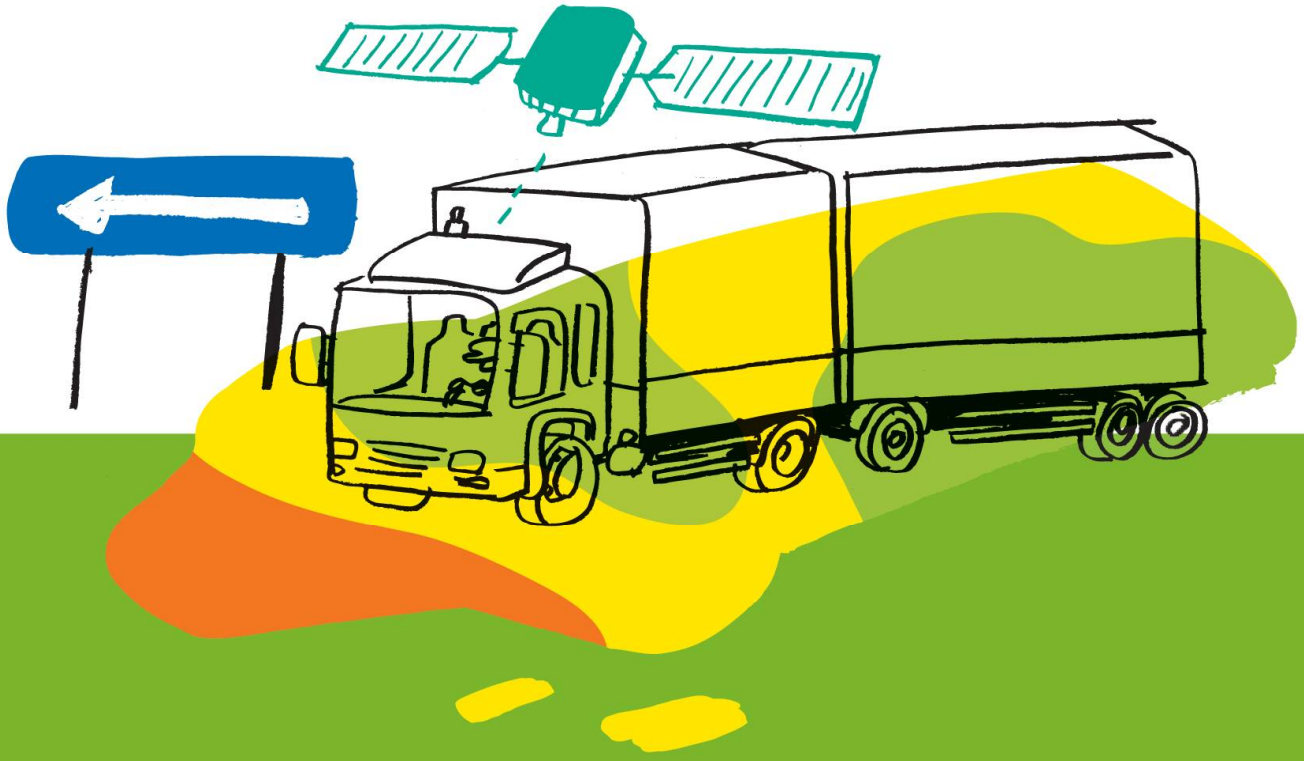

A market based approach to achieve EFC interoperability in Europe

Carl Hamilton, Policy Technology

arena

ARENA REPORT 2008:5 2008-02-29

The ARENA project

ARENA is a national project that aims to build competence for a future introduction of a road user charging system for Heavy Goods Vehicles (HGVs) in Sweden. The project has been developed in accordance with EU Directives and the Swedish public authority plans to introduce a kilometre tax for HGVs. ARENA started in 2006 and is financed by the Swedish Road Administration and the Swedish Governmental Agency for Innovation Systems. NetPort.Karlshamn is the project coordinator.

The approach of ARENA is to take a wide view and not only focus on technology. Innovation potential, consequences and possibilities related to an implementation of road user charging is also important as well as respecting that different stakeholders have different needs and requirements. This requires interaction between relevant stakeholders at an early stage. The role of the ARENA project includes the following elements:

- acting as broker both between groups of stakeholders who normally do not meet and between competitors within the same group
- develop and support knowledge both within the project but also as a coordinator between other projects

A concept for a kilometre tax system in Sweden is developed with a functional approach, which does not prescribe any technical solutions. The concept is generic rather than specific, in the sense that it should be possible to implement the result in several ways. Hence, we are trying to define the system independently from its final technical design. The motivation for this is that the time horizon for realisation is far ahead, maybe 3-6 years, and we can expect considerably changes in technical preconditions over this period. The concept includes a number of characteristics that differs from existing systems, which will reduce cost, promote innovative solutions and enable European interoperability.

The work of ARENA will continue in ARENA 2.0, where the concept will be further developed in close cooperation with the industry and relevant authorities and administrations. A full-scale demonstration will be developed for the ITS World Congress in Stockholm 2009.

Swedish Road Administration

The Swedish Road Administration (SRA) is the national authority assigned the overall responsibility for the entire road transport system in Sweden. SRAs task is to co-operate with others to develop an efficient road transport network in the direction stipulated by the Swedish Government and Parliament. SRA has been commissioned to create a safe, environmentally sound and gender-equal road transport system that contributed to regional development and offers individuals and the business community easy accessibility and high transport quality.

VINNOVA

VINNOVA (Swedish Governmental Agency for Innovation Systems) is a State authority that aims to promote growth and prosperity throughout Sweden. VINNOVAs particular area of responsibility comprises innovations linked to research and development. The tasks are to fund the needs-driven research required by a competitive business and industrial sector, and to strengthen the networks that are such a necessary part of this work.

About this report

This report is produced on the initiative of the ARENA project.
The project has presented a conceptual solution for how a distance based HGV tax can be introduced in Sweden. This report broadens the scope, and looks at in what European context a Swedish solution would have potential to thrive and interoperate with neighboring systems to the benefit of the economy in general and the EFC industry in particular.
Invaluable reviewing and feedback has been received from Ulrik Janusson, Johan Hedin, Inger Gustafsson, Jonas Sundberg, and Samuel Henningsson.

