Preface

This report addresses a market based method to achieve a comprehensive approach to electronic road usage charging in the State of Oregon and interoperability within the State and the surrounding region.

This report is produced on the initiative of the Oregon Department of Transportation (ODOT). It aims to satisfy a seamless integration with existing intelligent transportation systems (ITS) and future road usage charging (RUC). ODOT is addressing road usage charging in the context of tolling, high occupancy toll (HOT) lanes, improvements to its mass-distance truck charging, and replacement of the fuel excise tax for part or all of the fleet. These services are only part of the integrated ITS plan orchestrated by ODOT.

The “User Pays” principle is constitutionally established in the State for fair and equitable funding of Oregon’s transportation infrastructure. In order to create an integrated and interoperable system that takes into consideration the needs of all parties, the road usage charging system is being developed in cooperation with authorities, users and industry partners. The project has been established to help coordination and preparation of a comprehensive, efficient, reliable and sustainable implementation of a road usage charging system in Oregon.

This report explores a potential “Open System Architecture Model” (OSAM) solution and incorporates a functional description of the actors and how they interrelate. The aim is to produce an understanding and framework which RUC can thrive and interoperate in a highly efficacious manner providing user choice, seamless integration, efficiency, cost effectiveness and economy of scale. The concepts employed in the model and system should also benefit the economy in general and enhance the acceptance of the concepts with all the stakeholders. Interoperability is established with the OSAM both within Oregon and region including the adjacent states of Washington and California.

With a sound and judicial framework, this general description will evolve into further definition of the various links and common standards available to ensure the results predicted in this report. The linkages referenced are not only internal to the OSAM presented herein, but to the ITS architecture, whether in place or planned. The synergy of the net effect of the whole will therefore be greater than the sum of any single component.

March 2014 - ODOT NOTE: The document provided here is a concept document that uses a toll collection system and tolling infrastructure as a basis for a Road Usage Charge system. Those with a background in tolling will appreciate the correlation of the concepts and advantages noted as options of using a foundation of existing toll systems for a RUC system.

Presently, ODOT has moved beyond a toll collection system as a baseline for setting up a RUC system and has advanced its vision into using on board Mileage Reporting Devices and telematics some of which are GPS enabled. Please explore the other ODOT RUC documentation for more detail on current RUC Program objectives and system architecture.
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The market for electronic road usage charging (RUC) has not on its own established any comprehensive regional or national interoperability between different charging systems. The USDOT and FHWA see any further fragmentation of the market as increasing the difficulties to reach their vision of interoperability. The State of Oregon, through the Oregon Transportation Commission consequently issued a policy directive dated December 12, 2006 aimed at harmonizing the technologies and procedures employed in electronic fee collection.

Furthermore, the policy directives to ODOT by statute mandate that the technology employed and system operations should be:

- Reliable
- Easy for motorist use
- Be enforceable
- Have low capital costs; and
- Have low relative operating costs.

The Oregon legislative policy body formed to address transportation funding alternatives, the Road Use Fee Task Force (RUFTF), augmented these directives to further stipulate that the system should:

- Not charge out-of-state travel
- Protect motorist privacy
- Provide gas tax credit
- Seamlessly transition
- Minimize private sector burden
- Allow congestion pricing; and
- Allow local options.

The new implementation vision for RUC elaborated on the above directives with four objectives for future electronic road pricing and charges that may replace the existing state fuel tax for part or all of the fleet of Oregon registered vehicles. The objectives presented were:

1. An open system technology platform with common standards that allow on-board unit technology to evolve
2. No government requirement for an on-board unit with vehicle location technology
3. Tap into market forces to provide data collection and payment services
4. Provide “user choice” for:
   - Means by which the user reports mileage
   - On-board technology to suit user needs
   - Method of invoicing and payment
The purpose of this report is to provide a general operating description to address the above directives and on-going ITS harmonization efforts within the State of Oregon with a market based approach. The report aims at answering the question: How should the road usage charging market be structured in order to maximize market dynamics and create strong incentives for the actors to solve the issue of interoperability in an open system architecture?

In answering this question, two different models are outlined for comparison, one regarding a closed system architecture and one outlining an open system architecture. The difference between them indicates the degree of user choice and the market dynamics.

In the first model, aimed mainly at domains with electronic tolling systems using either Dedicated Short Range Communication (DSRC) transponders, (more commonly referred to as “tags”), a strict and ridged structure exists. In this model, the “actors” are the road user, the road or facilities (bridge, tunnel, etc.) and the toll charger (toll agency, concessionaire, DOT). In this closed system, if the road user wishes to use the road facilities, the road user must pay and follow the account processing rules set by the toll charger. The road user has no choice or options: if the road user wants to use the road facilities then the road user must comply with the rates charged and the account processing rules set by the toll charger. In effect, it is a monopolistic model. Typically, the toll rates are set and monitored by a higher authority or established by law, but the business rules and processing of the revenue collected by manual, electronic or video means are done by the sole discretion of the toll charger. This is defined as a “closed system model” where an internally integrated system is controlled by a single entity with essential components that cannot be substituted by other external components that perform identical functions. A simplified diagram of this model is seen in figure 1 below.

![Closed System Model Diagram](image)

**Figure 1: Closed System Model**

The second model introduces a new actor, the Trusted Third Party Service Provider (TSP). In this model, the separation between toll charger and service providers is proposed. This is similar to the split between providers of infrastructure and services, which has become popular in markets such as electricity and railroads. The purpose is to isolate a natural monopoly, which is the toll charger’s operation, and to open the remainder of the industry for continuous competition. This way the road users become customers rather than recipients of transportation services. While the toll charger normally is responsible for the road and facilities, the toll charger has an agreement with the TSPs for the collection and reconciliation of transactions generated by road users. Because there is more than one TSP, the user has a choice to contract with any one of several TSPs and switch freely between them.

The TSPs discriminate their services by offering various value-added services that appeal to the road user which drives the creation of an efficient and competitive market place rather than a monopoly. The toll charger still sets the rates for the toll but separates the base toll rate from the toll charged,
which may include embedded service fees or percentage of fees for the service provider. Because of the need to interoperate between the toll charger, the road facilities and the service providers, common standards and interoperable products are necessary in this model to assist the service providers to procure, install, maintain and service their road usage clients with on-board units that can be read by the road facilities, create transactions, direct the proper transactions to the appropriate service provider and reconcile between the toll charger and the service provider.

The definition therefore of an “open system model” is an integrated system based on common standards and an operating system with unencumbered access to the marketplace whereby components performing the same function can be readily substituted or provided by multiple providers. The open system model has characteristics similar to the internet. A simplified diagram of the open system model is depicted in figure 2 below.

![Figure 2: Open System Model](image)

Another aspect of the open system model is the handling of exempt, special or bad accounts. This is shown in the center of the graphic and is a logical extension of the open system model.

In every case, the entire set of road users will be paying customers and exempt users. Exempt users are typically public service vehicles (Police, fire, emergency services, etc.) and others legally exempted from paying any tolls or road usage charge fees. The distribution and outfitting of this subset of the fleet will typically be the responsibility of the toll charger. In addition, there may be individual road users who cannot qualify for the service plans offered by the TSPs. There may be other road users who default their obligations to one or all the service providers. In these cases, and where the road user elects or chooses to have their account handled by the toll charger, the toll charger will, by exception handle the account. Due to the nature of these accounts, they are anticipated to be debit accounts where the road user must pre-pay and maintain a positive balance while usage through transactions are deducted from the running balance. Since it is anticipated that TSPs will offer post-payment for usage and services, just like any credit card, utility or other commercial accounts, the distinction between the two entities providing accounting services are distinct. The financial arrangement guarantees the toll charger the revenue due and the risk for collection is taken by the TSP who is better positioned to ensure payment based on the breath of services and value added to the road user. Furthermore, the handling of these accounts provides a
good basis of comparison and measurement of efficiency between the two distinct account holders and provides a running test against a common baseline.

In the second model, a suggestion is laid out for how autonomous systems can be organized differently compared to traditional road usage charging and tolling based systems historically used in the transportation marketplace. This is also based on the observation that the different technologies create different market conditions and value-added propositions to entice road users. The suggestion consists of market principles observed and feedback from earlier pilot studies. Offering the end user a real choice between service providers, and service providers with a real choice as to the design of their systems, a more publicly acceptable system can be established.

In at least three areas these models challenge the existing status quo in the marketplace:

1. **Actors and roles:** In the directives and implementation vision of RUC, a role model is used where distinction is made between the responsibilities of the end user, toll service provider and toll charger. There is nothing preventing the combination of the roles of toll charger and toll service provider in one organizational body. This report claims that requiring a strict separation between these roles cultivates competition, efficiency and gives the actors strong incentives to establish interoperability as a norm for operations.

2. **Harmonization of methods for measuring and reporting:** The directives and implementation vision of RUC are attempting to establish interoperability partly by harmonizing the technologies and procedures used, both for all technology options and for autonomous systems. This report claims that when it comes to autonomous systems, regulating the technical solution is not only unnecessary, but even harmful to the market by standardizing a technical solution on a single vendor’s product, thus creating a monopoly and restricting the free market implementation of other services and ITS solutions. The monopolistic tendency of suppliers has shown time and again to offer poor value and higher costs to all actors in the system over time.

3. **Design of the control system.** In the directives and implementation vision of RUC, a framework for a common transaction is laid out for all road usage charging applications. Currently, road usage fees in neighboring states Washington and California are based on the interface for short range communication of the on-board unit. This report argues that for autonomous systems, identifying this communication link as broadly as possible and avoiding mandatory and detailed interaction with existing on-board units in the western region is of more harm than benefit, as it is limiting the toll service provider’s right to design his service in an optimal way. The toll charger can provide multi-protocol readers and create an interoperable environment with other states while providing the service providers the greatest possible flexibility, efficiency and effectiveness at a lower cost by other means. If the toll charger is hesitant or opposed to the installation of multi-protocol readers for interoperability, the service providers can assist the toll charger with the multi-protocol readers and negotiate a higher transaction fee to cover their investment.

2 - **Background**

The US market for electronic RUC has historically been characterized by large contracts, where government agencies and, more recently, private road owners sign wide-ranging deals for system construction and operation with a single contractor. In more recent years, these contracts have sometimes been split between the system construction of the lane level and roadside infrastructure specialized equipment and the computerized back office system which consists of the transaction processing computer equipment, the call center, customer service center, traffic management control center and the accounting/receivables/reconciliation system. A small number of top tier
system integrators and equipment manufacturers compete intensively during the procurement phase, after which one of the bidders signs a contract for operation typically ranging from 5 to 20 years.

These procurements, depending on size of the system, have ranged from $3 million to $25 million. Suppliers of the equipment have tended to lock-in their clients with proprietary hardware and software, which they rigorously defend by the judicial process using intellectual property laws to prevent encroachment by any means by their competitors. Interoperability exists to some extent on a regional basis, but as an exception rather than a rule seen over the entire North American marketplace. In many cases, the government agencies tasked to run the tolling or road usage charging facilities procure separately and tend to procure what they consider the best deal for themselves without regard for other usage charging facilities in the state or region. In historical hindsight, many times there were no other facilities but as tolling and road usage charging have become more of a mainstay for financing infrastructure, later entities were forced to propagate the selection of the previous proprietary systems. Today, that same cycle perpetuates itself and regional differences balkanize the North American marketplace. Figure 3 shows the regional variations of proprietary systems across the continent.

