A practical approach to Road User Charging
Road users will experience more road charging systems in the future, both in Sweden and abroad. The ARENA project contributes to efficient, technical, organizational and commercial solutions, nationally and within the EU.

This report summarizes the results of the second ARENA project, ARENA 2.0. The report is an updated and thematic expansion of the final report from the first part of the project,\(^1\) which developed a concept for distance-based road user charging for heavy vehicles according to the conditions that were given by a Swedish commission on road traffic taxation (SOU 2004:63). This report also shows how the feasibility of the concept from phase 1 was verified through trials attracting significant international attention. At the same time the original concept for heavy vehicles was expanded into a proposal for a coordinated national strategy for all types of road user charging systems.

Road user charges in Sweden include congestion taxes, bridge fees and road tolls, and might also include distance-based charges in the future. A basic requirement is that the road user (driving the vehicle) and the customer (paying the fee or the tax) shall experience the tolling systems as an integrated system with the same interface for the different functions of the systems. He or she shall also be able to use the same equipment and methods for all payments.

The Swedish road traffic system must be seen as part of the European traffic system. The EU Commission pleads for road user charges, with the intent to combat congestion, facilitate funding and internalize external costs.\(^2\) The test results of ARENA, presented in this report, show that it is possible to build interoperable road user charging systems for all kinds of vehicles according to the EU directive on interoperability.

This report also shows how the role model of ARENA can be translated into a Swedish context, with the Swedish Transport Agency as Toll Charger, responsible for collecting charges from all road users in the Swedish toll domains. This is relatively simple for vehicles registered in Sweden, but technology and changes in legislation are required in order to include foreign vehicles to ensure a complete and thus fair fee collection.

ARENA has also contributed to creating Test Site NetPort in Blekinge and Skåne offering a platform for extensive testing within the areas of e-transactions, road user charges, intelligent logistics and other mobile services. The partners involved in the test site offer expertise, software and hardware supporting the whole chain from research, development and demonstration to full-scale implementations. A goal for the future is to expand the operation and also include certifications, e.g. of EETS-services, the European service for road user charges.

The development of Test Site NetPort is coordinated with ARENA’s longterm goal to establish a research center for ITS (Intelligent Transport Systems) focusing on mobile solutions and e-transactions at the Blekinge Institute of Technology campus, NetPort Science Park in Karlshamn. The research group BLITS (Blekinge Logistics and ITS) has been established and intends to develop into a cooperation platform for researchers and those involved in the practical work jointly addressing the many challenges within ITS.

Current research focuses on technical questions regarding road user charging systems, with related management of information, as well as market and implementation problems concerning ITS.

ARENA will hereafter focus on continued development of the Swedish road user charging system within the frame of a Nordic and European cooperation. The goal is to simultaneously stimulate the operation in Test Site NetPort and the research and development within BLITS.

\(^1\) ARENA REPORT 2008:01 A kilometre tax for HGVs in Sweden – a proposal for a functional concept 2008

\(^2\) WHITE PAPER - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system COM(2011) 144 final
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1 From kilometer taxation to a national road user charging strategy

Road traffic causes a series of different negative effects that can be measured in monetary terms and are thus seen as costs. These effects are, for example, emissions of different kinds, congestion, accidents and noise. Making the users of the road network pay for these costs, to internalize the external costs, is one of the goals of the Swedish transport policy for the development towards a sustainable society. A better and safer road infrastructure is required for the increasing traffic, but funding these improvements is a growing problem. This asks for co-funding - for example through road user charges.

1.1 What ARENA offers

The ARENA project develops a future-oriented road user charging system and operates an international test site to demonstrate related practical solutions. At the same time ARENA lays the foundation for an innovative research center for e-transactions.

The first part of the project, between 2006-2008, was a result of political plans to introduce kilometer taxation for trucks and the necessity to harmonize potential national solutions with the European development. However, although national road user charging of heavy vehicles is introduced in more and more European countries, this issue has been removed from the Swedish political agenda and been replaced by other means of regional or local road user charging schemes, for example the congestion tax in Gothenburg.

The second part of the project, ARENA 2.0, had a slightly different direction than the first one. Focus changed from the development of a complete specification for a distance-based road user charging system for heavy vehicles to lay the foundation for interoperable road user charging systems in Sweden in general, including a strategy for dealing with foreign vehicles in these systems. The role model developed in ARENA 1, which is also envisioned in the so-called EFC-directive, play an important part in this strategy.

ARENA 2.0 has, together with several international actors, proven that the concept with competing toll service providers works in practice. Thanks to this, an internationally recognized test site has been established in the two southernmost provinces of Sweden, Blekinge and Skåne. The practical experiences from the field trials has supported the Swedish Transport Administration and the Swedish Transport Agency in their EU-work and also contributed to European development.

1.2 A joint arena

ARENA has established itself as a meeting place for all actors in the industry, both nationally and internationally, which lays a solid foundation for the wide approach that the project has chosen. With electronic fee collection as a starting point, the project, together with academy and business, promotes an innovation system built around the concept of e-transactions.

The project creates knowledge that contributes to a national strategy for road user charging. It sees great potential for in-vehicle co-operative systems that can support different ITS services. The information exchange can help the development of new ITS services, as well as improve the transport systems in a more sustainable direction and promote a better use of infrastructure in line with transport policy goals. ARENA is building expertise within the area of ITS.