Stockholm, November 21st 2007

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1 Executive summary

So far, the market for electronic fee collection (EFC) has not on its own established any comprehensive European interoperability between different charging systems. The European Commission sees any further fragmentation of the market as increasing the difficulties to reach their vision of pan European interoperability, and has consequently issued a Directive aimed at harmonising the technologies and procedures employed in electronic fee collection. The purpose of this report is to challenge the ongoing harmonisation efforts within the Union with an alternative market based approach. The report aims at answering the question; *How should the EFC market be structured in order to maximise market dynamics and create strong incentives for the actors to solve the issue of interoperability themselves?*

In answering this question, two different models are outlined, one regarding those toll domains where DSRC systems are employed, and one for those using autonomous systems.

In the first model, aimed at domains with DSRC systems, a strict separation between toll chargers and toll service providers is proposed. This is similar to the split between providers of infrastructure and services, which has become commonplace in markets such as electricity and railroads. The purpose is to isolate a natural monopoly which is part of the toll charger's operation, and to open the remainder of the industry for continuous competition. This way the end users become customers rather than recipients of a mandatory service, while offering interoperability becomes a competitive advantage for service providers.

In the second model, a suggestion is laid out for how autonomous systems can be organised differently compared to traditional DSRC based system, based on the observation that the different technologies create different market conditions. The suggestion consists of six principles, offering the end user a real choice between service providers, and service providers with a real choice as to the design of their systems.

In at least three areas these models challenge the existing Directive and forthcoming Decision;

- **Actors and roles:** In the Directive and working draft of the Decision, a role model is used where distinction is made between the responsibility of the end user, toll service provider and toll charger. There is however nothing preventing one and the same actor from combining the roles toll charger and toll service provider in one organisational body. This report claims that requiring a strict separation between these roles cultivates competition and gives the actors strong incentives to establish interoperability on their own.
- **Harmonisation of methods for measuring and reporting.** The directive and draft decision is attempting to establish interoperability partly by harmonising the technologies and procedures used, both for DSRC-based 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.
- **Design of the control system.** In the draft Decision, a framework for a common control transaction is laid out, based on the interface for short range communication of the onboard unit. This report argues that for autonomous systems, making mandatory such a detailed interaction with the onboard unit is of more harm than benefit, as it is limiting the toll service provider's right to design his service in an optimal way, and that the control process can be solved more effectively and at a lower cost by other means.

2 Background

The European market for electronic fee collection (EFC) is characterised by large contracts, where governments or private road owners sign wide-ranging deals for system construction and operation with a single contractor. A small number of top tier system integrators and EFC 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.
From an end user point of view, the EFC 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. Interoperability exist to some extent on a regional basis, but as an exception rather than a rule seen over the entire Union. Toll chargers does not under current circumstances have strong enough incentives of their own to overcome the challenges involved and establish interoperability between each other.
This report deals with the issue of how the market circumstances can be changed, in such a way that the actors themselves chose to introduce interoperability, because it is in their interest to do so.
As a part of EU's Lisbon strategy, the European Commission has signed up to the ambitious goal that the EU shall become the most competitive and dynamic knowledge economy in the world. For the EFC industry, at least three goals can be derived from the commitment of the Lisbon strategy.

1. In order for the transport industry to operate effectively and compete fairly, any system for electronic fee collection must be simple, interoperable and cost effective for the end users.
2. Among toll service providers there must be a real and ongoing competition throughout the entire operational period, with a responsibility not only to toll chargers but also to end users. New entrants from other industries must have a real possibility to establish themselves in the market.
3. Among equipment manufacturers innovation must be encouraged, with incentives for continuous improvement of the solutions offered, not only for the toll charger and service provider, but also for the end user.

This set of goals is wider compared to what has effectively been the case within EFC traditionally. Priorities of the road owners have been dominating the market, as it is them who 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 A dynamic market for DSRC based systems

3.1 Roles

Within the EFC industry, a model has been developed throughout the years, describing the different roles an actor can take on the market. The three main roles of the model are; the *Road User*, who can be a private motorist or a haulier company. It is the road user who is ultimately liable to pay for the road usage. A road user can have a subscription with a *Toll Service Provider (TSP)*, who might provide the road user with a piece of onboard equipment (OBE). The TSP also collects payments from the user, for example by invoice, based on a road usage specification sent from the *Toll Charger (TC)*. The TC owns and manages the road side equipment and the system for gathering and processing passage information.

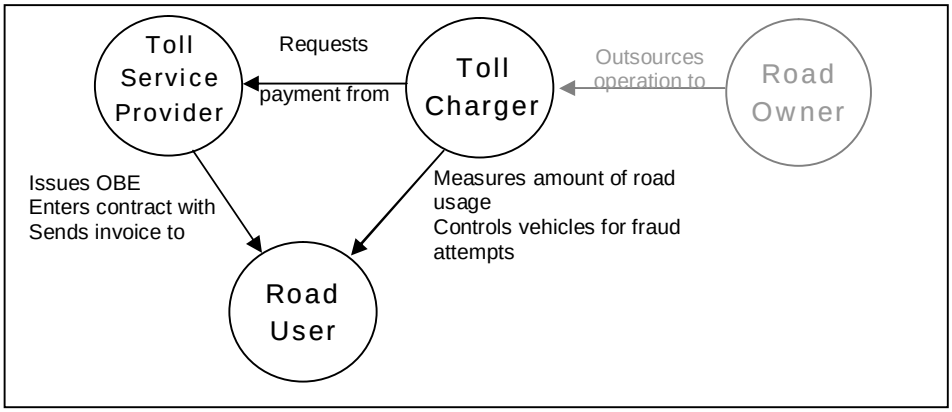

Figure 1: Roles and responsibilities within DSRC EFC

Roads are typically owned by governments, but in some cases private or public-private hybrids have the role of road owner. When a road owner assigns the role of TC to an actor, the operation can span over an entire country, a city core, a number of road stretches within a region or a single bridge, tunnel or mountain pass. Within such a toll domain, the TC is the sole representative of the road owner's charging capabilities.

3.2 Actors

An actor who is assigned TC in a toll domain is in most cases also trusted by the road owner to act as TSP within that same domain. This means that the actor who has an operational contract for conducting the on-the-road activities is normally also issuer of onboard equipment and collects payment from the road users. So by observing actors rather than roles, the primary relationships look more like the chart below, where a combined toll charger and toll service provider (TC/TSP) has all the relations to the road user. The dual-role actor TC/TSP thereby becomes the sole supplier within his toll domain, not only of on-the-road activities, but also of the services related to invoicing and payments.
From the TC/TSP:s point of view, the road owner is the customer. Keeping that customer happy is a top priority if they want to win future operations contracts and retain their business. Keeping the road owner happy is primarily about 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 road owner's evaluation of a TC/TSP. Because traffic in automated toll lanes normally generates less operational cost than those who pay manually, there is a clear incentive for the TC/TSP 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 is a better deal for the user than not doing so, the TC/TSP has established enough incentives for the road users to avoid manual alternatives.

