If blockchains have a fundamental paradox, it is this: by offering a way of setting the past and present in cryptographic stone, they could make the future a very different place.