From an end user point of view, the RUC industry consists of a set of local monopolies rather than a real market. As a vehicle owner and road user, one has typically no alternative other than using the services offered by the supplier contracted by the road owner. Despite US DOT and FHWA initiatives under the past appropriations bill for interoperability, little to nothing has been accomplished at the federal level to create a national interoperable service. The International Bridge, Tunnel and Turnpike Association (IBTTA), the professional group representing the industry, has conducted several conferences dedicated to the subject and currently has a running committee formed to study the issue, but there is little resolve in the organization to change the status quo. Equipment suppliers and vendors are also happy to spend lobby efforts to protect their current market and fight strenuously to protect their current fiefdoms in the marketplace. Under current circumstances, the historic market players simply do not have strong enough incentives of their own to overcome the challenges involved and establish interoperability between each other.

Figure 3: USA EFC map indicating the balkanization of the market with proprietary systems
This report deals with the issue of how the market circumstances can be changed, in such a way that the actors themselves choose to introduce interoperability, because it is in their interest to do so.

As a part of stated directives and vision, Oregon has signed up to the ambitious goal that it will become a more competitive and dynamic energy and knowledge economy in the USA. For the RUC industry, at least three goals can be derived from this commitment and strategy.

1. In order for the transportation industry to operate effectively and compete fairly, any system for electronic road usage charging must be simple, interoperable and cost effective for the end users.

2. Among TSPs there must be a real and ongoing competition throughout the entire operational period, with a responsibility not only to ODOT as the toll chargers but also to road users. New entrants from other industries must have a perceived and real possibility to establish themselves in an open market.

3. Innovation must be encouraged among equipment manufacturers, with incentives for continuous improvement of the solutions offered, not only for the toll charger and service providers, but also for the end user. The continual upgrade and improvement of integrated services to the road user, much like the “App Store” for smart phones, has to provide value added services to meet the emerging and growing needs of the road users.

This set of goals is wider compared to what has effectively been the case stated by other RUC agencies, state DOT’s or FHWA traditionally. Priorities of the road owners have been dominating the market, because they have procured the systems and services which today make up the industry.

If the market can be changed so that the road users are transformed from involuntary recipients of a system into customers with a real choice between competing alternatives, then suppliers will find it in their interest to provide their customers with interoperable services, even if this is not a legally binding requirement.

3 - Road Usage Charging Overview

The functional description sets out a high level description of the major functions of a Road Usage Charge (RUC) system and develops these into a high level functional design. This provides a full breakdown of the RUC processes and procedures, in an architecture to handle all customer or user requirements, accounting, reconciliation, billing, and handling of on-board units (OBU) and/or image based transactions. The design identifies the required communication interfaces and associated technical requirements. The required interfaces to external systems and architectures are also identified. Network management and testing/monitoring of roadside equipment (RSE) and on-board unit (OBU) inventory and handling will also form part of the functional design. To be noted is that the functional design is largely independent of the procurement method and the broader commercial model adopted for the delivery of the RUC system.

This report sets out a number of commercial and procurement alternatives that may be appropriate for the delivery of a RUC System. In order to progress from the functional design to a functional specification and tender documents that can be taken to market, it will be necessary to refine these alternatives to a preferred procurement strategy. This will require a number of decisions to be made by ODOT in consultation with the various project stakeholders. These decisions will need to be made in relation to a number of key areas including:
Ownership – Who will have responsibility for owning and operating the RUC system and where the ownership boundaries lie in relation to other systems with which the RUC system must be integrated?

Procurement – Who will manage the procurement of the RUC system and the general strategy and philosophy to be adopted e.g. the degree of contracting out and private sector responsibility, if any, for ownership and operation?

Scope of Supply – Where will the interfaces between existing systems and the new RUC system be set, in particular the extent to which it will use existing infrastructure and platforms from ODOT, police and courts such as the department that registers motor vehicles, TSPs, communication networks, call centers and so forth?

3.1 Foundation and General Requirements

A major element underlying the production of this report is the development of various directives, objectives and principles into tangible (at this stage functional) requirements. The intent is to ensure that the legislative and policy requirements, guidelines and potential options are thoroughly described early in the project to act as filters for the development of process and technology options and an overall ITS functional design.

Under the legislative dictates, revenue from a RUC system is dedicated revenue for transportation purposes only, which includes:

- planning,
- design,
- supervision,
- construction,
- maintenance, or
- operation of a new infrastructure.

The main drivers in terms of functional design are the need to provide alternative methods of payment, the need to provide a method of payment that does not require storage of personal information, and the ability to impose administration charges.

3.2 High Level Functional Description

As with all processes, it is possible to break the whole down into its constituent parts. The RUC system is no different. From a high level, the RUC system can be seen as a having two major components. These are the Roadside Equipment (RSE) and Back Office Computer System (BOCS) which, in an open system architecture, may be a fully capable BOCS or a transaction processing center (TPC) with links to TSPs who have BOCS capabilities. For ease of understanding, this document will address the BOCS as a single entity.
These functional components are shown together in Figure 4, the functional model of the RUC system as it could be implemented under a typical tolling scenario that uses Road Side Equipment (RSE).¹

Figure 4: High Level RUC Functional Components

The BOCS is the heart of the RUC system. All internal and external interfaces are managed by this component. Customer interfaces, either direct or through an agent network account, pass through or are set up and maintained by this component. All RUC data is collected, processed, managed and reconciled by this component. All audits, data and revenue reporting, statistical reporting and supporting activities such as on board unit (OBU) maintenance are coordinated by this component. The determination of net revenue is calculated by this component, as is the distribution of revenues to the Road Controlling Authority (RCAs) or private toll road operators, if they exist.

In the absence of cash collection, the preferred method of RUC administration is to establish accounts in advance and equip vehicles with OBUs. Vehicle and account information is collected from tags or devices by roadside equipment. RUC transaction records are created for each vehicle passing under the gantry. Variations for road use include license plate number recognition, infrequent user accounts and unregistered vehicles. In all cases, RUC transactions are recorded against a RUC account.

While there is one BOCS envisaged for the entire state, there may be any number of road usage charging applications owned by ODOT, local jurisdictions or private operators. Each road charging application would be equipped with its own set of Road Side Equipment (RSE)². The RSE would be tailored to meet the specific requirements of the facility or operators. The RSE must be fully automated fee collection systems with dedicated communication links to the BOCS.

¹ This text uses the terms fee, toll and charge interchangeably, regardless of whether the fee levied is based per passage, per visit, or per mile.

² Or cloud services in the case where the cloud is used instead of RSE.
3.3 Charging Components

Notwithstanding, the key to a successful implementation is a well-designed and sensitively implemented program of public information and consultation to demonstrate that RUC provides benefits to the community at large and to road users in particular. Such a program will need to include a clear communication of the makeup of the charge. The charge conceptually has up to four major components:

- base charge
- collection charge
- demand management charge
- environmental charge

The combined charge or fees equate to the amount the user pays. In this way, the road user will understand the components in the total charge and any discounts between RUC products. This understanding will assist road users to make more informed driving decisions and motivate the road users to select more cost effective RUC products over others.

![Charging Components Diagram](image)

Figure 5: Components of a Road Usage Charge

The decision to implement multi-lane free flow tolling focuses the direction on defining parameters for system design to achieve the RUC process envisaged in the directives as well as achieving the RUC designs addressed above. Since there will be no manual toll collection, all revenue must be either collected electronically or through image based tolling. The shape of the system architecture to support multi-lane tolling is therefore determined.

The RUC communication system is the glue that binds all the components of the RUC functional design description together both internally and externally. Selecting the correct voice and data telecommunications infrastructure and architecture is critical to the success of this RUC System and provides all of the communications flow between sub-systems, internal staff, external agencies and

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the general public. A dedicated communications system will be required to service the operational requirements of the RUC project.

3.4 Functional Description: Roadside Equipment

The proposed tolling for ODOT is a highly automated Electronic Fee Collection (EFC) System that allows charging at highway speeds without vehicles being required to stop or slow down.

The major equipment included in this component of the work includes gantries, gantry-mounted sensors and a roadside controller (computer). The system will also include software to support the road project requirements and will download data transaction records in a format required by the Back Office Computer System.

A diagram of the RSE and its functionality is displayed in figure 6 below:

![Figure 6: Roadside equipment functionality and Interfaces](image)

The four major components required in the field are:

- OBU Reader/Writer and OBU Tracking (Localization) System (EFC Reader);
- Vehicle Detection and Classification (VDC) and Vehicle Tracking system, which uses overhead sensors to determine the type of vehicle so that the proper toll can be charged;
• Image Based Tolling (IBT), which refers to the various components to capture images of the license plates (front and or Front and rear) of vehicles that use the facility without a valid OBU so that the owners can be identified and notified that a toll is due; and

• Physical support structures over the roadway. Note that any facilities installed over roadways must be shown to meet ODOT safety requirements.

These components are supported by the OBU, which is the electronic unit that the road user installs in the vehicle. Although the OBU is not strictly RSE, it is shown as part of the RSE for the purposes of demonstrating its functionality.

A separate vehicle detection, counting and classification system will be installed at the gantry areas. This equipment operates independently of the gantry system and is expected to be a digital loop system installed in the area below the toll gantries. This sub system will record vehicle counts and vehicle classifications. This system will have a separate server and communicate directly with the BOCS and Trusted Third Party Service Providers for reconciliation and accountability.

Nevertheless, various choices remain within the within the RSE technology framework, including multiple vendors for various commercially available configurations. Therefore, the framework provides ODOT with a competitive environment, in which to obtain best quality and price considerations.

The functional design must also address the process of how to handle a range of RUC projects that may or may not be used on current and future toll charging schemes. To make the Functional Design as flexible as possible, it must consider all the potential RUC project designs where the fee structure presented above in Section 3.3 may be charged or combined into a RUC transaction for handling in the system. The fee basis is the “unit of charge” and determines when the processing of a fee calculation may occur. The table below summarizes the possible fee basis for an integrated system.

<table>
<thead>
<tr>
<th>Charge Basis</th>
<th>Processing Occurs When</th>
<th>Rationale for RUC Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gantry</td>
<td>Gantry is known</td>
<td>Supports open tolling architecture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supports distance based charging where distance is applied per road segment.</td>
</tr>
<tr>
<td>Distance</td>
<td>Distance is known</td>
<td>Support RUC specific architectures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Support future VMT based transactions</td>
</tr>
<tr>
<td>Trip</td>
<td>Trip is complete</td>
<td>Support a grouping of gantries into a single trip and application of a trip charge rather than a charge per gantry for EFC transactions.</td>
</tr>
<tr>
<td>Duration</td>
<td>Time Duration is known</td>
<td>Support expansion to future products such as road pricing or traveler demand management where charges vary per time period (e.g. peak period charging, variable tolls or “value pricing”) or a single charge is made no matter how many gantries or how much of the road network is used (such as using OBU and/or video identification for entry/exit charging for parking, recreation areas, state parks, etc)</td>
</tr>
</tbody>
</table>
Table 1: RUC possible alternate charging methods

The above RUC designs may be used by ODOT or private operators in the future to provide the packaging of fees for fair, convenient, flexible and reliable transactions that are acceptable to the public. One project design may not fit all future RUC schemes in Oregon or gain public acceptance. The functional design must consider the flexibility of the process above if it is to be future proof.

Payment methods must also be established to meet all the future project designs and provide road users with a product and payment means to adapt to their use of the RUC facilities and not the other way around.

Finally, the architecture must be capable of supporting the above RUC schemes in an efficient, reliable and automated manner. The automation is necessary to eliminate future price escalations by over reliance on human intervention or handling of transactions by operations personnel. The reliability ensures that the functional design can operate with the lowest possible operational and maintenance costs. The efficiency to handle the above schemes is necessary to achieve the lowest possible transaction cost.

3.5 Back Office Computer System Description

The BOCS is the central component of the toll system. The system will be designed to expand for future toll road schemes, future methods of toll collection, future electronic collection systems and uses as desired by ODOT and stakeholders. Expandability, flexibility and future proofing will be built into the BOCS design process to ensure the lowest long term transaction cost based on the commercial and procurement method selected.