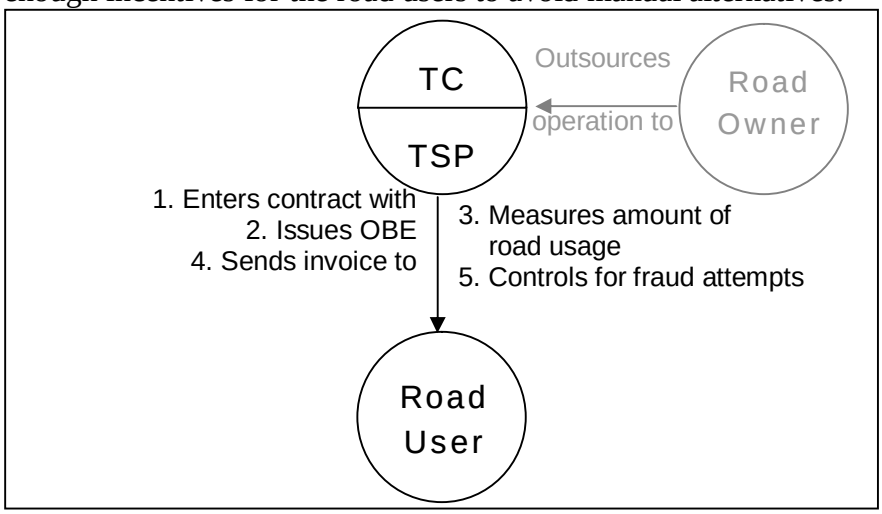

Figure 2: Roles distributed on actors as it looks in most real life implementations

3.3 Interoperability

Now it might happen that some road users travel on roads in more than one toll domain. They will then need to sign up with the local TC/TSP in each domain, who will also provide them with the same number of OBE:s. Since it is not very practical for the user to keep several subscriptions in parallel, there is demand from the users for an interoperable OBE with an associated cross domain subscription.

There are some cases where this type of coordination have been put in place in practice in Europe. When that happens, the distinction between the role of TC and TSP starts to make a difference. Because it is with the TSP 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 usage and passes on the request for payment to the issuing TSP. This is illustrated in the graph below.

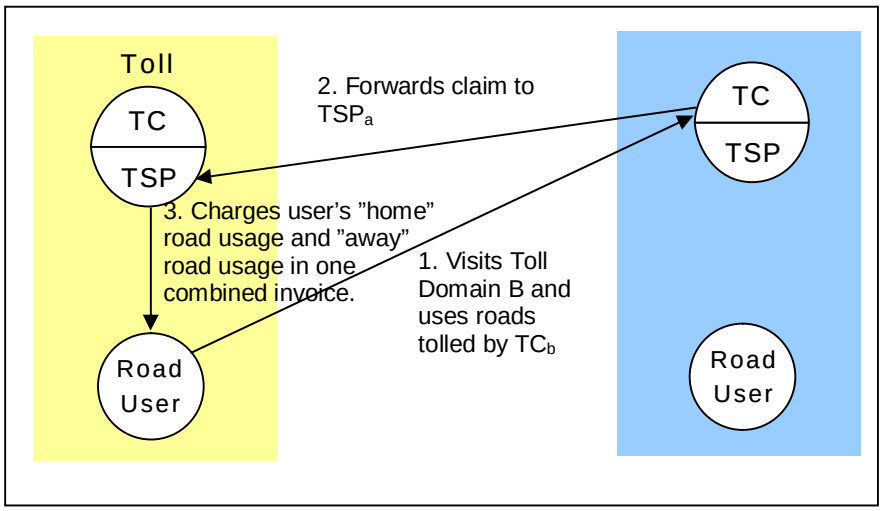

Figure 3: Interoperability between two toll domains means that the distinction between TSP and TC is again relevant, but only for visitors from the remote interoperable domain.

In a systems where OBE usage is optional, one of the main incentives for a TC/TSP to establish interoperability is related to the extent its introduction is expected to reduce the operational cost, by achieving a higher share of automatic identifications and payments.

If a large share of the traffic in toll domain is bogging down the manual payment options, and at the same time already has a subscription with a TSP in some other toll domain, then it might be worthwhile starting to accept those visitors' onboard equipment.
In systems with mandatory use of OBE the corresponding saving is derived from not having to issue OBE:s to visitors who already are equipped from some other system. The logic is the same, in that the TC/TSP incentives to invest in interoperability is dependent on the share of potentially reusable OBE:s from other toll domains circulating in the system.
There is a cost side to be considered as well for any TC/TSP 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/TSP 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 onboard equipment, one for each toll domain, TC/TSP:s have no incentive for introducing interoperability, as there is no cost savings to be gained from it. On the contrary, the TSP/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/TSP.

3.4 Market structure

On a map of Europe some toll domains coincide with countries, others with cities, regions or single road stretches. Every toll domain has by definition one TC, which in most cases also happens to be TSP for users in that domain.

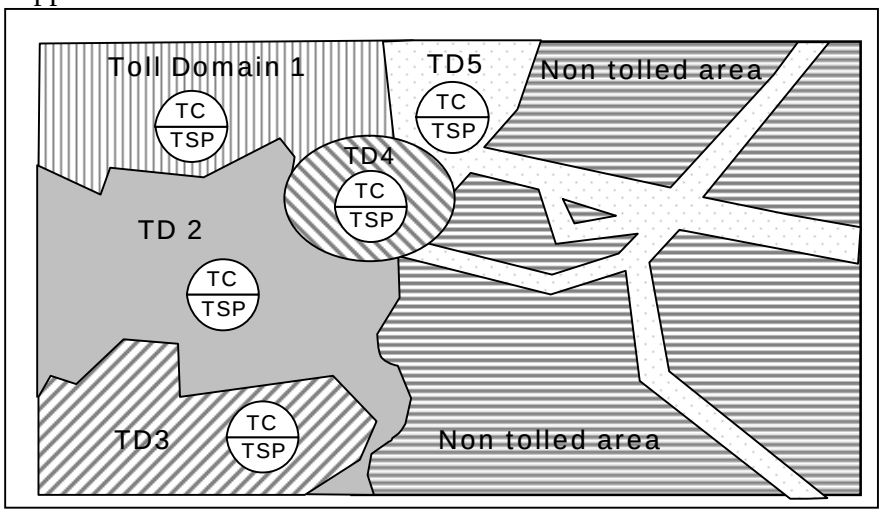

Figure 4; Generic map illustrating five neighbouring toll domains with each one having a local TC/TSP

On the map above, five neighbouring toll domains are depicted in a generic manner. Each domain has its own combined TC/TSP. This situation resembles the circumstances experienced in Europe up until the early 1990:s in the markets for fixed line telephony[1], electricity 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

[1] Sometines a comparison is made between EFC and GSM based telephony. One distinguishing difference is that GSM is not a natural monopoly. Instead there are several suppliers competing with their own parallel infrastructure within the same area.