ARENA has delivered reports that highlight different aspects concerning road user charging, a test site for advanced ITS services has been established and the first steps towards a research center have been taken. European compatibility for road user charging has been tested in practice through both the test site and the international cooperation, with positive impacts also on the European level. Representatives from the project have also participated in national and international conferences and have thus spread the results from the project and expanded the network.
Cooperation with other national and international projects and organizations has taken place during the time span of the project, for example Mobile IT – ICT for cargo on road, EasyWay, GSC and CESARE.

ARENA 2.0 was funded by the Swedish Transport Administration, VINNOVA, and the European Regional Development Fund. The triple-helix-actor\(^3\) NetPort.Karshamn was the coordinator of the project, supported by Sweco and Blekinge Institute of Technology.

This report, and the others that have been produced by the project, do not claim to represent authorities’ or other actors’ opinions. More detailed information than what is contained within this summarized report is available in the reports on the attachment list. The text also contains direct references to several of the reports.

1.3 The structure of the report

A review of the political and legal conditions for road user charging in Sweden is presented in chapter 2, as an introduction to the overview in chapter 3 of the steady European development towards more road user charging systems, especially for heavy vehicles.

Chapter 4 describes the role model that the trials are based on, which is a vital part of ARENA’s proposal for a national strategy.

The concept of a national system for distance-based road user charging (“kilometer taxation”) has been developed and tested in a full-scale demonstration involving the vital parts of such a system. The trials, and the cooperation with the companies that participated, allowed for a thorough analysis of the concept. The results are summarized in chapter 5.

The originally developed concept for distance-based fee collection has widened during the ARENA 2.0 project. It now treats the concept as a part of a national strategy for road user charging in general, which includes all current and upcoming Swedish systems. ARENA’s proposal for a national strategy also makes room for distance-based road user charges in the future. The proposal is explained in chapter 6.

The focus of ARENA 2.0 has been redirected, from originally concentrating on technical assistance for the procurement of a distance based or kilometer taxation system, to the development of a nationally coordinated approach to road user charging systems in general. The main objective has been to assist the Swedish Transport Agency and the Swedish Transport Administration in their work on developing a national strategy that unites Swedish requirements with the European development. Required changes and additions to the Swedish legislation are discussed in chapter 7.

One of the aims of the ARENA project is to promote regional development through the use of ITS as a tool for strengthening regional competitiveness, activity and employment. The field trials area that has been established in southern Sweden under the name of Test Site NetPort, which has been used by ARENA, offers a platform for an extensive field trials operation within e-transactions, user charging, intelligent logistics and other mobile ITS applications. The build-up of the test site is described in chapter 8.

ARENA has begun establishing a research center, BLITS (Blekinge Logistics and ITS), with focus on mobile solutions and e-transactions, located at the BTH campus at NetPort Science Park in Karshamn. The center is aiming to handle challenges and issues in ITS which both practitioners and researchers of today are facing. BLITS is described in chapter 9.

Lastly, chapter 10 describes the plans for the continued work with developing the national strategy in the European context and simultaneously stimulating the operation in Test Site NetPort and the research and development within BLITS.

\(^3\) Etzkowitz, H., Triple-Helix-the new innovational model. SNS Förlag 2005
2 Road User Charging in Sweden

Sweden joined the cooperation of Eurovignette with Denmark, Germany, Belgium, Holland and Luxembourg in 1998. Eurovignette is a time-based road user charge that covers heavy trucks above 12 tons. During 2005, Germany introduced distance-based road user charging and thus left the cooperation. A vignette that is paid for in one of the cooperating countries entitles to travel on the other countries’ road networks. The income from the road user charges is distributed according to a predetermined proportion between the cooperating countries. Some countries, e.g. Denmark and Belgium, are expected to leave the cooperation in the upcoming years as they are planning to introduce distance-based road user charges.4

Road user charges are financing the fixed Öresund and Svinesund connections. The Swedish State is engaged as a share holder of the two consortia which are operating and maintaining the road user charging systems. Several new infrastructure investments are currently planned that will be co-financed with the help of road user charges:

- Bridge over the bay of Motala, national road Rv 50 (approx. in 2013)
- Bridge over the fjord of Sundsvall, E4 (approx. in 2015)
- Bridge over the strait of Skuru, road nr. 222 (approx. in 2016)

During 2007, a congestion tax was permanently introduced in Stockholm, after a large-scale trial period the preceding year. The parliament decided during 2010, that Gothenburg shall introduce a congestion tax from 2013. The income from the congestion tax will be a part of the funding of a set of infrastructural investments in the Gothenburg area.5

Sweden, Denmark and Norway have been cooperating since 2007 in EasyGo, which is a service that makes it possible for drivers to pay their road user charges (and even parking fees) using one OBU resulting in one invoice. About 2.4 million vehicles in the Nordic countries use this service for the Öresund and Svinesund bridges, as well as for other toll roads and ferries that are included in the cooperation. Expanding EasyGo to be compatible with the distance-based road user charges on the Austrian motorways is currently being looked into.