To this end, the BOCS functional design process will include but will not be limited to:

- Account creation and maintenance;
- Road usage and customer data collection and processing;
- Reconciliation and audit of road usage data and revenue collection and distribution;
- Financial data processing and statistical reporting;
- Administrative and operational support activities.

An illustration of the BOCS is shown in figure 7 below.
In the absence of cash collection, the preferred method of road use/payment is for the users to establish accounts in advance and equip their vehicles with OBUs. Vehicle and toll account information will be collected from the OBUs by roadside equipment and toll transaction records will be created for each vehicle passing under the gantry.

Vehicles without an OBU or with an invalid OBU will have their image captured and the BOCS will use the vehicles License Plate Number (LPN) as means of identification and revenue collection. These users may be registered as infrequent users (with accounts) or not registered users (without accounts). In all cases, toll transactions are recorded against an LPN based toll account.

- Major EFC functions undertaken by the BOCS include:
  - Process transaction data;
  - Process images and match with accounts or establish new accounts;
  - Reconcile vehicle and classification data;
  - Revenue Collection;
  - Debt Collection;

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3 This section describes a tolling scenario using roadside equipment. For RUC, data will be gathered and stored using cloud-based servers, not roadside equipment.
• Customer Services;

• Administration & Operations.

Toll account products may be customized to accommodate the needs of customers. Frequent users who wish to use the road for the lowest possible cost will select an OBU account. Commercial companies may want to monitor usage by vehicle. Non-revenue users can avoid enforcement issues and simplify their toll road usage by use of an OBU. Private accounts can remain anonymous by use of an account with an OBU that is not associated with a LPN.

The system will support communications with financial institutions, mobile phone agents and others. Electronic payment from all customers or agents is preferred, but the system will support the following methods of payment:

• cash
• check
• money order
• bank and electronic check
• credit card
• electronic funds transfer

The system will also enable debtors to post-pay for use of the toll road. In doing so the system will ensure that:

• Toll charges recorded against exempt users are not enforced;
• Debtors have been given opportunity to make payment prior to being enforced;
• The regulatory requirements for bank transfer processing have been met.

3.6 Back Office IT and Communication Systems Description

The Toll Processing Center (TPC) will house a number of systems for the operation and monitoring of the toll roads. It is proposed that all of the systems within the TPC communicate via a common network infrastructure based on IP Converged technology. Modern information systems rely on the ability to generate, store, retrieve and transfer data electronically, efficiently and reliably. Selecting the correct back office systems is critical to the success of this toll system project and provides all of the operational monitoring and processing of the system. Figure 8 shows the perspectives that will need to be considered when developing the IT architecture.

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4 In this case, the OBU is associated with a Vehicle Identification Number (VIN).
**Functional Perspective**

The functional perspective covers what the overall business functionality that the architecture needs to support. For example, what are the prioritized business requirements and how can technology effectively support them?

**Systems Perspective**

The systems perspective covers what components need to be assembled. For example, what are the components, where will they be used, and how will they interact with each other?

**Platform Perspective**

The platform perspective covers what specific underlying technology will be used. For example, what technology is needed to allow the systems to deliver the desired business functionality?

Within the TPC there are a range of services, which may not be physically located in the same building. An IP Converged (IPC) network is one that has the ability to carry data, voice and video traffic over a single network infrastructure and overcome these constraints. In physical terms the convergence is the data network enhanced to carry real time voice and video with the existing traditional voice networks becoming redundant. IP telephony and IP contact center systems have now gathered considerable momentum in the industry such that shipments of IP enabled Private Branch Exchange (PBXs) exceeded those of traditional systems.

It is intended that the system will provide sufficient storage capacity for “steady state operation” of the system as forecast in the 10th year of operation. The system architecture will be demonstrated to scale up to an expanded configuration that achieves the following performance requirements:

- An expanded system will be demonstrated to process 100% of the benchmark load in no more than 2/3 of the benchmark time.
• An expanded system will be demonstrated to process 150% of the benchmark roadside load (and 100% of other benchmark loads) in no more than the benchmark time.

• The expanded system architecture may comprise a combination of the deliverable hardware with non-deliverable hardware, so long as all components are commercially available and supported by the vendor of the main system.

A significant number of system interfaces will be required to pull together all of the components of the system. A number of design decisions are required around how the system will integrate with the internal and external systems. Therefore, it is likely that a large percentage of the system implementation costs will be spent on application integration development.

3.7 General Operations

There are a number of internal support processes that must occur to ensure the efficient running of the system. While these are indirect processes that are largely not technology focused, the infrastructure for them (e.g. managing the agent network contractual arrangements) is considerable and must be considered in terms of the total delivery cost of the solution. These processes are:

• Agent network contractual arrangements
• Public information
• Public relations
• Legislative and policy framework
• Monitoring and evaluation
• Maintenance.

The primary inputs to deliver these internal processes are likely to be human resource and organizational development costs.

4 - The Market Model for RUC Based Systems

4.1 Roles

Within the RUC industry, a model has been developed throughout the years, describing the different roles an actor can take in the market. The three main roles of the model are: the Road User, who can be a private motorist or a truck freight company. It is the Road User who is ultimately liable to pay for the road usage in a “user pays” model. A Road User can have an account with a RUC Service Provider (SP), who might provide the Road User with a transponder or device, the on-board unit (OBU). The SP actor also collects payments from the user, for example by invoice, based on a road usage specification sent from the Toll Charger (TC). These payments are typically pre-paid and actual trips are debited from the account that is matched to the Road User. The TC owns and manages both the road and the roadside equipment (RSE), which reads the OBU as the Road User drives past the readers. The created transaction is automatically communicated to a Back Office System (BOS) that aggregates the transactions and then matches the transactions to an account for debiting and account management.

In this generalized case, which is industry norm, each toll road typically runs its own system. In other words, the RSE and the BOS used on the actual toll road are owned and operated by the Road Owner (RO). The Road Owner acts as the TC in setting the rates and business rules that are implemented by
the SP. Hence the model is a “closed model” and a depiction of its operations appears as indicated below in figure 9 below.

**Figure 9: Generalized Toll Industry Model**

Governments typically own roads in the USA through the Department of Transportation at local, state and federal levels, but there are some cases private or public-private hybrids that have the role of road owner. When a road owner assigns the role TC to an actor, the operation can span over a single road or bridge, or tunnel, or a sub-network of those assets in a state or other jurisdiction. Within such a toll domain, the TC is the sole representative of the road owner’s charging capabilities. Many toll authorities have domain over several toll assets in the network. For example, Washington State Department of Transportation manages the toll collection on the Tacoma Narrows Bridge, HOT Lanes on the SR-167 and the SH-520 bridge, and in California, the Bay Area Rapid Transit (BART) manages several bridges in and around San Francisco Bay.

### 4.2 Actors

An actor who is assigned the role of TC in a RUC domain is in most cases also trusted by the Road Owner to act as SP within that same domain. This means that the actor who has an operational contract for conducting the on-the-road activities is normally also the issuer of on-board units and collects payment from the Road Users. So by observing actors rather than roles, the primary relationships look more like figure 9 above, where a combined Toll Charger and Toll Service Provider (TC/SP) has all the relations to the Road User. The dual-role actor TC/SP thereby becomes the sole supplier within his RUC domain, not only of on- and off-the-road activities, but also of the services related to invoicing and payments.

From the TC/SP’s point of view, the Road Owner is the customer. When the TC/SP is also the Road Owner, typically the government, the top priority is to minimize risk and exposure. As a government entity working on behalf of the public trust, the TC/SP manages and operates the facility to avoid Road User complaints and maintain the facility to the highest standard that the budget allows. Customer Service is measured in terms of comparative services that other government departments or departments within the DOT umbrella provide the public. Cost of transactional efficiency is typically not a benchmark and there are no standards for comparing operational efficiency because a common framework for comparison does not exist. Without any benchmarks or common means to compare efficiency of operations, it is not done. If it is done, it is historical comparison of past to present performance of statistics. Performance review deals mostly with keeping the facility open and in good condition and avoiding headlines or public scandals that would draw attention.

Because traffic in automated RUC lanes normally generates less operational cost than those who pay manually, there is a clear incentive for the TC/SP to offer an EFC solution, which is more attractive for
the Road User than any manual alternative. As long as opting in and using a DSRC transponder or other electronic tolling device such as an OBU are a better deal for the user than not doing so, the TC/SP has established enough incentive for the Road Users to avoid manual alternatives. The industry has evolved to a fully automated, cashless, free-flow multi-lane environment where open road tolling is today’s norm.

Since the Road Owner, Toll Charger and Toll Service Provider roles are performed by the same actor in this model, and the Road User must interface with a single entity that sets the business rules, controls the payment services and access to the facilities, the model architecture is, by definition herein, a “closed system” as previously defined. These closed systems in a RUC domain act independently unless the Road Owner or DOT responsible for the entire road network in the domain consolidates the various RUC TC/SPs into a single, large, integrated domain. An example of where this has happened is in State of Massachusetts.

4.3 Interoperability

Road Users are not constrained by RUC domains, zones or state lines. They roam or drive to fit their individual travel requirements or business needs. Some Road Users travel on roads in more than one toll domain. For example, business and casual users in and around the Portland area may travel freely in and out of Washington State. Students in Eugene, Oregon may live in California and travel to classes as required. Truck traffic and freight moves freely between ports in Vancouver, BC, Tacoma, WA or Long Beach, California. The movement of freight and goods up and down the I-5 corridor are perfect examples of road usage across multiple jurisdictional and RUC domains.

The Road Users, however, need to sign up with the local TC/SP in each domain, who will also provide them with an OBU and they are required to maintain an account with that TC/SP. To compound the problem, the Washington State domain currently has three different technologies for OBU’s. California is different and has one standard OBU, at this time but is looking to upgrade the current Title-21 communications 915 MHz standard to possibly the FHWA and RITA financed Intellidrive℠ standard, which is an 802.11x protocol, or wireless internet communications standard. Since it is not very practical for the Road User to keep several subscriptions in parallel, there is demand from the users for an interoperable OBU with an associated cross-domain subscription.

There are some cases where this type of coordination has been put in place in practice in the USA. In the Northeast, 26 toll domains agreed within themselves to standardize on a single source of EFC OBU and readers and create an identity called the Interagency Group or IAG. Each of the 26 IAG members exchanges transaction data for standardized interoperability. When that happens, the distinction between the role of TC and SP starts to make a difference. Because it is with the SP in the ‘home’ domain that the user has a subscription, and who sends the invoice, while it is the TC in the visited domain who register the Road User and passes on the request for payment to the issuing SP. This is illustrated in the figure 10 below.

This case illustrated is fairly simple, but cannot exist unless there is technical interoperability between the two domains. In other words, the OBUs have exact protocols or the readers in the RSE configuration are multi-protocol readers that can read and process transactions from different OBUs. As addressed earlier in this section, the technical differences in the surrounding Oregon state area make this difficult. There are not simply two different protocols or OBU standards in the region, but there are several. This exceeds the ability of any multi-protocol reader to accurately and reliably read and process a transaction. In addition, the problem is compounded because the vendors of the OBU’s in circulation today have patented or protected their OBU, reader and communications protocol between them. The additional compounding problem is that in the region, there would be several

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5 RITA – Research and Innovative Technology Administration
domains and the cost of forwarding and interchanging transactional detail with every other TC/SP domain creates unwarranted overheads and operating costs for all participants.

Figure 10: Domain Interoperability between two TC/SPs

In systems with mandatory use of OBU the corresponding saving is derived from not having to issue OBUs to visitors who already are equipped from some other system. The logic is the same, in that the TC/SP incentive to invest in interoperability is dependent on the share of potentially reusable OBUs from other toll domains circulating in the system.