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 travel by train.
When it came to international telephone calls, using electric power from plants in other countries, or travelling abroad by train, there were normally interoperable solutions available making that possible. Local monopolies made deals with their counterparts in other countries, and connected calls, power, railroad traffic through each other's systems when so required.
Industries such as these three mentioned here are characterised 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 train company ran on their own tracks, and that every telco 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 of the 1980:s and 90:s, many European governments, urged by the Commission, 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 power producers, telcos and train companies came to compete on a platform of common infrastructure.
Within the framework of DSRC based EFC, the business conducted by the toll charger 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 toll booths and other equipment in parallel on the road.
There is however nothing to prevent TSP:s 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 onboard equipment, as long as the onboard equipment can communicate with the infrastructure that TC has made available.
Was one to apply the same logic of deregulation on the EFC industry as has been done on the markets for fixed line telephony, electricity and railroads, the combined TC/TSP:s would be split up. Each toll domain can be compared to a country for those other industries, and the TC activities make up the natural monopoly as they are based on the single instance infrastructure.
In this scenario TC's primary goal remains to charge the toll at lowest possible cost rate. The methods available for doing this are however changed. Instead of itself issuing OBE subscriptions to road users, the TC has to go out to the market and find one or many TSP:s who are willing to offer payment services for the toll domain. By establishing a clearing agreement with a set of TSP:s whose subscribers collectively make up the majority of traffic in a TC:s toll domain, the TC is able to reach a large share of automatic payments.
Whether to invest in interoperability or not is no longer a negotiation between two TC/TSP:s, based on making mutual savings in operational cost. Instead, interoperability between TC and TSP:s becomes a necessity in order for the TC to get paid by the road users, and a method to directly reduce operational cost. Thereby TC:s have a strong incentive for establishing interoperability, as there will be fewer manual payments by interconnecting with more TSP:s.
A TC is still closely tied to the road owner. Its main activities will be to operate the road side equipment, gather passage data, identify passages and forward them to the right TSP, and to enforce non compliance behaviour on the road.

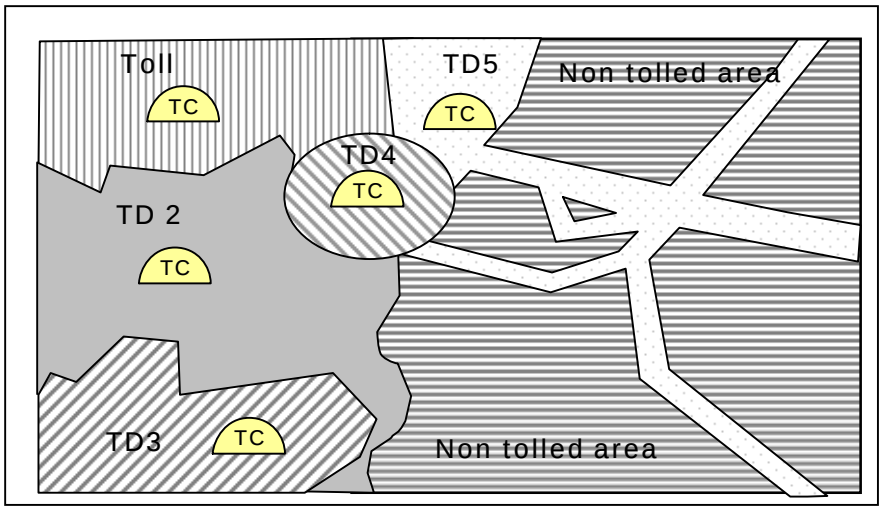

Figure 5: It is only the toll charger part of TC/TSP which has a natural connection to the toll domain, by owning and maintaining the equipment physically located there.

The other half of what used to be the TC/TSP, i.e. the toll service provider, brings with it the business of signing up road users and issue onboard equipment in its part of the split up business. The TSP is now no longer tied to a specific toll domain, but acts instead freely over the entire European EFC market.

There is nothing to say that the number of TSP:s shall be the same as the number of TC:s, 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, but instead the road user. A stand alone TSP can choose as its strategy to offer road users a service valid over a lager area, across multiple toll domains, or they might wish to offer a simple and low cost solution which only works in one or a few domains.

By allowing TSP:s to operate across multiple toll domains the total market for toll service subscriptions gets larger, and thus allows TSP:s 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.

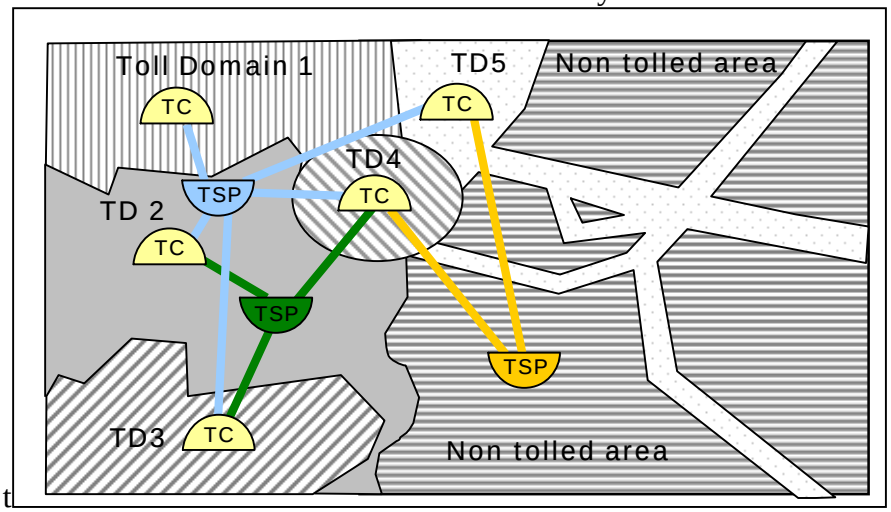

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Figure 6: A TC is by definition bound to its local toll domain, while a TSP can associate itself with any TC regardless of its origin. A TSP does not even have to be based in an area where roads are charged for at all.