2.1 Co-funding and user fees

Co-funding is becoming increasingly important for the funding of new infrastructural projects in Sweden. In the infrastructure bill (2008/09:35 “Travel and transport in the future”), the government argues that co-funding does not change the fundamental distribution of the responsibilities for funding of the infrastructure between the state and the municipalities, but to expand the total amount of resources available for transport infrastructure investments. The West-Swedish infrastructure package, the South and North links in Stockholm and the City tunnel in Malmö are examples of big infrastructure projects that are, or have been, funded with the help of different interested parties.

The financing of new roads by user fees, also known as road user charges or fees, is becoming increasingly important. User fees can be combined with other kinds of funding and for example be used for funding of new bridges, which result in gains of both time and convenience and thus create a sufficient payment interest among the users. Hence, road user fees can be considered as a form of regional co-funding as most of the traffic normally is regional and local.

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4 The Eurovignette Directive defines the possibilities to have road charging on the same specific road link
5 Also known as the “West-Swedish package”, Västsvenska paketet.
2.2 Tax or fee?

The question of what is tax and what is fee is important when introducing road user charging and affects the conditions for collecting the levy. The question is discussed in detail in the governmental report on congestion taxes (SOU 2003:61), which concludes that it is difficult to draw a clear line between what is a tax and what is a fee in Swedish legislation. The crucial criterion is if some kind of compensation is received through the payment. A tax does not require something in return, whereas a fee does.

The use of the existing road network is considered as an unfunded service, in contrast to the use of the Öresund and the Svinesund connections, because the bridges are partially financed from this revenue. Congestion charges are thus considered a state tax, even if the intent to lower the congestion can be regarded as a municipal responsibility, but a municipality does not have the right to tax others than its own residents. During 2011, a review of the proposition “A reformed constitution” (2009/10:80) is underway. The government is investigating whether it is possible to remove the constitutional obstacles for municipalities to make their own decisions regarding congestion taxes.

Distance-based road user charging, or kilometer taxation, is according to previous arguments to be considered as a tax just as it was between 1974 and 1993, when Sweden had kilometer taxation for most diesel vehicles. This tax was abolished shortly before Sweden joined the EU, mainly because the tax procedure could interfere with the rules about free mobility within the EU.

2.3 The legal framework

Road user charges are regulated by decisions in the Swedish road law (1971:948). According to the law, the government can decide that road user charges can be collected to fund new roads. They can even decide how this should be accomplished, but within the framework of the EU-legislation. EU encourages its members to use road user charges as a way to deploy the principles that “the user and the polluter pays” which are determined in the Treaty as a means to internalize the external costs related to road transports. The EU-framework aims at harmonizing the use of road user charges in the EU by defining maximum fees and technical standards. Four legislations are included in the framework: The Eurovignette Directive (1999/62/EC, changed through directive 2006/38/EC), directive 2004/52/EC and the Commission’s Decision (2009/750/EC) on the definition of the European Electronic Toll Service and its technical elements.
2.3.1 The Eurovignette directive

Directive 2006/38/EC changes directive 1999/62/EC, with the intention to establish new rules for fee collection in road traffic. The Directive defines the conditions for the member states to introduce or maintain different kinds of road user charges. Presently, the directive applies to vehicles with a total permissible weight above 12 tons, from 2012 vehicles above 3,5 tons is covered. According to the directive, road user charges can be differentiated depending on vehicle characteristics, EURO-class, time, place and congestion conditions. The directive contains restrictions concerning the maximum fee per vehicle and year and regulates the combination of several kinds of road user charges. Distance-based and time based road user charges may not be collected at the same time for the use of a certain road section with the exception of bridge fees, tunnel fees and congestion charging.

The EU commission has discussed changes in the Eurovignette directive since 2008, for example the possibility to increase the fee in certain regions and the possibility to differentiate depending on congestion.

2.3.2 The EFC directive and the decision on EETS

The so-called EFC directive (2004/52/EC) regulates interoperability of road user charging systems within the EU. In October 2009, a decision regarding the definition of the European Electronic Toll Service (EETS) was taken. EETS shall be available within three years, as of October 2012, for vehicles with a total permissible weight above 3,5 tons and within five years for all types of vehicles.

The basic idea with EETS is to achieve a structure that enables payment of road user charges with a single onboard unit resulting in one invoice. EETS supplements national or local systems for electronic road user charging in the member states by making it possible for a foreign user to pay the road user charges electronically. It is not allowed to let foreign users pay a higher charge, even if the administrative costs are higher. If the member states have road user charging systems, they have to take measures to increase the use of electronic road user charging systems. In Sweden, the Öresund and Svinestund connections will be covered by EETS when the legislation comes to power, because on-board units with microwave communication are used.

Member states that introduce electronic road user charging systems are responsible for ensuring that their systems are compatible according to EETS. One or more of the following technical solutions must be applied in all new electronic road toll systems that are introduced from 1 January 2007:

- Microwave communication (DSRC)
- Satellite based positioning
- Mobile communication by usage of GSM-GPRS

To allow technical development of EETS, member states can temporarily, on limited parts of their road network and parallel to the EETS system, allow test systems for road user charging that involve new technology which does not comply with the decisions of the EFC directive and the EETS decision.
3 Road User Charging in Europe

3.1 Road user charging – an international development

The increase in traffic in Europe during the last couple of decades has brought consequences for roads in both urban and rural areas. The congestion, both inside and outside urban areas has increased, which in turn increases the wear and tear of the infrastructure. Aside from that and despite increased efficiency, the road transport sector struggles with increasing emissions from CO$_2$ and other greenhouse gases. The external effects of the road traffic are increasing and many countries therefore study the possibilities to internalize these effects through road user charging.