There is a cost side to be considered as well for any TC/SP contemplating to introduce interoperability. The cost consists of the technical and operational changes required to harmonize one’s own system to that with which one wishes to become interoperable. Depending on how big the differences are this cost can range anywhere from marginal to overwhelming.

Note that the TC/SP incentives are focused on their cost/revenue ratio, rather than the demand of the end users. In a situation where a large share of the traffic is already using double on-board equipment, one for each toll domain, TC/SPs have no incentive for introducing interoperability, as there is no cost savings to be gained from it. On the contrary, the SP/TC has already gained the benefits as most of the traffic is being automatically identified and paid for. In such a situation the only one to gain anything from introducing interoperability is the Road User, and they have limited bargaining power against the TC/SP.

4.4 Market structure

On a map of the west coast, the overlay of RUC domains coincides with states, cities, regions or single road stretches. Every toll domain has by definition one TC, which in all cases also happens to be SP for users in that domain.

Oregon’s neighboring RUC domains are depicted in a generic manner in figure 11. Each domain has its own combined TC/SP. This situation resembles the circumstances experienced in the historical markets for fixed line telephony, mobile telephone coverage, utilities and railroads. In most countries
these industries where dominated by a single state controlled provider, who owned the infrastructure as well as produced the services delivered on top of it. Consumers rarely had any alternative suppliers to choose from when they wanted to make a phone call, use electric power, or other utilities.

Figure 11: Different Regional RUC Domains

For long distance telephone calls or using electric power from plants in other states or other utilities local monopolies worked to create interoperability. These entities made deals with their counterparts in other states, and connected calls, power, utilities or railroad traffic through each other’s systems when so required.

Industries such as these mentioned here are characterized by being natural monopolies. It means that it is either impossible or highly impractical to have several competing suppliers, all establishing parallel competing infrastructure. That would have meant that every utility company ran on their distribution system, and that every telephone and power company installed their own copper lines to each house, ending in their own privately branded jack on the wall.

During a wave of deregulation and interstate commerce implemented changes to these industries, in order to increase competition and allow for new actors to enter the markets formerly dominated by government controlled monopolies. At its core, these changes meant splitting up of the monopolies in two separate entities. One part was created from what constituted a natural monopoly, i.e. the part that owned the infrastructure. This part was kept either as government owned, or strictly regulated.

Meanwhile, the remainder of the operation, the part producing and marketing services, was typically made a public company and had to compete with other service providers for business. That way, several utility companies such as power producers, telephone companies and train companies came to compete on a platform of common infrastructure.
Within the framework of RUC based EFC, the business conducted by the TC is a natural monopoly. It is so as it is not reasonable to have more than one actor taking that role within a toll domain. It would simply be inconvenient to have several competing actors putting up their gantries or toll booths on a publicly controlled and restricted highway while a DOT was in charge of the overall safety and maintenance of the roadway and its right-of-way.

Additionally, toll collection, the dominant type of road usage charging, was historically a manual process since coins and dollar bills were interoperable across state lines. Being human resource intensive made toll authorities and collection of tolls a market segment that was not attractive to consolidation. As the industry became more automated and electronic, the collection of toll fees required no manual collection processes at the point of toll collection and more back office oriented. The introduction of EFC and cashless open road tolling in the industry meant that the road user never interacted face-to-face with the EFC processors and the EFC processing could be remote or centralized. In addition, the internet and now cloud computing allows transaction processing of EFC transactions to be centralized and take advantage of the economies of scale.

In today’s EFC world, there is nothing to prevent SPs from running competing businesses in parallel within one and the same toll domain. It is fully possible that several service providers offer subscriptions to end users and issues on-board units, as long as the on-board unit can communicate with the infrastructure that TC has made available and the transaction files are formatted in a standardized fashion.

If one were to apply the same logic of deregulation on the EFC industry as has been done on the markets for fixed line telephone, utilities and railroads, the combined TC/SPs could be split up. Each toll domain can be compared to a retail outlet where customers can purchase access with one of several credit cards and receive a single invoice at the end of the month for the services or road usage consumed.

In this scenario, TCs primary goal remains to charge the toll at lowest possible cost rate and syndicate the customer service and accounting to Trusted Third Party Service Providers (TSPs) who the TC has authorized for his domain. The agreement between the TC and the several authorized TSPs would incorporate the business and financial rules on how each would interact and payments be recorded and reconciled.

The shift or change to separate TC and SPs to TC and TSPs will usher in a new model for interoperability and operations of RUC domains. It is an open system architecture, which was defined and presented previously. It is depicted below in figure 12, which will be explained and expanded in detail in the following section of this report.
The logical split of the TSP and the TC creates several new dimensions to the previous “closed system” architecture model. It is worthy to highlight these changes.

First, in the closed system, the TC and SP integrated the RUC system internally. Having full control over all facets of the internally integrated system, the TC and SP procured equipment from the RUC supplier vendors. As a stand-alone authority and having no account to a wider market or higher authority, decisions were made on technology that provided the lowest cost. Due to the proprietary nature of the RUC vendors, the procurement approach by government agencies meant that vendors would literally “trap” the region or state into a sole source arrangement for follow-on procurements. Once established, the TC/SP would risk a whole scale swap of EFC equipment if it didn’t select the same vendor on subsequent procurements.

Additionally, the unique and proprietary nature of the EFC equipment meant that transition to a new standard was difficult. The road users and existing accounts would have to recalled and reissued new OBUs to upgrade or changeover to a new EFC protocol. If the previous vendor lost to a competitor in a subsequent procurement, the original vendor used intellectual property law and legal threats to prevent replacement of his equipment. If that failed, lobby efforts and press releases were undertaken to embarrass the TC/SP over the costs of the system replacement. These attacks highlighted the fiscal responsibility to the public in wasting the toll revenues collected when selecting the original vendor could be accomplished more simply and at a lower cost. If cost did not sway the TC/SP, the vendor used the lack of interoperability between the old OBUs and the new suppliers OBUs. In short, once the initial procurement was completed, the TC/SP was committing to long term relationship with the vendor, without realizing it.
5.1 Role of the Road User

The Road User (RU) is a primary actor in the Opens System Architecture Model. The RU has the freedom to choose any TSP or the TC to handle his road usage charging transactions, but has the responsibility to pay his/her fair share of the road usage consumed.

The RU transgresses that basic premise if the RU fails to pay his fair share or whose behavior or actions defraud the TC or TSP of the revenue due for the usage of the road network in a toll domain.

The RU determines his own amount of road usage by the RUs trips on the road network in a domain.

The RU has the choice of making the trip with his individual vehicle, a rented vehicle, a borrowed vehicle or a shared vehicle. Alternatively, the Road User has the choice to make the trip with public transit. This includes the usage of trips in a specific TC domain or domains outside the region or State.

The Road User has the choice of TSPs. The Road User must determine which TSP offers a service package that makes the best sense for the RU's life style and travel patterns. Once determined, the RU is also free to switch TSPs after he completes the service agreements of the contract between the RU and TSP. The Road User can also sign up to the limited package offered by the TC in the toll domain if the RU so chooses.

The Road User also has responsibility to maintain his TSP OBU in working condition. If the OBU indicates or if the RU thinks the OBU is malfunctioning, the RU is responsible to contact the service arm of the TSP and have the OBU tested and replaced if necessary. If the OBU is providing other value added services, the RU will most likely see value in the OBU so the imposition of this responsibility is not onerous to the RU, but may be an irritation should the value added service not provide the value anticipated.

The Road User also has the responsibility, depending on the specific services of the TSP, to retain all records for any credits or refunds that are determined by the TC in the toll domain. For example, out-of-state mileage may be one refund due to the RU. In this case the TSP may have a device that can determine in-state and out-of-state mileage or trips. Another case may be off-road travel, especially in a rural setting or on a farm. Ultimately, it is the Road User who should keep his own records to ensure these are properly recorded and accounted for by the TSP or the RC.

Otherwise, the Road User is responsible for the responsibilities signed-up with the specific contract the RU signs with the individual TSP or TC. One of these responsibilities is prompt payment for the services on the schedule provided by the TSP. If the RU decides to contract with the TC, then the RU is responsible for keeping his RU account in a positive status and charged so road usage fees can be deducted.

If the RU is improperly cited for a failure of the road charging fees, and the RU is certain that his account with the TSP or TC is valid and up to date, the RU has the right and responsibility to bring the
citation to the TSP or TC for handling and dismissal. If the RU account is out of funds with the TC or in-between TSP contracts, the RU has the responsibility to clear the citation with the enforcement authority identified in the citation.

The RU is also responsible for all regulatory and safety requirements of the state and jurisdiction the vehicle is registered to abide by the regulations and laws governing the driving of a motor vehicle. There is nothing in the payment of road usage charges that obviates that basic responsibility of the Road User.

5.2 Role of the Toll Charger (TC)

A TC is still closely tied to the road owner. Its main activities will be to operate the RSE equipment (if there is any), gather transaction data from Road User passage data, identify passages and forward them to the right TSP, and to enforce non-compliance behavior on the road.

The TC may also be the Road Owner and would operate and maintain the physical asset of the road together with the overall management of the facility to include its safety and sustainability of the asset. This also may include the installation, maintenance and upkeep of the RSE installed on the road network of the TCs domain.

The TC would also be responsible for setting the fees for all RUC applications in his domain. It is recognized that many domains would need high jurisdictional approval, but it is important to note that the TC sets the base fee, the overhead costs, the maintenance costs and the margins for processing the transactions. In this last category, the TC is responsible for the calculations of all incremental fees for all classes of vehicles, transaction handling costs, bank fees, loses due to theft of service (violations) and estimates of uncollectable fees or write-offs. Maintenance fees or maintenance escrow accounts must also be included in the margins for processing transactions.

In RUC fees, there can also be environmental fees for the externalities caused by various classes of vehicles with different drive trains. Noise and other externalities may also be estimated into the environmental externalities. In some cases, demand management fees based on levels of congestion can be included and used to help manage demand on segments of the network, zones, time-of-day, or seasonal variances caused by natural attractors (e.g. beach resorts in the summer, ski areas in the winter, etc.)

Whether to invest in interoperability or not is no longer a negotiation between two TC/SPs as in the closed system architecture model. The relationship between the TC and the TSPs is based on making mutual savings in operational cost. The variable costs of account management, call center operations, marketing, customer relations and technology upgrades and evolution are now shifted to the cost of doing business for the TSPs. They offset these costs with transaction fees gleaned from each transaction processed. While the TC still is responsible for the provisioning and maintenance of the EFC readers and RSE equipment on the RUC facility, these devices, like many of the other roadside kit – lighting, guardrail, call boxes, signage, gantries, communications gear, and ITS systems employed...
are known and familiar to the Road Owner and Toll Collector. In the split, the TC now focuses on keeping and guaranteeing the toll facility availability so Road Users can access and create transaction. In addition, the TC also retains the enforcement of safety and policing of the facility.

In closed systems architectures employed by TC/SP across the USA, the range of overhead is typically 18% to nearly 40%. Stated differently, every dollar collected carries an average of approximately $0.28. This is because of the staffing, functions and variable costs of customer relations and operations and risk management to protect the public image of the EFC operations. In comparison to an open system architecture model in Singapore, the transaction overhead is 8%. In calculations done in Manchester, UK for a RUC system design, the open system architecture of the TC was calculated at 9% to 12%. Taking the average of these two ranges, a 10% overhead may be considered reasonable for open system architecture.

The cost difference between the closed and open system architecture models is therefore suggested to be 20%. If the TC negotiated a 10% transaction fee with the TSP, commercial firms who already deal with the Road User would be willing to become a TSP. The case to be a TSP will most likely be based entirely on the percentage and financial arrangement between the TC and the TSP. Any value added services projected in the business case of the TSP would be speculative and discounted by a commercial company’s investment committee.