3.5 Implementation

It might seem radical to suggest a forced split between TC and TSP, and instead tie TSP:s prime loyalty to the end users. But going back to the roles and responsibilities model depicted in figure 1, it resembles more what is suggested here than the real life situation in many countries and toll domains today, where the TC/TSP monoliths are prevailing.

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 TSP:s in order to make use of the DSRC 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.

Common European legislation can be useful in the pursuit of improved competition in the DSRC-EFC market and to encourage interoperability. Such legislation could add some pressure on harmonization of technical DSRC 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 TSP.

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 European departments of transport and other 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 TSP:s to deliver the complete service, circumstances are established for road users to choose from several parallel offerings.

Alternatively, the actor contracted as TC might be allowed to act as TSP as well, as long as it keeps the two business operations separate, and treats all other potential TSP:s in a fair and equal way, not offering any preferential treatment to the internal TSP.

4 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 onboard equipment. Even though such onboard 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 rich[2] onboard equipment are 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 as *Global Satellite Navigation System / Cellular Network* (GNSS/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.[3]

4.1 Principles for autonomous systems

The technical characteristic that lies in that autonomous systems measure road usage in the vehicle as opposed to by the road side has far reaching consequences, for the kind of system architecture opportunities as well for the business models made possible. As the onboard equipment is issued and controlled by the TSP, while the road side is TC's 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 TC. Instead the onboard equipment can communicate with its issuing TSP directly, after which TSP can pass the road usage information required to the TC in the toll domain visited.
It does not matter if one sees this flow of information – from OBE to TSP to TC – 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 DSRC based systems. In either case, the fact that it is sufficient for an onboard unit to communicate with its issuing TSP only, and never anyone else, is significant for how interoperability between toll domains can be solved.
Accepting that the onboard equipment only has to communicate with its own 'home' system means that there is no need to harmonize the external interface of the onboard equipment. The need for a common interface of the onboard equipment is replaced by a need for how the different actors interact with each other, and that need 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 is presented;

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[2] Functionally rich is said in relation to DSRC tags, without making any distinction between a thin and a thick client.

[3] Such alternative technologies could for example include gyroscope, odometer/tachograph, compass, or ground based positioning systems to measure usage, and removable cards, WiMAX or DSRC for reporting data.

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
Principle 4: Toll Chargers monitor and control toll service providers
Principle 5: Toll Service Providers monitor and control road users
Principle 6: Toll Chargers monitor and control non subscribing road users

4.1.1 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. Advance 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.
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 with that who offers the most attractive conditions and services. The road user has now subscribed to the service *getting help* with reporting their road usage. Responsibility for truthful reporting rests ultimately with the road user himself.

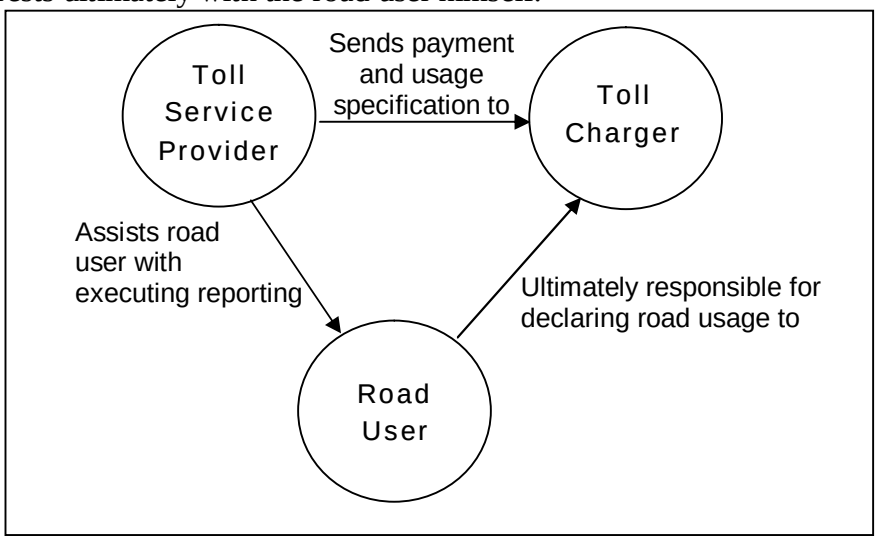

Figure 7: The road user is responsible for declaring its usage information, but might choose to let a TSP assist with measuring and reporting . Information flow and responsibilities thereby differ slightly from what is typical in DSRC based systems .

This is the same principle used when someone use 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 possible that a TSP, as an additional service, accepts the credit risk for its subscribers, and offers a payment guarantee to its associated TC:s. Thereby the payment duty

is fulfilled even if some road users should fail to pay. 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 onboard 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 or a call centre. 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.

4.1.2 Principle 2: Toll Chargers set targets and quality requirements

For a TC the prime concern is to accurately capture as large share as possible of the traffic liable for road toll. This concern is reflected in a set of quality requirements used when selecting which TSP:s to award authorization to operate in the toll domain. TSP:s 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.
A TSP must, in order to get an authorisation 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 defining 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.

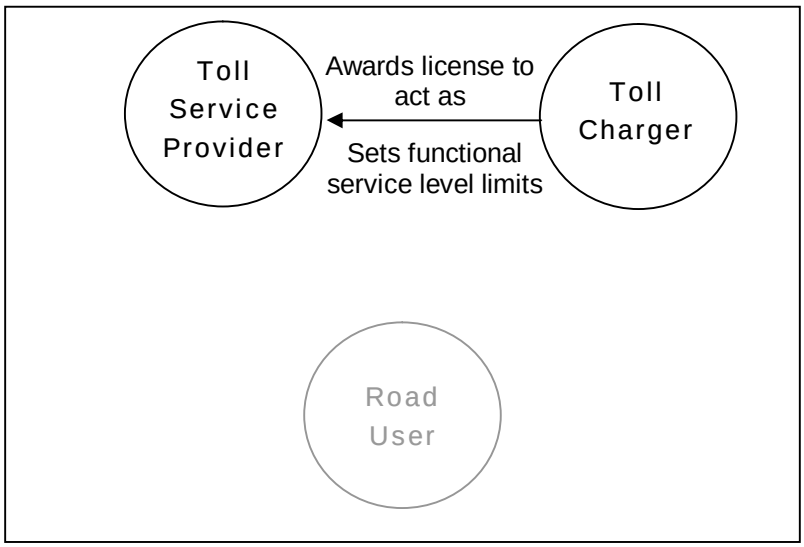

Figure 8: TC issues an authorisation to those TSP:s who can show that they can measure and report road usage with sufficient accuracy.