More and more road user charging systems have been introduced during the last decade. Electronic Fee Collection, EFC$^6$, means that so-called free-flow systems can be built, which do not demand that drivers have to stop at gates for payment, which is the traditional way for fee collection.

The implementation of congestion charging in London and Stockholm are examples of this development. The so-called paper vignette for heavy vehicles has been replaced by an electronic version in the countries participating in the Eurovignette cooperation. Preparations for a congestion tax in Gothenburg, bridge fees in Motala and Sundsvall, to name a few, are currently on-going in Sweden. Five European countries have implemented distance-based road user charging for trucks and there are currently many investigations going on about different kinds of road user charging of cars and trucks, especially distance-based charging systems for trucks.

![Figure 1: The map shows different road user charges for trucks within the EU, January 2011.](image)

Figure 1 shows that there are many types of road user charging systems for trucks e.g. road user charging based on physical barriers with a bar that opens after payment, vignettes that are based on time spent in the country or distance-based road user charges depending on the vehicle’s characteristics. The last ten years show a trend from the traditional charging systems to distance-based road user charges. This chapter summarizes the development of road user charges for trucks in Europe. More details and comparisons between the different countries can be found in one of the project reports.$^8$

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$^6$ EFC = Electronic Fee Collection
$^8$ ARENA Rapport 2011:01 PM distansbaserade vägavgifter.
3.2 Countries with distance-based road user charges for trucks

This summary gives an overview of the systems in Switzerland, Austria, Germany, the Czech Republic and Slovakia. All countries have implemented a nationwide distance-based road user charging system for trucks.

**Switzerland** charges trucks heavier than 3,5 tons on their entire road network. The fee is based on weight and EURO-class. An average vehicle\(^9\) pays 0,69 EUR/km. The revenues are around 1 billion Euros per year, 1/3 of the revenues are distributed regionally and the rest is used for a state-owned infrastructure fund that invests mainly in the building of railway tunnels.

Since 2004, **Austria** charges trucks heavier than 3,5 tons for travel on motorways and some express-ways. The average vehicle pays 0,33 EUR/km. The revenues were 926 million Euros in 2009. The revenues are used for the infrastructure of the tolled network. The number of axles and EURO-class decide the fee.

**Germany** has charged trucks heavier than 12 tons on motorways and certain roads since 2005. The average vehicle pays 0,16 EUR/km. The revenues were 4,2 billion Euros in 2010 and they are distributed mainly to infrastructural investments for road, rail- and waterways. The fee is decided based on the numbers of axles and on the EURO-class.

**The Czech Republic** has since 2007 charged trucks heavier than 3,5 tons on motorways and certain other large roads. The average vehicle pays 0,17 EUR/km. The revenues were 224 million Euros in 2008 and they are distributed mainly to the road infrastructure. The fee is decided based on the numbers of axles, EURO-class and congestion on Friday afternoons.

**Slovakia** has charged trucks and busses heavier than 3,5 tons since 2010 on motorways and major roads. The average vehicle pays 0,19 EUR/km. The revenues were 141 million Euros in 2010. The revenues are dedicated to the road infrastructure. The fee is decided based on the numbers of axles, weight and the EURO-class.

3.3 Countries preparing distance-based road user charging

Several countries are planning, or are considering the implementation of distance-based road user charging systems for trucks. They have reached different phases in the process and their motives are different. An overview is given below.

**Poland** is expected to charge trucks heavier than 3,5 tons on motorways, starting in the middle of 2011. Their own vignette is replaced by distance-based road user charges.

**France** is expected to charge trucks heavier than 3,5 tons from 2013. The tax is planned to include the motorway network that currently is not subject to road user charging, i.e. approx. 10 000 km. The purpose of the tax is said to be to move freight transports from the roads and to reduce CO2-emissions.

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\(^9\) A Euro-class 5 truck and trailer combination with 5 axles and a maximum gross weight of 40 tonnes.
Until 2010, the Netherlands planned to introduce distance-based road charging for cars and trucks, gradually introduced from 2012 to 2016. A new government stopped the planning.

The Danish government is planning to introduce a road user charging system for trucks heavier than 3.5 tons during 2014. Denmark is thus expected to leave the cooperation of Eurovignette in a couple of years.

The three regional governments of Belgium have agreed to introduce a distance-based road user charging system for trucks heavier than 3.5 tons after year 2013. Belgium is thus expected to leave the Eurovignette co-operation in a couple of years.

Hungary is preparing distance-based road user charging for trucks in the near future, but the time plan is currently unknown.

The United Kingdom plans to charge trucks from year 2014. Implementation of road user charges has been discussed for several years. There are currently neither vignettes nor other types of road user charges for HGVs in UK.

Slovenia has since several years had plans to introduce a distance-based road user charging system for trucks heavier than 3.5 tons for the whole motorway network.