Instead, interoperability between TC and the TSPs becomes a necessity in order for the TC to get paid by the Road Users, and a method to directly reduce operational cost. Therefore TCs have a strong incentive for establishing interoperability, as there will be fewer manual payments by interconnecting with more TSPs.

One further function of the TC in the open system architecture model is the handling of exempt and bad accounts. Exempt accounts are those accounts that legally do not pay the road usage charge. This is established in legislation and can be a range of specific entities (police vehicles, fire department vehicles, ambulances, military vehicles, etc.) Providing an OBU to these vehicles and ensuring that they do not get charged for their road usage is the responsibility of the TC. The best way to handle these vehicles is the issuance of an OBU and establishment of an account with the TC. An Image Based Transaction of reading the vehicle license plate can also do it, but accuracy and handling are more costly to the TC. An inexpensive EFC tag, such as an 18000-6C transponder tag which can be obtained for less than two dollars is a cost effective and efficient way to handle these exempt vehicles.

Another logical extension of the model is the TC handling bad or problem accounts. The TC must be the port of last resort for handling road usage charges for Road Users who fall into this category. For example, a Road User initially signs up with a TSP, in this case TSP-1. The Road User fails to make payment to TSP-1, but before TSP-1 can collect the debt, the Road User jumps to TSP-2. The Road User repeats the same behavior with TSP-2 and jumps to TSP-3. In short, the Road User becomes a bad credit risk to all of the TSPs and cannot establish an account with the TSPs. As a result, the Open System Architecture Model could prevent the Road User from access to the transportation network, which would be a legal constitutional issue and a problem for the state.

Video or image based transaction are an outgrowth of cashless, open road fee collection. When a vehicle passes a fee collection station or RSE charging point, the vehicle has its OBU read, or takes an image of the front, back or front/back license plate. These vehicles may be out-of-state vehicles, may be state vehicles, which are exempt, may be newly registered vehicles, or are vehicles with a malfunctioning OBU. In any case, the TC handles the transaction as an image-based transaction (IBT) and uses modern OCR processing to match the image-read of the number plate to a digital IBT.

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6Gopnath Menon and Jack Opiola reference paper, dated 2005
7Booz Allen Hamilton Business Case Analysis for the Manchester Association of Governments, UK DfT TIFF submission.
processing is part of the TCs BOCS. The IBT records are then aggregated and sent to all the TSPs who reconcile them with their records. As a result of reconciliation process, the TSPs match the digital IBTs to their records and charge the transaction to the proper account. In return, the TSP sends back the culled list of IBTs to the TC. The TC, after vetting the list with all the SPs has a sub-set of IBTs that are proper accounts, exempt vehicles, out-of-state vehicles, or alternate payment road usages. These records are then processed with the enforcement processing and citations are sent to the individual Road User for collection of fees due plus any administrative, citation costs or court handling costs.

Should the individual Road User who has a valid account with a TSP or TC receive a citation notice from the enforcement processing, the Road User must notify the TSP holding his account. The TSP and TC must have a process whereby an enforcement notice, which is in error, can be eliminated from the enforcement process by a special process established. In this case, the TSP failed to cull the IBT transaction when these were vetted and the TSP pays a transaction fee back to the SP to cover the TCs handling of the transaction. This sets up an operational procedure where the TSP loses money on the erroneous citation transaction, thereby establishing a precedent to operationally eliminate such occurrences. In addition, it also provides an incentive for a Road User, who did violate the system, to convert the violation to an account with a TSP. In this case, the emphasis is getting all vehicles registered into the system over prosecuting enforcement proceedings.

Privacy is another issue enhanced with the open system architecture model. In a closed system architecture model, the TC/SP requires the Road User to establish an EFC account with the services provided by the TC/SP. The TC/SP is also responsible for violation and enforcement management and has links to the DMV and vehicle records. As a result, it is perceived that the TC/SP has data to associate the person with the vehicle and trip transactions. The impression to the public is that the TC/SP has all information necessary to associate a person with trips at given times of the day based on the transaction records, video imagery, transaction details and vehicle registration details.

The open system architecture model, on the other hand, has no such linkages other than the video image based transaction to the DMV registry. This link will be used for violation enforcement or where and when violation enforcement must be evaluated for a possible violation of non-payment. In the open system architecture model, the TC only has a transaction of an OBU that he knows belongs to a specific TSP. The TSP has the contact details and account information to match and manage the transaction to a specific Road User and account. As such, the open system architecture model is more like a Swiss bank account where the TC only knows that the OBU is a valid OBU and no personal information to associate the Road User, the vehicle and the private details. The TSP, who has the relationship with the Road User does have the details and if the TSP already had a relationship with the user (e.g. bank, credit card company, gas credit card company or utility company) the user has already established and maintained a trusted relationship with the entity. Therefore, there is greater privacy protection for an open versus a closed system architecture model.

To handle the bad or problem accounts, the TC handles such accounts for the system. The TC can outsource these and pay the outsourced entity for the handling, but the simple fact is that the TC is responsible for these accounts. These accounts, due the bad or problem Road User behavior, handle them as a debit account. In other words, the Road User must prepay and keep a positive balance in the account, which is debited with each transaction. This is how most current TC/SPs handle all accounts in today’s EFC market.
5.3 Role of the Trusted Third Party Service Provider

The other half of what used to be the TC/SP, i.e. the toll service provider, in the closed system architecture model is the Trusted Third Party Service Provider (TSP). The TSP is an outsourced service to the TC to handle the account servicing and Customer Service Relations Management (CRM) of the Road Usage to the all domain TC. In this report, the role will be defined as the agreement and relationship of a TSP to a single domain TC, but in expanding the system, the TSP could be handling the relationship of multiple domain TCs. In the case of Multiple Domain TCs, this dynamic establishes interoperability over a region, multi-state jurisdictions and possibly on a national level. The agreement between each TSP and TC can be different, but the functional relationship does not change between the two entities.

One of the primary responsibilities and roles of the TSP is to offer the Road User “choice”. It is recognized that multiple TSPs with different and unique service offerings, which they are free to customize, give the Road User a choice of who he wishes to handle his road usage charges. It is also recognized that a primary right of the Road User and the TSP is freedom of the Road User to switch TSPs or resort to the TC to handle his account.

The TSP business of signing up Road Users and issuing on-board units is an organic part of the split up business between the TC and TSP. The TSP is now no longer tied to a specific toll domain, but acts instead freely over the entire region or west coast. Of immediate attention are the Road Users that drive between the neighboring states of Washington and California. A responsibility of the TSP is to sign-up and register the Road User account both into his own system and to send a valid OBU identification to the TC domain(s) that the TSP has a contractual arrangement. The TC upon receipt of the OBU identification acknowledges the addition and provides the TSP feedback that the RSE and TCs BOCS are synchronized for future transaction ownership.

There is nothing to say that the number of TSPs shall be the same as the number of TCs, or that those acting as TSP shall have a past in the EFC industry. It might just as well be financial institutions, insurance companies, parking service provider, vehicle equipment retailers, or anyone else who already has a relation to the Road User, its vehicle, or its payment routines.

To a standalone TSP, the road owner is no longer the primary customer. The Road User is instead. A stand-alone SP can choose as its strategy to offer Road Users a service valid over a larger area, across multiple toll domains, jurisdictions or they might wish to offer a simple and low cost solution which only works in one or a few domains.

By allowing TSPs to operate across multiple toll domains the total market for toll service subscriptions gets larger, and thus allows TSPs to focus on niche user groups, which would have been
considered too small to be worth any attention if assessed in each domain by itself. An example may be freight haulers or interstate trucking firms.

A TC is by definition bound to its local toll domain, while a TSP can associate itself with any number of TC domains regardless of its origin. A TSP does not even have to be based in an area where roads are charged.

In an Open System Architecture Model, equipment is procured through a certification process. The TC establishes a common and interoperable EFC protocol. The protocol is typically a certifiable IEEE standard such as 18000-6B or 18000-6C or 802.11p. The protocol and the interface details are established and a certification agent is appointed. The role of the certification agent is to test and certify that the EFC or RUC equipment meets the interface and protocol standards established by the TC. The certification agent can be a standards entity, an independent test lab, or a branch of the state technical university. A technical arm of the TC can also be established with the role of the certifying agent, however, it is best to have an independent body be the certification agent.

Furthermore, a TSP not only handles the accounting and CRM of the Road User to a TC domain, but also can further embellish that relationship by providing value added services to entice Road Users to sign up with the specific TSP rather than other TSPs. Multiple TSPs are in competition with each other. They provide a unique service proposition with the Road User community, even if that service is an existing service arrangement that exists. For example, a bank, insurance company or gas credit card company (e.g. Shell, Exxon) may be a TSP. These entities may already be offering a service to the user and the handling of RUC fees is a marginal business to their existing services being provided since they already handle monthly invoices, customer services and CRM to the Road User. In this case, the TSP may offer packaged discounts on the other services as an enticement to the Road User to join his TSP or he may share the percentage of the transaction fee with the Road User therefore offering a discount on his RUC fees when compared to the other TSP offers.

It is beyond the scope of this report to identify all the value offered services that a TSP could provide the Road User. The logical ones that have been provided in other Open System Architectures begin with the simplification of filing the RUC. In the RUC structure, there will be credits for miles driven on private lanes outside the public road network, there will be out-of-state mileage, and there may be further discounts and credits for energy efficient and low emission vehicles. The filing and maintaining records by the individual Road User can be administered by the TSP with the type of OBU provided to the Road User. The first value added service must be recognized as simplification of the Road User’s responsibilities. In NZ, the eTOLL company provides this service of simplification of filing off-road and usage reports to the government on behalf of the Road Users who do business with them.

Other value added services that are logical extensions are parking and traveler and traffic information. The TSP can enter into a special arrangement with a parking concession for off-street parking. This provides the Road User an end-to-end solution for trips into urban centers and a simplified means to receive on monthly invoice for all road usage and parking. In Ireland, Egis Projects provides this service for Road Users in Ireland and the Dublin area.

The providing of travel and traffic information is another value added service that can be provided by a potential TSP. This travel and traffic information combined with road usage charges can provide an attractive incentive for commercial fleet vehicles signing up with a TSP. In this case, the TSP may offer a monthly discount on the traffic and travel information package to all Road Users who sign up with the TSP.

The TSP has responsibilities to the TC. These include the maintaining of the Road User’s account, transactions, customer service and CRM. This entails the receiving and accounting of usage transactions received from the TC and reconciling with the TC on a daily basis. In addition, it entails internal reconciliation to the account base and collection of road usage charges from the Road User
by invoicing the Road User on a periodic basis. If the TSP is a bank or other financial institution, this may simply be the debiting of the user’s checking or savings account on a routine daily basis. If it is a credit card or gas credit card company, it may be the collection of the daily road usage and attribution to the user’s account for monthly invoicing. One advantage the above describe of the TSP for the Road User is the more familiar payment for services received versus the current TC/SP debit account requiring a Road User to pay up-front for services that he may use. This is also a distinction between the TCs handling of bad accounts and the TSPs handling of Road User accounts, pre and post payment for services, respectively.

The TSP must also reconcile both OBU transactions and image based transactions (IBT) with the TCs. It is envisaged that this occurs on a daily basis with the TC. In the agreement between the two entities, the TC and TSP must set up a reconciliation process, which would recognize in the accounting system the realization of the transaction. It is recommended that this be done daily. It is at this time that any irregular transactions are also handled and the running daily reconciliation culminates into an accounting month reconciliation of all transactions – OBU, IBT and irregular transactions. Based on the agreement, actual revenue can be transferred at the end of each calendar month or quarterly to provide the TSP the ability to handle cash flow on its post-payment accounting and take advantage of the daily float on the revenue as the TSP business case dictates and allowed by the TC Agreement. It is also highly recognized that the TSP be governed under state and federal banking rules to ensure protection and security of public funds in trust.