This way it is possible for actors who already have an installed base of onboard equipment to reuse them, as long as they reach the functional quality requirements raised. Such actors could for example be already established TSP:s 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 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 TSP:s to authorize for operation in its domain, as long as it is done on fair and market-based grounds. Only if the TC has the right to select and deselect which TSP:s to associate with, real competition is achieved, and TSP:s are incentivized to improve their performance in terms pricing, quality and service levels.

4.1.3 Principle 3: Toll service providers design their own solution

Because the TC does not prescribe any particular technical solution, and instead delegates to the TSP the whole issue of how to meet the quality targets, it becomes a TSP responsibility to design and develop the appropriate combination of equipment, information processing, and compliance control system, which, as a whole, fulfils the requirements on accuracy raised by the TC, and which the TSP deems can be successfully marketed to a segment of the road user community.
This freedom to design solution opens the market for yet to be established technologies and methods. Today most people agree that satellite positioning is the only method with enough accuracy to be used for positioning vehicles, and thereby measuring distance and determine tariff. 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 TSP:s does not become as powerful barriers for new market entrants.

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.

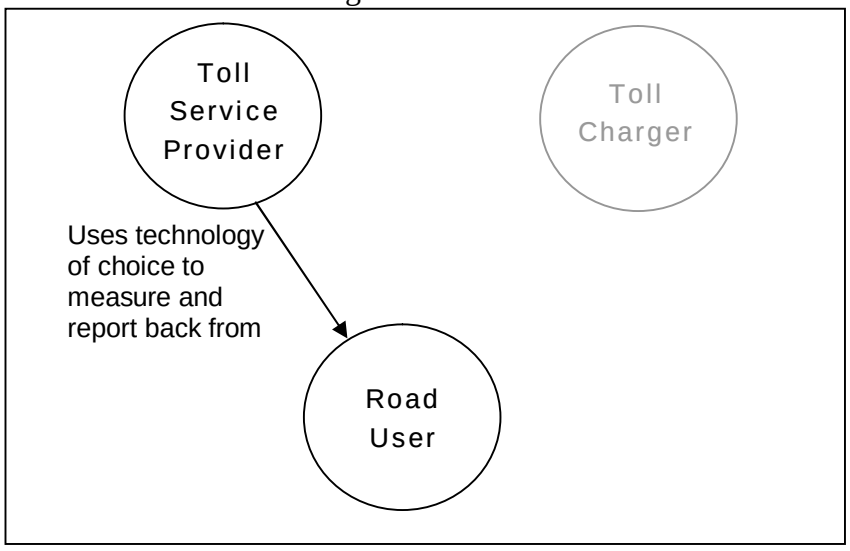

Figure 9: TSP is free to design their solution for measuring road usage without the direct influence of the TC. Different TSP:s can offer completely different solutions, associated to the same TC, from which the road user can choose.

In the market place, the effect is that several TSP:s have to compete for the appreciation of the end 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 vehicle 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 services. Those road users who regularly travel through many toll domains

probably appreciate seamless interoperability services. Ultimately, only the road users themselves who can decide what aspects they consider most important, and how much they are prepared to pay for the service.

4.1.4 Principle 4: Toll Chargers monitor and control Toll Service Providers

When a TC has authorised a number of TSP:s to operate in its toll domain, it must have some way of ensuring that the TSP:s are fulfilling their commitment with enough 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 onboard equipment.

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.

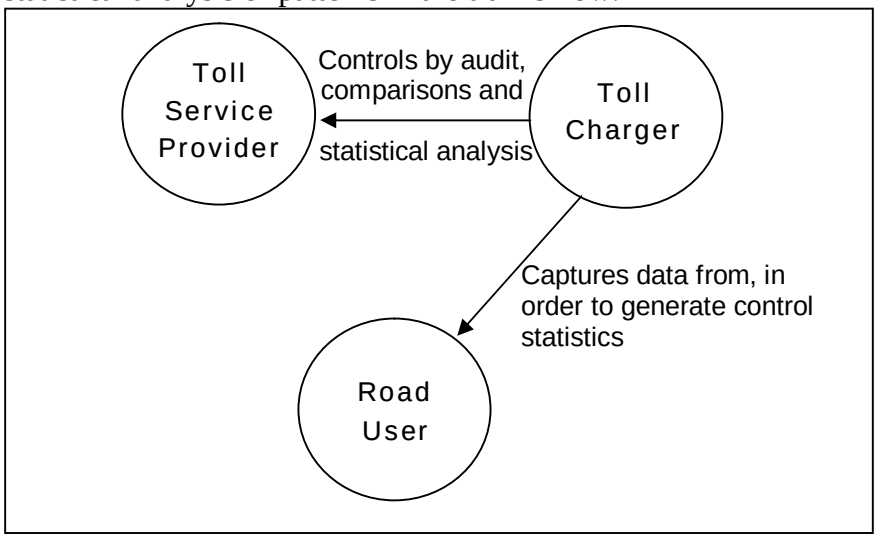

Figure 10: TC collects information from several sources in order to ensure the accuracy of TSP reporting; audit, reconciliations, and statistical analysis.

Through these three 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

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 onboard 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 TSP:s.

An important aspect of having TC:s verify TSP's compliance as opposed to checking the road users directly is that the control effort follows the contractual relations. TC:s have authorization contracts with TSP:s to carry out the measuring, and therefore it is natural that it is the TSP:s who are held accountable to the terms and conditions they have agreed in accordance with principle two above.
[Practical examples of how the monitoring and control can be carried out are further developed in Appendix 1]

4.1.5 Principle 5: Toll Service Providers monitor and control road users

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 onboard equipment chosen by the TSP 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 TSP:s 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 in their customer relation. Again there is room for gradually relaxing the control effort as confidence is grown.