3.4 Experiences from abroad

The experiences of the countries that have introduced distance-based road user charges for trucks show that it is a mechanism for impacting on e.g. route choice and vehicle fleet composition. The design of the system has a great impact on the behavior of the road users.

Several studies have been made to analyze the effects of the road user charging systems in Switzerland, Austria, Germany and the Czech Republic. Particularly Switzerland has made extensive analyses to assess the impact on vehicle fleet, transport volumes and environment. A general conclusion is that the new charging systems promote a development of the fleet toward vehicles of higher environmental classifications, as the fee generally depends on the EURO-class\textsuperscript{10}. There are studies reporting improvements of transport efficiency by an increased load factor and developed logistics systems.

\textsuperscript{10} East West Report "East West Transport Corridor – Final report WP 2 (2007)
4 The ARENA role model

ARENA’s proposal for a national road user charging system is based on a number of cooperating actors in different roles interacting via well specified interfaces. This chapter delivers an overview of the basic terms and definitions which are important to the proposal.

4.1 The Toll Charger (TC)

The Toll Charger provides a transport service\(^{11}\) that is tied to a fee and collects the revenues from the charging system. The Toll Charger can be an authority or an operator of a tolled bridge or road. The extent of the road user charging service is defined as a toll domain. The Toll Charger signs agreements with one or more Toll Service Providers (TSP), which give the customers the possibility to use electronic units to register their use of the transport service. The Toll Charger collects the necessary information (reading of the unit or taking a photo of the license plate) and then demands payment from the TSP provided that the user has a contract with the TSP. Otherwise; payment is demanded directly from the owner of the vehicle.

4.2 The Toll Service Provider (TSP)

A Toll Service Provider gives the client access to the equipment (the on-board unit) that is necessary for electronic payment of the road user charges and provides an account- and invoice system, as well as signs the necessary agreements with the Toll Charger. The client and the Toll Service Provider have an agreement that regulates the conditions for the service, which enables the Toll Service Provider to act as an intermediary in the payment process between the client and the Toll Charger.

In the case of autonomous systems\(^{12}\) (e.g. distance-based charging\(^{13}\)), the TSP will collect the data from the on-board units and relay the required charging information to the Toll Charger.

4.3 The EETS Provider

This is a Toll Service Provider that works in accordance with the EFC directive and provides a pan-European service. The client is given access to all European toll domains with the on-board units that the TSP provides, and receives one invoice presenting all the road user charges. The Toll Service Provider is liable to pay these fees to the Toll Charger.

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\(^{11}\) E.g. often road usage.

\(^{12}\) A system where the on-board unit is able to collect the information necessary for the calculation of the fee

\(^{13}\) E.g. kilometer based taxation

Figure 2: Actors and relations in the Swedish road user charging system
4.4 The client or subscriber
The client is responsible for payment to the Toll Service Provider, e.g. by signing the contract for an on-board unit, or by being the registered owner of a vehicle.

4.5 The road user, the driver
The road user is the one that benefits from the transport service and is responsible for the proper functioning of the on-board unit. The road user is often (but not always) the same as the client registered with a TSP.

4.6 The electronic on-board unit (OBU)
The on-board unit, OBU, or OBE (on-board equipment)\textsuperscript{14}, is an electronic device that has the necessary functionality and information to accomplish an electronic registration for road user charging. There are two alternative and supplementary solutions for on-board units:

a) Autonomous systems that work without toll stations, where the OBU and built-in technology (e.g. satellite positioning and mobile communication) collects the required information for fee calculation and forwards it to the concerned TSP for fee calculation and subsequent submission to the Toll Charger.

b) Transponder-based systems (microwave, DSRC communication) that are used in traditional toll stations. The Toll Charger checks the information from the passing OBU, compiles the claims and sends them to concerned TSP or directly to the vehicle owner.

\textsuperscript{14} Tag transponder, etc
5  Field trials confirms technology, interoperability and role model

5.1 The EFC directive in practical applications

The EFC directive launches the European Electronic Toll Service (EETS) with the principle of one contract, one OBU and one invoice which makes it important to ensure interoperability between different European road user charging systems. A vehicle shall be able to travel through Europe, drive through several different road user charging systems with only one OBU installed and receive all road user charges on a single invoice. The EFC directive includes all EU countries and requires EETS to be provided for heavy vehicles in October 2012 and for other vehicles in October 2015.

With the role model (see chapter 4) as a base, ARENA has, as the first European project, turned the EFC directive’s intentions into practical solutions. ARENA has demonstrated interoperability between manufacturers and potential TSPs, whose on-board units were installed in trucks running in normal daily operations in the test site area.

ARENA’s field trials took place from November 2009 to April 2010. Six different companies from three different continents participated as TSPs. The test site consisted of the complete road network in Blekinge and Skåne, the two southernmost provinces in Sweden, consisting of 11 000 km of roads divided into 65 000 road links. Four trucking companies in Karlshamn contributed with a total of ten trucks. The vehicles continued their daily operations and drove both within and outside the test area during the field trials. The vehicles transmitted their route information to the TSPs that calculated the road user charges according to the rules given for the trials and transmitted the results to ARENA that simulated the Toll Charger’s role.

ARENA developed three interfaces for communication between TSP and TC for the trials based on the concurrent draft ISO 17575 standards.