The TSP is also responsible to procure OBUs from the certified list of OBUs managed by the Certification Agent (CA). The TSP procures the OBUs and manages the inventory for its use. The TSP can work with a technical partner and create a new OBU that best fits the TSPs business case. In this case, the TSP has the freedom to create a new OBU, but the responsibility to have the OBU certified by the CA and successfully show its full interoperability. Once certified, the TSP can distribute the OBU or the application to the Road Users. It is specifically recognized that the TSP could write a specific application for a smart telephone or a navigation device (Garmin, TomTom, INRIX, etc.) that can inter-operate with the TC system and the application on the specific smart mobile telephone or navigation device fully inter-operates with the TC RSE. Therefore the TSP has the freedom to innovate a technological device that best fits the TSPs business case for road usage services and value added services, but also has the responsibility to have it certified by the CA.

The TSP also has the freedom to engage agents and other third parties to assist it in CRM. For example, the TSP could use a major mobile telephone operator as an agent network. This would provide Road Users a recognized and familiar storefront or commercial business to handle the initial account sign-up process, inquiries or issues with the TSP OBU or application.

The TSP is also responsible to handle the daily reconciliation of IBTs. These would be processed based on matching the account base against the TC supplied list of daily recorded IBTs and determining if one of its Road Users has a malfunctioning OBU. It could also identify new accounts that have signed up but in the sign-up process the TC did not receive the new account association link to the TSP. In all cases, the responsibility to reconcile the IBT listing is one reconciliation responsibility of the TSP. The TSP is also responsible for any errors or omission on the IBT listing to the TC. In cases of mistakes or omissions, the TSP is responsible to handle the Road User’s citation and have it nullified with the TC. The TSP will pay a special transaction fee to the TC for each occurrence and the TC will maintain a log of these transactions. The TC may consider the TSP in question should this log show an inordinately high degree of such missed or omitted IBT transactions. Such events, based on the Agreement with the TC could be cause for termination of the agreement or impact the transaction rates agreed between the parties.

Keeping that Road User happy is a top priority of the TSP, if they want to win future operations contracts and retain their business. Keeping the Road User happy is primarily about providing services and value added services that entice the Road User to sign-up with the TSP. The TSP is also in
competition with other TSPs in capturing charges for an as large as possible share of the traffic, at lowest possible operational cost. This is measured as operational cost’s share of operational income, and is a key metric for the TSP.

5.4 Role of Certification Agent

In an open system architecture model, equipment is procured through a certification process. The TC establishes a common and interoperable EFC protocol. The protocol is typically a certifiable IEEE standard such as 18000-6B or 18000-6C or 802.11p. The protocol and the interface details are established and a certification agent is appointed. The role of the certification agent is to test and certify that the EFC or RUC equipment meets the interface and protocol standards established by the TC. The Certification Agent can be a standards entity, an independent test lab, or a branch of the state technical university. A technical arm of the TC can also be established with the role of the certifying agent. However, it is best to have an independent body be the Certification Agent.

Vendors interested in supplying equipment to the TC for the RSE can have their equipment tested and certified at any time. The vendor pays the Certification Agent for the testing. If the equipment passes the certification test, it is given a certificate for the specific version and model of equipment. It is also added to the list of certified equipment and any interested TSP or the TC can ask the vendor for a current price quotation for the quantity that he is interested in procuring. If the vendor fails the certification test, the CA will provide a detail report of why the equipment failed. The vendor can use the report to fix any issues in hardware or software noted and repay for a new certification test. The vendor can retest his equipment as many times as he desires.

Should the vendor modify, upgrade or enhance his certified equipment model, either in hardware or software, it must be retested and re-certified. It is the CA’s role and responsibility to ensure proper modification and change control of the equipment on the certified list maintained for the TC. Should the vendor make changes or upgrades and not notify or inform the CA, the certification has the responsibility to inform the TC and TSP of the breach in certification and the vendor’s equipment would be dropped from the certification list until it is retested and recertified with the latest changes.

The certification process ensures that the TC uses the proper RSE equipment that can read the OBUs that the TSPs procure and distribute to the Road Users. OBUs in this open system architecture scenario would be issued by the TSPs. Interoperability would be guaranteed by the SP only procuring OBUs from the certified list to prevent any TSP customers from not interacting or communicating to the RSE in the various RUC Domains.

Based on the TSP’s business plan, the TSP may provide value added services to his Road Users that are his customers. These value added services would also interact with the certification process in that the value added service may procure readers or other certified equipment from the list.
For example, a parking garage wants to be a value added service provider with the TSP so that the Road Users can pay for their RUC fees and parking fees on one monthly bill presented to the Road User by the TSP. In this case the parking garage agent can procure readers from the certified list and take advantage of any bulk order discounts and quantity discounts allowed by the vendor to the TC.

In another example, the TSP wishes to provide traveler and traffic information to his road usage customers. The OBU on the certification list does not support a second means of data transfer and the travel and traffic information company can’t use any of the OBUs on the certification list. In this case the travel and traffic information company can work with a vendor or a new vendor on a new OBU that is exclusive to the TSP who is also investing in the OBU for the purpose of selling more value added services. The new OBU would have to be certified by the certification agent. Once certified and put onto the certification list to ensure interoperability, the TSP can provide the new OBU to his customers and they can interact with TC on all RUC facilities in his domain and neighboring domains.

The advantage of certification is that it removes the TC from procuring RUC equipment indelicately and risking unique or non-interoperable systems. More importantly, it shifts troublesome procurements to a certification process. The certification process is open to all vendors. The Certification Agent ensures the sanctity of the certification list and the TC does not have to invest or be troubled over equipment that does not interact with the TSPs. The TSPs can have a choice of multiple suppliers to outfit their customers of road usages and not be held captive to a single monopolistic supplier whose revised pricing negates the TSP’s business case. It also protects the TSP’s source of supply should the vendor stop producing OBUs or equipment. It also allows the TSP to design and customize equipment and OBUs to fit their business case to offer and sell value added services to its customer base.

### 5.5 Full Model and Other Relationships

Relationships exist that were highlighted in the above text for the various actors, but not shown in Open System Architecture Model Figure 12 for sake of simplicity. These are reflected in the full relationship model in figure 17, below. Added to this model are the relationships with enforcement and with the DMV.

These relationships are handled by the Road Owners empowerment of the TC. This is especially true when the Road Owner and the TC are government entities in Oregon, it is recognized that these are one in the same organization, ODOT. These relationships already exist and are exercised on a normal basis between the entities and are not new relationships.

Each will be addressed below in sub-sections. It is also recognized that these two entities have a relationship with the Road User and in this Open System Architecture Model, have no relationship with the TSP. In the case of the TSP, the TSP interfaces with the TC who maintains the relationship and the TSP handles all matters with enforcement vicariously through the TC.
5.6 Enforcement

The TC is responsible for ensuring compliance of vehicles not using any automated measuring and reporting mechanism based on the on-board equipment. These are examples of how such compliance control mechanism can be designed.

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Figure 18: Example of process flow of data and information, including images involved in a typical enforcement process for road usage charging
For vehicles registered in the toll domain it can be done quite simply by comparing reports from various sources, such as annual vehicle inspection, accounted refueling, customer invoices and so forth. If a vehicle is registered in a domain, but has not made any manual reports at all, and other sources confirm that the vehicle has been used, then the secondary sources can be used to estimate the value of the fee and a fine can be issued.

Out-of-state vehicles can be checked using data collected from the traffic monitoring system established as part of the statistical traffic analysis, as described under principle 4 (TC monitoring TSP’s). In this context, TC has acquired the possibility to photograph and measure the passing vehicles at key points in the road network and at state border crossings. Non-registered users are identified at these check points, and each piece of evidence is added to the corresponding violator’s account in the TC BOCS system.

Automated license plate reading has become increasingly accurate in recent years, and it is likely that the vast majority, between 84% to 87% for single front or back plate reads and 88% to 92% for front and back plate reads, of vehicle passages are identifiable by such means. But even if no license plate can be read, the total set of optical measurements - images as well as laser measurements - is enough to create a unique vehicle fingerprint. By taking into account visual cues from the images, such as vehicle decoration, stickers, placement of head and taillights and vehicle shape, etc., it is possible to recognize one and the same vehicle from different passage events. This way a repeat offender might not be completely identified by the camera equipment, but the fact that it is a repeat offence will be noted, and all evidence of unlawful road usage will be collected under one - so far anonymous - account.

When the enforcement agency plans its work, it can start with the worst violators, by focusing on violator accounts with the highest number of non-reporting passage evidences. The enforcement agency or the police position themselves downstream from a control gantry and awaits the next repeat violator. As soon as a vehicle with more than the determined threshold of repeat offences is recognized passing under the RSE gantry, an alarm is sent to the enforcement officers, and all the related evidence data is sent to them. When the non-compliant driver is stopped, he can be presented with evidence not only for the failure to pay for the on-going trip, but also for all other non-registered trips through the domain done previously.

A main advantage of this approach is that the costly operation of manual enforcement on the road can be limited to a smaller number of targeted actions against repeat offenders, where the evidence is strong and the outstanding debt of unpaid toll is material. By combining a set of established technologies this way it is possible to achieve a higher level of compliance at a cost much less than carrying out sample test.
5.7 DMV

The DMV database of registered vehicles is an important component of a well-designed Open System Architecture Model. First, the Road User must register and enroll a vehicle. License plates are issued from the DMV and the Road User is responsible for maintaining the accuracy of his/her contact details of the enrolled vehicle. Vehicle characteristics and engine type should also be registered and the new classification of high-efficiency vehicles (hybrids, plug-in hybrids, alternate fuel and electric vehicles) should be recorded in the DMV database.

Record checks of IBT can be checked by the TC through the DMV database and if the vehicle is not registered for EFC, the contact details for enforcement can be obtained. Secondly, this data is combined with the records for the enforcement process after the list of IBTs has been vetted by the TSPs.

An important feedback loop that is necessary to enhance the overall system is that once an enforcement process has collected updated information on the Road User or the vehicle, that updated information should be re-sent to the DMV to update their records and improve the overall accuracy of the complete system.

Therefore, the synergy of the TC working closely with the enforcement process and the DMV is an important relationship for all three actors in the system.

Another extension of the system is that TC domains must work together. Therefore, there is a way to handle out-of-state vehicles and receive records for these vehicles by cross-domain cooperation between the TCs. The DMVs can exchange data and an exchange agreement can be executed, at least for the region, to help each TC domain increase its efficiencies.

5.8 Implementation

It might seem radical to suggest a forced split between TC and SP, and instead tie TSPs prime loyalty to the end user, the Road User. But going back to the roles and responsibilities model depicted in figure 12, it resembles more what is suggested here than the real life situation in many states and toll domains today, where the TC/SP monoliths prevail.

Some countries have made movement in the direction outlined here, notably in Norway, Spain, and Portugal. When the new bridge between Norway and Sweden was built, it was decided to establish a standalone TC to manage its charges. That meant that there was an immediate need for that TC to connect with nearby SPs in order to make use of the EFC tags and associated subscriptions in vehicles passing the bridge. Propelled by this strongly incentivized TC, the interoperability project grew, and turned into what is now the Nordic interoperability service EasyGo.