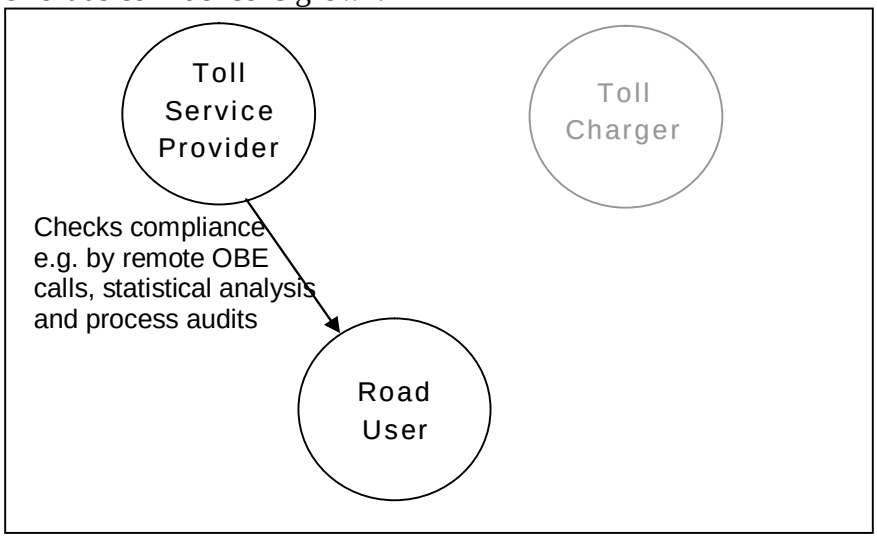

Figure 11: TSP checks that road users adhere to the conditions they have accepted by subscribing to the service. This can be done by remote reading of the OBE, auditing, or statistical analysis

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 OBE readouts, and auditing.
As earlier, compliance control follows the contractual relations. The TSP is monitoring the compliance of a agreement in which they are part.
[Practical examples of how the monitoring and control can be carried out are further developed in Appendix 1]

4.1.6 Principle 6: Toll Charger monitor and control non subscribing road users

Regardless of what conceptual solution 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 instructions to sign up with a TSP, and neglect any calls to install onboard equipment. For these a solution is needed to catch the residue of users, who are not recognised any other way. And since the road users in this group by definition are not associated with any TSP, 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.

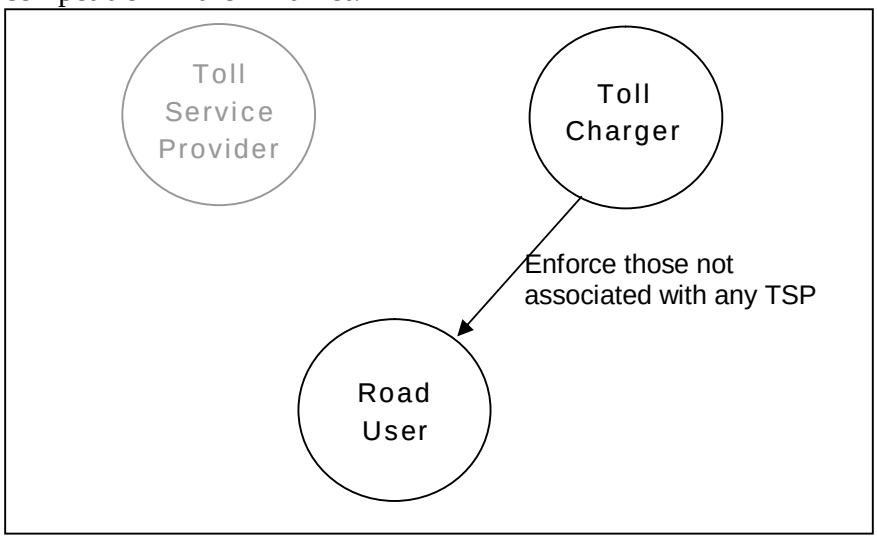

Figure 12: Road users who do not subscribe to any TSP services are still subject to the mandatory self declaration, whose compliance is checked by the TC.

Compliance checking of domestic vehicles can be carried out by reconciliation of other domestic systems and identify anomalies. If fuel consumption, book keeping, and tachograph readings all indicate more road usage than what has been reported, TC has a strong case against the road user.

Foreign vehicles, for which there is less access to 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 toll domain are registered optically, and accounts are kept on repeat violators. Enforcement is focused on the those with the largest outstanding debt first, thereby costly spot checks are not needed.

It is not only cheaters who drive without any onboard equipment and subscription. Also road users who have chosen the option of manual self declaration will appear on the roads without any onboard equipment.

In principle, the actor offering a self declaration option is also a kind of TSP, only this one do not issue any onboard equipment or establish long term relations with its customers. For the TC it becomes necessary to keep up to date lists of paying road users and the routes for which they have paid, so that these users can be filtered out before initiating an enforcement activity.

[Practical examples of how the monitoring and control can be carried out are further developed in Appendix 1]

4.2 The 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 Europe can 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 tolling system is based on mandatory self declaration and another is based on mandatory usage of an OBE, or if one wish to exercise compliance control 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.

4.2.1 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 European TC:s 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 travelled? 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 a TC 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 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 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 TSP:s take an active stance and reuse the usage traffic data they collect and generate de-personalised 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 road owners or city planners, as well as radio stations who broadcast traffic update or satnav providers with integrated traffic information.

4.2.2 Relation to EETS

According to the EFC directive of European Union, a TC must be able to point out at least one associated TSP whose services can be used in their own as well as all other European toll domains. This service is defined as the European Electronic Toll Service, EETS.
The approach of the directive is however only a requirement that the service shall exist, so that a TC can refer to it. There is no guarantee that the service will be practically useful or priced in a way that users will find attractive. Thereby there is a risk that the market, despite the directive, not will be characterized by pan European interoperability.
The approach suggested in this report is neither any guarantee that there will be a pan European service such as EETS. The service will be offered only if a TSP believes it can be sold to the road users, and if enough many road users are willing to pay for the additional cost incurred from being interoperable with every toll domain.
On the other hand, it is likely that this approach leads to the establishment of clusters of interoperable TSP:s and TC:s, gradually integrating, and that they eventually cover the vast majority of European toll domains. This way EETS can emerge as the last phase in a gradual market driven evolution, rather than through dictate.

Appendix 1 – methods for compliance checking of autonomous systems

1.1 TC checking TSP's accuracy

TC is monitoring and controlling TSP using the methods and techniques they have at hand. The most important ought to be auditing, reconciliation with other systems, and statistical analysis of traffic flows. The techniques described here are examples of how the compliance control procedures can be implemented in accordance with the principles. Note however that it is just examples and not part of the set of core principles.