- Context data
- Charge report
- Compliance check
5.1.1 Context data

Context data specifies the factors affecting the road user charge. In the ARENA concept, the main condition is that the traveled distance on road is a basis for the fee calculation; a pricing that should be based on the marginal cost principle. The fee varies depending on where and when the vehicle is on the road as well as its EURO-class and maximum permitted gross weight. The tariffs used during the trials were based on the marginal cost calculations in the governmental official report on road taxation (SOU 2004/63).

Context data consists of a map database and an associated tariff database. Map data for the field trials was collected from the National Road Database, NVDB, which is operated as a cooperation between the Swedish Transport Administration, municipalities and counties, the forest industry, the Swedish Transport Agency and the Swedish Mapping, Cadastral and Land Registration Authority. All roads or road links for the test area can be found in the map database from the field trials (see figure 4). To enable price differentiation depending on location, every road link has been given an attribute that varies depending on what road type (urban roads, rural roads, highways and non-charged roads) the link belongs to.

Map data is used by the TSP to measure the distance the vehicle has traveled on the different road types. The final road user charge is decided by multiplying the distance for every road type with the tariff that is derived from the tariff database.

5.1.2 Charge report

The TSP is responsible for calculating the road charge and report to the TC. The charge reports in the tested concept only specifies the actual time interval for the travel and the fee that shall be paid, which is calculated based on the tariff information obtained from the TC. The reason for this aggregated declaration, which does not reveal which routes was taken, is a regard for personal integrity. Whether this type of declaration is sufficiently detailed is a matter for the legislators to decide. What is important to point out is that the system in itself is not intrusive. It is possible to get more detailed information from the charge report if the legislator demands so.

5.1.3 Compliance check

The ARENA concept includes spot tests to check compliance and prevent cheating, which is probably going to be done primarily with roadside cameras, e.g. speed enforcement cameras that also detect vehicle type and stores the license number. Based on such an observation the TC can ask the TSP for the observed vehicle’s position data for the current time through the interface for compliance checking. The TSP has to answer to this demand from the TC if fines should not be issued.
5.2 Interoperability despite different technical solutions

The companies that participated in the ARENA field trials did so with different technical solutions. Some companies used only position indicators to calculate the road user charge; others also used data from the vehicle’s digital tachograph supplemented with data generated via different sensors to measure driven distance on different road types. One company divided map data in different segments and then applied an algorithm to determine the distance driven based on what segments the vehicle had been using.

ARENA’s field trials show that interoperability can be achieved regardless of the differences between the solutions. The ARENA concept allows several TSPs in the same road user charging system. The separation of responsibility and roles, and functional, rather than technical requirements, enable interoperability between different systems. The TSPs were able to adjust fairly easily to ARENA’s specifications and apply their existing technology to measure the distance driven and provide the road user charging service.

5.3 Correct and verifiable charge reports

ARENA also showed that a high charging accuracy can be achieved as demonstrated in the final part of the test ‘Test Track’. This was performed as a series of controlled blind tests. The intention was to evaluate the TSPs’ charging accuracy, the ability to calculate the correct charge under controlled, but challenging conditions.

During Test Track, the TSPs’ technical systems were exposed to five different challenges, where every challenge consisted of calculating the charge for a specific distance. Every challenge represented a “worst case scenario” rather than an “ordinary” trip, where the difficulties consisted of, i.e. coping with irregularities in the map database, difficult geographical conditions, as well as power failure in the OBU. The challenges consisted of:

- The vehicle is driven on roads that do not exist in the map database (i.e. no debit)
- The vehicle drives forward to stop and then back up (i.e. debit for both directions)
- The vehicle is driven on a non-charged road that runs parallel with, and close to a charged road (i.e. no debit)
- Power failure in the OBU when the vehicle is standing still (i.e. how fast can the OBU start up and determine the first position)
- Power failure in the OBU while driving (i.e. if the OBU can compensate for the interruption and still calculate the correct charge)

\[
\text{Charging Accuracy} = \frac{\text{Fee reported in TSP Charge Report for the Challenge}}{\text{Correct result for the Challenge}}
\]
Test Track consisted of a 45-kilometer long loop divided into five different sections where every section represented a challenge. All of the TSPs’ OBUs were installed in the same truck during Test Track to minimize the impact of external conditions and to create fair conditions for comparison. The distance was driven a total of 20 laps during one week and every TSP submitted 100 charge reports. The accuracy of the charge reports was calculated according to the formula above measured as percentages, where a result of 100 percent meant that the calculated charge was correct. Figure 5 illustrate that several of the six TSPs managed to cope with the challenges and calculate the accurate fees.

5.4 Needs for revision

The concept and its practical application proved to work well. The TSPs’ different technical solutions were able to create interoperable services and deliver required information, even under challenging conditions. However, the experiences from the field trials show that:

- The road database (NVDB) needs to be developed, in order to be used for distance-based fee collection. It needs to be supplemented with a special layer of tariff data.
- The definitions of the three interfaces between TC and TSP needs to be more precise and the current standard taken into account.
The experiences from the field trials also raise three issues for discussion:

Which detail level is required for the charge report? How much and how detailed information does the TC require? During the project, ARENA developed a concept where it is up to the TSP to calculate the tax, rather than sending detailed information about the traveled route to the TC, who would then calculate the tax. The question is whether the Swedish Transport Agency would allow this procedure.