In Texas, the Central Texas Regional Mobility Agency, CTRMA, has recognized the efficiencies and cost savings of the Open System Architecture Model. They are currently procuring TSPs for their TC Domain. Interface and exchange of data is through a central interchange switch for the large Texas TC Domains of Harris County, Texas Toll Authority and the North Texas Toll Authority. While these TC domains are TC/SP domains, the CTRMA is using its access as a pass through for TSPs. It is hoped that in the future, the TSPs grow and the TC/SPs break up and assume a TC Domain role while using TSPs. An image of this relationship is shown below in figure 20.
In New Zealand, the RUC system has been charging all diesel vehicles in the country for mass and distance since 1977. This system was originally a TC/SP model. In 2003, the Ministry of Transport first studied the upgrade of the RUC. In 2004 and 2005, a more comprehensive study was conducted and the system considered a GPS-based solution. Due to concerns of mandating a GPS technology to replace the RUC hub-odometer base system, the Ministry introduced a change to the eRUC system to introduce an Open System Architecture model instead. In this context, the MOT allowed TSPs to exist and handle the role described herein. The TSPs came into existence and have assisted the Ministry in the new eRUC system. The Ministry therefore did not take any technology risks and the choice of using a TSP and the service offering of the TSPs was by choice, not dictate.

Common European legislation can be useful in the pursuit of improved competition in the EFC market and to encourage interoperability. Such legislation could add some pressure on harmonization of technical EFC interfaces, but more importantly, they need to stimulate the conditions for competition between actors and real choices for the customers. In an effort to promote competition, EU could for example legally prevent a TC from also acting as SP.

But it is also possible to achieve a situation similar to what is put forward here entirely without any directive, only using decisions made by the state departments of transportation and other private road owners. Road Owners who are considering introducing EFC for the first time, or who are about to renew their outsourcing arrangements, can shape the market by consciously model the procurement of the products and services.

By contracting one party to carry out the TC related services only, and require that they in turn negotiate with potential TSPs to deliver the complete service, circumstances are established for Road Users to choose from several parallel offerings.
5.9 A dynamic market for autonomous systems

Some countries have tested alternative solutions, requiring a minimum of equipment bound to the road side, and instead placed the core functionality - registering of road usage - in the on-board equipment. Even though such on-board equipment is more expensive to produce, the solution as a whole can be more cost effective, if the number of vehicles is limited and the number of road sections to charge for is very large.

This type of functionally with on-board equipment is widely expected to use satellite positioning to determine the vehicle’s route, and the data services of mobile telephony for reporting the measured road usage to a central system. From these two technologies this kind of systems are sometimes referred to in the literature as Global Satellite Navigation System or simply GPS/Cellular Network (GPS/CN).

That is slightly misleading, as the aspect differentiating this type of system from the road side centric solutions with dedicated ground based infrastructure is not the technologies per se, but rather the fact that they are self-sufficient inside already existing third party infrastructure. That is why some choose the generic term autonomous systems, and thereby leave open for alternative technologies to be used for measuring road usage and for reporting the data to the central system.

6 - Principles for an Open System Architecture Model

The technical characteristic that autonomous systems measure road usage in the vehicle as opposed to by the Road Side Equipment (RSE) has far reaching consequences, for the kind of system architecture opportunities as well for the business models made possible. As the on-board unit is issued and controlled by the TSP, while the RSE is the TCs responsibility, moving core functionality from the road side to inside the vehicle, effectively means moving a chunk of the business operation from one role to another, from TC to TSP.

And since the road usage information, which the TSP needs to invoice the user, is already in the hands of the TSP by being captured by its equipment, there is no immediate need to route road usage information via the TC. Instead the on-board unit can communicate with its issuing TSP directly, after which TSP can pass the road usage information required to the TC toll domain visited by the Road User.

The TC does measure, record and manage road usage by means of intelligent transportation system (ITS) traffic recording equipment on the road network in the toll domain of the TC. In effect, the TC continues the role of traffic and congestion management for the Road Owner. From the video capture of license plates and the measurement of traffic on road segments in the TC domain, the TC can enforce non-payment and collect statistical data to adjust road pricing levels for demand management.

It does not matter if one sees this flow of information - from OBU to TC to TSP - as merely a technicality, introducing a network proxy controlled by TSP, or if it is seen as a real change to the roles and responsibility model familiar from EFC based systems. In any case, the fact that it is sufficient for an on-board unit to communicate with RSE and the TC providing the information to the issuing TSP only, and never anyone else, is significant for how interoperability between toll domains can be solved. The same is true for the capture of image-based transactions (IBT), which is done by the TC and vetted with each TSP. This is the enforcement role and responsibility of the TC and impacts the TSPs, if only in the trust that it is being done to ensure no leakage in potential revenue to the TSPs. On a higher level, these trusts extend and define the ultimate reliability of the system to the public at large.
Accepting that the on-board unit only has to be accountable with its own 'home' system, that is the issuing TSP, means that the exchange of information between the actors needs to be harmonize and interoperable across all TSPs. The need for a common interface of the on-board unit is not limited to technical interfaces. Rather, a set of governing principles for roles and responsibilities between the actors in the market must be agreed upon. By establishing such a set of common principles it is possible to make interoperability an inevitable consequence of the market dynamics.

In the following, a suggested set of principles for the Open System Architecture Model:

| Principle 1: Road users are required to self-declare their road usage |
| Principle 2: Toll Chargers sets target and quality requirements |
| Principle 3: Toll Service Providers design their own solutions for user choice |
| Principle 4: Toll Chargers monitor and control Trusted Third Party Service Providers |
| Principle 5: Toll Service Providers monitor and control road users |
| Principle 6: Toll Chargers monitor and control non-subscribing road users |

Table 2: Principles of an Open System Architecture Model

Each of these principles will be discussed at length and explained in the following sub-sections.

6.1 Principle 1: Road Users are required to self-declare their road usage

Ultimately, the Road User must be responsible for declaring his usage of the road. Detail reporting of road usage seems impractical, but as a principle it is fundamental for allocating responsibility where it is best suited - with the end user - as well as for creating the right incentives for each of the actors involved. It is also a cornerstone of the open system architecture model that is to provide the end user the right to choose how to report road usage – through a self-declaration of the odometer reading or through a technical solution that simplifies his documenting of total usage on/off-road or in/out of state. The same is true of toll facilities. The user can declare in advance of using the facility and paying for it directly, or choosing to use a technology solution from a TSP who will account for the usage automatically. Value added services are another area where the user may want to pay for parking directly or have the parking event accounted for by the TSP and pay one monthly invoice for all parking and road usage. The choice is always the end users or Road User’s choice.

As keeping track of every route one plans to choose, and declare it prior to departure is a complicated and tedious task, it is likely that most Road Users prefer that someone steps in and assists them with an automated solution for measuring and reporting. When doing so, the Road User can choose between several options from different TSP’s and sign a subscription or contract with the TSP who offers the most attractive conditions and services. The Road User has now subscribed to the service getting help with reporting their road usage and selected value added services. Responsibility
for truthful reporting rests ultimately with the Road User. Information flow and responsibilities thereby differ slightly from what is typical in EFC based systems where few if any choices exist.

This is the same principle used when someone uses a tax consultant to prepare one's income tax statements. The tax payer is always responsible, but does not have to do the job. Effectively this makes the TSP act as a stand-in Road User rather than a stand-in TC.

An important consequence of this principle is that the end user is always required to report and to pay, even if some technical equipment has failed. Thereby it is in the interest of the Road User to keep the system working, rather than the situation where malfunctioning equipment is something a user might hope for, or even encourage.

It is also assumed that a TSP, as a part of the service offered to Road Users, accepts the credit risk for its subscribers, since an integral part of the agreement between the TSP and TC is that the TSP offers a payment guarantee to its associated TCs. Thereby, the payment duty is fulfilled even if some Road Users should fail to pay. It is always the TSPs responsibility to collect all debts owed to the TSP from the Road Users. In such a case, collecting the money from the end user falls under civil law between the TSP and the subscriber. Such a payment guarantee would be another example of a service offered commercially by the TSP.

This principle is based on a self-declaration option being not only available but also a realistic alternative to using on-board equipment. For that to work, there is a need for some kind of technical support for those users reporting manually, such as a web application, SMS text messaging, a smart phone application or a call center. By establishing a useable baseline self-reporting option, the issue of non-discrimination is solved at the same time, as it is a zero cost and no installation option that can be used by temporary visitors to the toll domain.
6.2 Principle 2: Toll Chargers set targets and quality requirements

For a TC the prime concern is to accurately capture as large a share as possible of the traffic liable for road fees. This concern is reflected in a set of quality requirements used when selecting which TSPs to award authorization or contracts to operate in the toll domain. TSPs are thus contracted to meet strictly functional criteria, while they are free to choose any technology and process design in order to achieve those targets, as long as the Certification Agent for the Toll Domain certifies the selected technology.

A TSP must, in order to get an authorization to interoperate with a TC, be able to show that it has the ability to register the road usage of their subscribers, with no more than “X” per cent error in the amount to be paid, per period of time. Exactly how they go about to solve that is not the responsibility of the TC, this is strictly TSP business. Thus, a TC does not have to have an opinion of what technology is best or most promising for the future. Instead, all they have to do is define the minimum requirements necessary for collecting the charge.

It is therefore important that no requirements are made that might limit the flexibility of the TSP in designing the measuring and reporting solution, by being overly detailed or tied to a certain technology other than those technology solutions that are certified.

This way it is possible for actors who already have a relationship with a set of Road Users to leverage that relationship and have that group of Road Users become an installed base of on-board unit accounts. The Road User has the choice to select that actor whom there exists a relationship or select another. As a final choice, the Road User can always default to the TC and switch later to a TSP. Such actors could for example be already established TSPs from other toll domains, fleet management services operations, insurance companies with Pay as You Drive schemes in place, or makers of satellite navigation equipment with integrated traffic flow feedback. New players can choose to enter the market by this means, and some of the equipment already obtained by end users for other purposes can be reused, allowing savings to be made in equipment acquisition cost as well as installation effort.

It is pivotal that each TC can freely choose which TSPs to authorize for operation in its domain, as long as it is done on fair and on market-based grounds. Only if the TC has the right to select and

Figure 18: TC issues an authorization to those TSPs who can show that they can measure and report road usage with sufficient accuracy.
deselect which SPs to associate with, real competition is achieved, and TSPs are incentivized to improve their performance in terms of pricing, quality, service levels and value added services.

6.3 Principle 3: Toll service providers design their own solution for user choices

Because the TC does not prescribe any particular technical solution other than those certified, it becomes a TSP responsibility to design and develop the appropriate combination of equipment, information processing, and compliance control system, which, as a whole, fulfills the requirement on accuracy of reporting and operating raised by the TC. The TSP can then deem which can be successfully marketed to a segment of the Road User community according to its own business plan.

This freedom to design solution opens the market for yet to be established technologies and methods. Today, many people agree that satellite positioning is a method with enough accuracy to be used for positioning vehicles, and thereby measuring distance and determine fees. But it is fully possible that new technologies and ideas lead to another just as accurate measurement of road usage. This way the market is constantly challenged by innovations, and the economies of scale held by established TSPs does not become as powerful barriers for new market entrants.

Furthermore, it takes the risk of technological evolution out of the hands of the TC and places where it can best be managed – the TSP. The TSP best understands how a technology can be applied to its business case and what the life cycle costs involved with such a selection. The internal selection process for change is typically a true benefit-cost analysis since the benefits are measured in bottom-line dollars and cents. The TC can only assume benefits and costs for any technological solution but many times emphasizes benefits that are never realized.

Road Users who have a need for an advanced solution will then subscribe to a service with those features, while those who give priority to low cost can be satisfied with a simpler alternative. The total cost for the system is thus decreased, while it is still able to meet the needs of its most demanding users.

Figure 19: TSP is free to design their solution for measuring road usage without the direct influence of the TC. Different TSPs can offer completely different solutions, associated to the same TC, from which the Road User can choose. The selected technology of choice measures and reports back disaggregate measurements of road usage that the Road User can see, understand and adjust road usage as the Road User sees fit.
In the marketplace, the effect is that several TSPs have to compete for the appreciation of the Road User, by offering a solution that fits them. Some users might prioritize equipment with low power consumption, someone else that the installation is rapid - so that the vehicles do not have to be taken out of business for a long time during installation. Others again might value attractive exterior design of the equipment, better privacy protection, low cost, or useful additional value added services. Those Road Users who regularly travel through many toll domains probably appreciate seamless interoperability services. Ultimately, only the Road Users themselves can decide what aspects they consider most important, and how much they are prepared to pay for the service.