1.1.1 Audit

Just like a financial auditor visits and verifies their client's accounting, a TC visits its associated TSP:s to verify their operation. The verification can be carried out as a substantive audit, where the auditor reviews a subset of transactions to verify their accuracy, but is more likely to be efficient in a controls based manner, where the auditor tests to verify the controls carried out by the TSP, to ensure that the internal control is sufficient for trusting the resulting calculations.

1.1.2 Reconciliation with other systems

Those vehicle fleets who belong within the same jurisdiction as the relevant TC can also be checked by comparing observations from other systems. By reviewing distance measured by the odometer or tachograph at official vehicle inspections the total distance made by each vehicle can be determined. Combined with review of customer invoices and other documents from a haulier operation it can be estimated how much of the operation is carried out in each toll domain or country. Fuel consumption and location for refilling add further to the reliability of the reconciliation.
Judged holistically, this sort of comparisons to data from other systems can be used to make a sanity check of reported road usage and determine whether a more detailed substantive audit is required or not. If for example a haulier company has 10% of its revenues from international traffic, but only reports 50% of its odometer measured total road usage inside the country, there might be reason to raise this with the associated TSP to determine if they meet their accuracy standards.

1.1.3 Statistical analysis of traffic flows

In most models for road charging either implemented or sketched for the future, the TC is taking a far reaching responsibility for checking the vehicles on the roads. This process make up a large share of the total cost in many implementations.
Instead of spot checking individual vehicles, TC establishes a system for continuous traffic monitoring, which could be implemented with a combination of existing technologies put together. Traffic recording stations are established and equipped with cameras and laser scanners, which can register the vehicle exterior and does not require any communication with the onboard equipment.
Additionally, DSRC beacons can be added to pick up vehicle and TSP identity transmitted from vehicle transponders, which are likely to be a part of most onboard units as it is needed for interoperability with road side centric systems.

The information captured will in most cases be sufficient to make a positive identification of a vehicle, with a picture of the license plate and possibly with a DSRC transaction to support it.
Based on the identification, vehicles are sorted according to what TSP they are using. The TC will not have a certain identification of 100% of the traffic, but over time they have accumulated enough statistics from key points in the road network so that they can predict with high precision how much they *expect each TSP* to report in, from within which vehicle categories and road types. These expected values are then compared to actual reporting, and TC can spot anomalies and knows which TSP:s to put pressure on.
Traffic monitoring stations are established at borders of the toll domain, and at a number of key positions in the road network. This way the TC can keep track of incoming and outgoing traffic, as well as collect useful statistics for analytical review.
Even if there is no complete reference installation available today capable of doing exactly what is suggested here, all functions described are available in commercially offered products.

1.2 Toll Service Provider's compliance control of its own subscribers

Typical testing methods available to a TSP include analytic review, remote readout from OBE, and auditing. The procedures described here are examples of possible implementations, not a specification of the principle itself.

1.2.1 Analytical review

By statistically analyzing the reported road usage coming in from the vehicles' onboard units, a TSP can compare patterns in different users' claimed road usage and spot anomalies. Subscribers whose reported road usage show unreasonable or abnormal patterns are selected for further scrutiny. Such anomalies can take the form of vehicles that never move at all, only travel on zero charge roads or at zero charge hours, make unexplained jumps from one place to another without reporting the route in between, drive considerably shorter distances than other vehicles in the same industry, or in any other way do not conform to expected patterns.

1.2.2 Remote OBE read out

One of the threats to the integrity of the TSP solution is the risk of someone managing to access the inner workings of the onboard equipment and make it send false reports. Real position and distance records might be replaced with fabricated data, so that they describe shorter routes or routes in areas where no charge is applied.
To counter this risk, a TSP might design the OBE in such a way that it uses multiple sources for each calculation, and when asked to is able to send raw data as well as computed totals, so that it becomes much more difficult to mimic a zero charge behaviour. A TSP might also use metadata from the data transfer, such as what mobile base station was first accessed when sending the report and compare to claimed positions. Such data is created after the records have left the OBE, and can thus not be replaced by the user.
A compliance control system should ideally be automated, so that it does not add any manual effort when increasing the level of control. It would also be beneficial if the parallel control system is only activated when a user has behaved in some way triggering a suspicion, so that most users are not monitored more than necessary to collect the charge.
There are numerous other possibilities for designing an automated control system based on some kind of parallel reporting, and it lies in the interest of each TSP to design and use the system which offers the best balance between achieved compliance and cost of the control.

1.2.3 Audit

Just as TC can include the right to audit in the TC-TSP contract, a TSP can include in the subscription contracts issued a right to visit the commercial road users, test their routines, and verify their compliance.

1.3 Toll charger's compliance control of non subscribing road users

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

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 etc. If a vehicle is registered in a domain, but have 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 embezzled toll and a fine can be issued.

Foreign 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 passing vehicles at key points in the road network and at 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 central system.

Automated license plate reading has become increasingly accurate in recent years, and it is likely that the vast majority, over 90%, 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 finger print. By taking into account visual cues from the images, such as vehicle decoration, stickers, dents and scratches 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 fraudsters, by focusing on violator accounts with the highest number of non reporting passage evidences. The enforcement agency 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 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 ongoing 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.

Terms

EFC	Electronic Fee Collection, in this text the term is used as fully interchangeably with road user charging, i.e. the act of levying a fee in direct relation to the amount of usage a vehicle is accumulating on a road
EU	I this document the term EU is used consistently for all aspects of the union, even those when *EC* would have been more accurate.
Interoperability	An agreement of technologies, classification, and procedures between a Toll Charger in one domain and a Toll Service Provider in another
TC	Toll Charger
Toll Charger	TC, a role held by an actor being the final recipient of toll payments in a toll domain, either by cash payment on site, or payment routed via a TSP. In systems employing road side infrastructure, this is operated by the TC.
Toll domain	The total set of road infrastructure covered by one and the same toll charger. Can be a country, a city core, a set of motorways or a single bridge, tunnel or mountain pass.
Toll Service Provider	TSP, a role held by an actor, in which the actor has a contractual relation with the road user and issues any onboard equipment if such is used. Often the actor who is TSP is also Toll Charger.
Toll	This text uses the terms *toll* and *charge* interchangeably, regardless of whether the fee levied is based per passage, per visit, or per kilometer.
TSP	Toll Service Provider

List of ARENA reports

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ARENA REPORT 2008:2. Sundberg, J., Janusson, U., and Sjöström., “A kilometre tax for heavy goods vehicles in Sweden – A conceptual systems design. Part 1: Requirements and preconditions”., SWECO VBB

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