Is an area-based tariff database acceptable? The original requirement was that all road links should be priced individually. ARENA’s field trials have shown that this can work, but also that the amount of data that has to be handled is a tough strain on the system. Tariffs with a limited number of road links (e.g. motorways) priced individually, while other parts of the network are considered as areas, would simplify the problem to handle missing links in the road database. The amount of data that the TSP has to handle would also be significantly reduced.

Is the concept of a trusted recorder the best way to ensure a correct report, or are there better solutions that are easier to implement to the benefit of a more dynamic development? The continued European development of interoperable road user charging systems will continue to explore the issue.
6 A Swedish strategy for road user charging

Road user charges, e.g. toll roads, congestion taxes and bridge fees are common in Europe and will be used more frequently in Sweden in the future. In that perspective, it is important that the system offers a convenient payment process to the road users, which does not interfere with the traffic or becomes a potential risk factor. A system that is easy to understand and is similar to systems in other countries will also reach a higher degree of acceptance and facilitate verification and monitoring of payments.

In this chapter ARENA presents a proposal for a cohesive Swedish strategy for fee collection of road traffic, which could serve as a basis for the activities of the Swedish Transport Agency, the Swedish Transport Administration and other actors concerned. The intent is to establish methods and techniques which can be perceived as an integrated national system for road user charging.

6.1 Integration with European requirements

An important starting point for the proposed strategy is the Swedish goal to integrate its traffic systems with Europe in general and especially with the neighboring countries. Sweden is also bound to follow the European legislation. Even if every Swedish charging system has to reflect specific conditions and local demands, there are still a couple of basic, general demands and conditions that we consider should be met to serve as foundation for a cohesive national road user charging system.

6.1.1 An integrated road user charging system

Road user charges in Sweden include congestion taxes, bridge fees, road tolls and possibly even distance-based charges (e.g. kilometer tax) in the future. A fundamental requirement is that the road user (driving the vehicle) and the customers (paying the fees) shall perceive this as one cohesive, integrated system with a common interface to the system’s different functions. The users shall be able to use the same equipment and methods for all payments in the Swedish road user charging system.

6.1.2 One relation with the system

An important condition is that all road user charging systems in Sweden are coordinated so that they are perceived as “one system” from the customers’ point of view, i.e. they get a single invoice for all of their charges, and if an on-board unit is used, then this equipment should work in all systems (c.f. EasyGo). The client should also have a single contact point when seeking information or having questions regarding invoices etc.

6.1.3 Interoperable with EETS and EasyGo

A fundamental condition is that it the so-called EFC directive, which defines the European road user charging service EETS, is implemented in Sweden. The directive stipulates, within different time frames for heavy vehicles and cars respectively, that all European TCs should accept clients with contracts according to EETS.

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18 Sometimes called "tag", "transponder", "vehicle unit", OBE, OBU, c.f. chapter 4.
19 A Nordic cooperation on interoperable road user charging c.f. www.easygo.com
The Nordic countries have cooperated since 2007 in providing the EasyGo service, which means that all on-board units for road user charges in Scandinavia, i.e. BroBizz and Autopass\textsuperscript{20}, can be used in all stations for electronic payment. The client gets all the fees on the same invoice. The order is very similar to the one that is supposed to apply to EETS and means that the distributor of OBUs has the payment liability, but collects the charged amount from the client. ARENA’s proposal for a road user charging strategy assumes that the cooperation within EasyGo is further developed to become a central part of a Swedish system.

6.1.4 The fee is independent of the origin of the vehicle

European legislation prohibits discrimination of foreign or temporary visitors in road user charging systems, which means that foreign vehicles may not be charged a higher fee than domestic ones. The argument that charging foreign vehicles is more expensive is not valid. This equality should be considered as a condition when designing a road user charging system.

Exempting foreign vehicles from payment is also not an approach to recommend. The opinion of ARENA is that foreign vehicles should be obliged to pay, since it increases the acceptance of road user charging amongst Swedish road users, especially the commercial users, which mean that the costs for compliance checks and sanctions decrease. Hence, the best solution is if foreign vehicle owners are clients of an EETS provider or EasyGo so that they can easily pay their road user charges in Sweden.

Whether a certain vehicle category (e.g. foreign) should be exempt from paying road user charges should be the result of an applied policy and not to be governed by the perceived technical or functional limitations of the system.

6.1.5 A cost-efficient system

All parts of the Swedish road user charging system shall be designed for low operating costs and the development shall be focused on improving efficiency. An important task in the establishment of the Swedish charging system is to define clear indicators of efficiency, user-friendliness etc, early in the development and use such key performance parameters for a continuous follow-up of the operation.

\textsuperscript{20} The Austrian GO-Box is planned to be included in EasyGo in 2012
6.1.6 Based on standards and open specifications

International standards shall be fully used in the Swedish road user charging system and the interfaces shall be based on open specifications, which is important to reach the highest possible cost efficiency.

6.1.7 Flexible and designed for continual improvement

The system shall allow competing solutions and suppliers within the framework of the established technical framework. Organizational, commercial and technical improvements of systems and services are stimulated driving innovation and cost-efficiency.