6.4 Principle 4: Toll Chargers monitor and control Trusted Third Party Service Providers

When a TC has authorized a number of TSPs to operate in its toll domain, it must have some way of ensuring that the TSPs are fulfilling their commitment with sufficient accuracy. Note that the TC is aiming at monitoring its contract partner, the TSP, as a whole. TC's aim is not to check each Road User's compliance on an individual basis. This means that there is no need at this stage to stop vehicles on the road or to read out detailed data from any on-board unit.

The TC collects the road usage from transactions recorded by the RSE. In turn, the TC, from that transaction only knows the OBU ID and the TSP it is associated. The TC sends the daily transaction list to each responsible TSP who allocates the transactions to the Road User accounts that the TSP manages. In return, the TC receives a reconciliation report and recognizes payment for each transaction agreed by TSP. Discrepancies and irregular transactions are resolved in the reconciliation process.

The TC also vets IBTs that are recorded with the TSPs in its TC domain. These are also reconciled and the remaining IBTs are further handled with the TC. These residual IBTs can be interchanged with the other TC domains and reconciled between the TCs. The TC can handle these remaining, unclaimed IBTs as violations and initiate enforcement action.

The TC can measure accuracy and audit the reconciliation of revenues with each TSP. The TC may want to employ or require the TSP to employ an independent auditing firm to audit the TSP accounting process and receive a copy of such independent audits. Since the TC writes the agreement with the TSPs, this can be a standard condition of the contract entered into by the TSP and TC.

The TC also can internally reconcile road usage on any segment with the OBU transactions, IBTs and its own accounting for exempt and bad account transactions. The use of ITS traffic measurement data can be used to cross reference the traffic counts and ensure that overall accounting for traffic is managed. Additionally, the use of video and traffic counts on each section provides the TC with data to report to the Road Owner (ODOT) traffic and congestion conditions on each segment in the road network. In order to achieve sufficient precision in the monitoring and control, a TC will combine at least three different methods; audit of TSP operations, reconciliation with other systems, and statistical analysis of patterns in the traffic flow.

The TC in Oregon can also use the data to produce equity ratios for each class of vehicle and assist ODOT in the submission of the bi-annual equity reports. The results of these reports to the Oregon Legislature may effect changes in rates which the TC installs and informs the TSPs of the rate changes per class of vehicle. The TSP handles the customer relations and marketing to inform the Road Users of the changes and the date they go into effect.
Figure 204: TC collects information from several sources in order to ensure the accuracy of TSP reporting; audit, reconciliations, and statistical analysis.

Through these above-mentioned methods a TC can spot anomalies in the reporting flow, and gather supporting evidence if they believe that a certain TSP does not report all its subscribers' road usage as expected.

Should it turn out that a TSP is continuously under reporting the usage of its subscribers, either as a result of intended deception or from negligence, it might lead to the TC recalling the authorization of the TSP to operate in the domain as a termination condition in the agreement between the parties.

If instead the TSP, after being challenged by the TC, finds out that a group of their subscribers have been cheating, for example by altering the functionality of on-board equipment, then the subscribing Road User has two potential litigations to look forward to, One case under civil law, for violating the terms of use of the subscription, and one case for failing to meet the self-declaration requirement, which the TC might choose to hand over for prosecution.

Conversely, if a TSP turns out to manage its measuring and reporting flawlessly over an extended period of time, there is room for the TC to reduce its substantive auditing efforts and make life simpler for the TSP. Thereby the TSP has a strong incentive to develop its internal quality control in order to reach a higher level of cooperation and trust, and to proactively ensure that accurate reporting becomes a natural part of the competition among TSPs. The level of competition between TSPs assists in gravitating the TSPs to an acceptable level of efficiency that is both understood and clearly known by the TC through its statistical analysis and independent audits of the TSP.

An important aspect of having TCs verify TSPs compliance as opposed to checking the road usage directly is that the control effort follows the contractual relations. TCs have agreements with TSPs to carry out the measuring, and therefore it is natural that it is the TSPs who are held accountable to the terms and conditions they have agreed in accordance with principle two above.

6.5 Principle 5: Toll Service Providers monitor and control road usages

A TSP is responsible to ensure compliance among its subscribing Road Users. When a Road User signs up with a TSP a contract is established and the subscriber receives the on-board unit chosen by the TSP off the certification list to measure and report road usage. It is then in the TSP's interest to
ensure that the equipment operates as intended and that the user does not attempt to obtain any unfair advantages by using the equipment incorrectly or by manipulating its functionality. Exactly how the TSP goes about to achieve this is up to each TSP.

Different TSPs will solve the compliance control differently depending on what technical solution they have chosen, but also depending on the level of trust they have managed to establish within their customer relation. In some cases, the trust is built up not only through the OBU usage, but when that device is also used in conjunction with other value added services. In many cases, the Road User will place a higher value on the OBU when it is used for application that the Road User finds particularly useful. For example, an OBU that also provides traffic information or route selection based on traffic levels on each potential link of the trip. In such cases, the OBU functionality enhances the Road User’s appreciation of the equipment. The TSP in monitoring the OBU has more data points to ensure that it is working properly. Overall, the synergy of the value added services and the collection of road usage charges can mesh harmoniously given the TSP’s creativity and freedom to choose and select their own technology. Again there is room for gradually relaxing the control effort as confidence is gained by the TSP with the Road User and the TC with the TSPs monitoring and quality control.

Eventually each TSP must put together a package of checks and controls which as a whole is powerful enough to keep the TC happy, at the same time generates low cost of operation to the TSP. Likely candidates are analytical review of traffic patterns, remote OBU readouts, and auditing.

Figure 21: SP checks that Road Users adhere to the conditions they have accepted by subscribing to the service. Remote reading of the OBU, auditing, or statistical analysis can do this.

As earlier, compliance control follows the contractual relations. The TSP is monitoring the compliance of an agreement in which they are part.

6.6 Principle 6: Toll Charger monitors and controls non-subscribing Road Users.

Regardless of what conceptual solution the TC had in mind when introducing electronic fee collection, the question always arises how to deal with users who flatly reject to participate, and do not register their use, ignore any incentives to sign up with a TSP, and neglect any calls to install on-board
equipment. For these a solution is needed to catch the residue of users, who are not recognized any other way. And since the Road Users in this group, by definition, are not associated with any TSP, or the TC accounting, the responsibility for compliance control falls back to the TC, who must identify and enforce the offenders.

When a TC designs its solution for this monitoring and control activity it will again be forced to weigh the cost of control against the value gained from it. The value stemming from a compliance control process is partly the additional amount of toll that is collected thanks to the control, but there is also value in the increased trust for the system as a whole created by the existence of the control function. Only if the transport industry knows that cheaters are eventually caught and punished, they will perceive the system as fair and reasonable for the competition in their market.

The trust in the system is also a key component of the relationship between the TC and TSP. The TSP will formulate business plans based on an estimated number of Road Users paying for their road usage. The formulation of this estimate or modelling will be based on the trust that the TC will monitor and enforce non-payment or evasion of payment. The TC therefore must design and implement a satisfactory level of enforcement and share with the TSP on a continuous basis that it is improving or maintaining a high level of enforcement in the TC domain.

![Figure 226: Road Users who do not subscribe to any SP services are still subject to the mandatory self-declaration, whose compliance is checked by the TC after vetting IBTs with TSPs and enforcing all non-account associated road usage through police and courts.](image)

Compliance checking of in-state vehicles can be carried out by reconciliation of other domestic systems and identify anomalies. If fuel consumption, bookkeeping, and odometer readings all indicate more road usage than what has been reported, TC has a strong case that leakage is appearing in the TC domain.

Out-of-state vehicles, for which there is less access a systems of comparison, are checked by using the same infrastructure established to create the statistical information about traffic on the roads for monitoring TSP compliance. Vehicles entering and exiting the TC domain are registered through video
sources, and accounts are kept on repeat violators. Enforcement is focused on those with the largest outstanding debt first; thereby costly spot checks are reduced.

It is not only cheaters who drive without any on-board equipment and subscription. Also Road Users who have chosen the option of manual self-declaration will appear on the roads without any on-board equipment.

In principle, the actor offering a self-declaration option will make the TC a kind of TSP, or an actual TSP, only this one does not issue any on-board units, applications for smart devices or establish long term relations with its customers. For the TC, it becomes necessary to keep vigilant and perform the necessary reconciliation processes with all TSPs and its own traffic and congestion management statistics to cross reference and filter out paying and non-paying Road Users before initiating an enforcement activity. This is done by the combined efforts of the reconciliation process, vetting of IBTs with each TSP and internal cross referencing traffic flow data collected by ITS systems and video image capture on each segment of the TC domain.

6.7 A way forward
Not everyone might agree to the full extent of the six principles outlined here. Perhaps some minor modifications, or even a completely different set of principles, would be needed in order to reach a solution that a majority of Road Owners in various states across the U.S. may agree on.

Regardless of which, agreeing on one common set of principles for roles, responsibilities, and incentives is essential for achieving interoperability in autonomous systems. Harmonizing the technical interfaces is not on its own a sufficient substitute; If one EFC system is based on mandatory self-declaration and another is based on mandatory use of a proprietary OBU, or if one wishes to exercise compliance control through a 5.9 GHz Intellidrive℠ for all vehicles where they happen to be located, and another based on where they are registered, then the underpinning legal framework is likely fall short of supporting interoperability, even if all parties use the same technical interfaces.

Agreeing on the principles for roles, responsibilities, and incentives is the most challenging task in achieving interoperability for autonomous systems. But once it is done, getting the technical interfaces in place to support it will be a less daunting task.

6.8 Agreeing on what to include in the reporting
In addition to the principles for roles and responsibilities outlined on a high level here, there are still a number of parameters on which ODOT must concur. The perhaps most important one is to agree what level of granularity is required for the information declaring road usage, sent from TSP to TC. Is it enough with the total amount to be paid, or must there be a specification for each vehicle, all its routes, where and when it has traveled? Something in between is probably optimal, where accumulated distance per type of road and time slot is reported.

The degree of detail required in this interface is not only driving cost of operation. A too high granularity can also limit the technical flexibility. Should ODOT for example raise a firm requirement that each vehicle report contain time stamped positional records, any solution trying to protect the end user’s integrity and privacy by dealing with aggregated information is unable to compete in that toll domain.

A TC can, however, have several reasons to wish for more detailed data than what is needed for the core charging operation. Firstly, and most likely, a TC might wish to gather as much detail as possible, as this information can be used for compliance checking. In this case it is important to keep reporting for charging separate from the information needed for control purposes. Principle four above describes how a TC can exercise a high degree of control of a TSP’s compliance, without requiring any additional level of detail in the usage reporting.
Secondly, a TC might want the detailed journey data to reuse for other purposes, such as traffic monitoring or planning. This is also a case where it is likely to add more detail than necessary for the core functionality, and thereby make interoperability more difficult. In order to create the traffic monitoring system desired it is probably better for the TC to use the information which is collected as part of the TSP monitoring (principle four) and for monitoring of non-subscribing Road Users (principle six).

It is also possible that TSPs take an active stance and reuse the usage traffic data they collect and generate depersonalized aggregated traffic flow information, which they can market as an additional service. Any business with an interest in up to date information of traffic flows can then subscribe to that service. It might be ODOT or city planners, as well as radio stations that broadcast traffic update or satellite navigation providers with integrated traffic information.