6.2 A proposal for a Swedish road user charging system

ARENA has developed a comprehensive proposal for a national road user charging system based on the international development and the requirements indicated in the previous chapter. The proposal, which is presented below, is best described by two key words: competition and interoperability.

6.2.1 Technology

The Swedish road user charging system is based on the registration of vehicles through either taking photos of license plates or readings of on-board units. The presence of an on-board unit from an EETS or EasyGo Toll Service Provider replaces the license plate identification of the vehicle. The Swedish system is prepared for distance-based charging based on satellite positioning in combination with mobile communication (e.g. GPS and GPRS).

Free-flow and unmanned technology

Road tolling stations are designed for undisturbed vehicle flows without lane separation. The tolling stations are unmanned and offer no possibility for payment in direct connection to the toll gate, which places high demands on the system's ability to identify vehicles that are liable for charging.

Reading of license plates

Video images of license plates are taken at toll stations and the license number is recognized through OCR. Each license plate, even foreign ones, is connected to an account at the Swedish Transport Agency. Automatic optical recognition (OCR) of license plates is the main solution for Swedish vehicles in Swedish systems\(^\text{21}\) currently used in the congestion tax system in Stockholm.

\(^{21}\) Except the connections in Öresund and Svinesund.
Short-distance communication
The toll stations have equipment for recognition of DSRC in addition to the video registration. Vehicles that are equipped with OBU’s for DSRC technology will be debited through the associated contracts with the EETS or EasyGo Toll Service Providers.

Control and enforcement
Vehicle owners not paying their charges as required are blacklisted and will be subject to enforcement procedures. The legal status of the unpaid fee, e.g. unpaid taxes have a higher penal value and priority than unpaid fees, decide the level of enforcement. Proof of passage at a toll station or the usage of a road (e.g. video registration) will be stored until the payment has been received.

Satellite positioning in combination with mobile communication
ARENAs strategy means that the Swedish charging system is also prepared for potential implementations of satellite-based systems (e.g. GPS in combination with GPRS), e.g. for distance-based road user charges. The Swedish charging system will be prepared according to EETS, for clients in systems where the information, e.g. a distance declaration, is sent via mobile communication.

Open interfaces and recognized specifications
All parts of the Swedish charging system shall be based on recognized applications of standards, as well as open interfaces and state-of-the-art security solutions, which demand a Swedish engagement in European cooperation.

The EasyGo accounts
A vehicle that is registered for an EasyGo-account will always be debited through this account, even if the transponder is not recognized correctly at the toll station. Photographed license plates are checked against the list of EasyGo subscribers, which of course requires that all EasyGo subscriptions are available to the Toll Charger for verification.
6.2.2 Organization

One Toll Charger
The function as Toll Charger is centralized to the Swedish Transport Agency, which is responsible for the management of accounts based on license plates and corresponding invoicing. The Swedish Transport Agency is responsible for the administration of the Swedish Toll Domain Statements and contractual arrangements with partners within the EasyGo- and EETS-cooperations. According to an agreement between the Swedish Transport Agency and the Swedish Transport Administration, the latter is responsible for the roadside equipment and the collection of passage data.

Competing Toll Service Providers
The Swedish charging system supports the establishment of multiple professional TSPs, specialized in managing on-board units and client contracts in road user charging systems. Swedish control points for road user charges shall accept EasyGo and EETS clients with connected DSRC OBUs issued by TSPs in Europe. Clients in Swedish road user charging systems can connect to any TSP within the frame-work of EasyGo and EETS depending on their service offer and choose to pay their fees through that TSP.

The development of EETS through regional cooperations
EasyGo is a regional cooperation between TSP and TC that offers interoperable payment of road user charges to a large amount of clients in the Nordic countries. The establishment and the expected development of EasyGo can be regarded as a model for the implementation of EETS in Europe. Regional cooperations that cover the main part of road users’ needs could be established all around Europe.

These bi- or multilateral agreements of cooperation that extend the validity of the concerned OBUs and related contracts are successively expanded until Europe is covered. Such a process of gradual regional proliferation driven by the needs of the users offers interoperable tolling services where they are demanded and EasyGo provides evidence of the success of such an approach.

6.3 Strategic questions and measures

ARENA’s proposal is built on a number of strategic positions and specific actions necessary for the implementation. The proposal also requires work on legislation and related instructions for the authorities as discussed in chapter 7.

6.3.1 How does EETS “arise”?

The EFC directive gives the impression that EETS will be implemented with something like a “big bang” - one day all the necessary parts will all come together and start working. There is however more flexibility in the decision that defines the EETS. The TSPs have an additional 24 months to make the necessary contracts to meet the requirement of a complete coverage of the EU. The proposal for a Swedish charging system assumes that reality demands more flexibility. The system is not depending on that every TSP has agreements with all European TCs, which is a requirement to reach EETS status. Hence, the proposal foresees that TSPs that aren’t fully EETS-compatible should be able to offer their services.
6.3.2 Market conditions
ARENA’s proposal assumes that the “market” is able to provide the system with subscribers and on-board equipment. It has usually been the case that the organization implementing a road user charging system handles all parts of the system and acts in the roles of both TSP and TC simultaneously. The proposal for separating the two roles builds on the experiences from the connection at Svinesund. This was the first example of an establishment of only the function of a TC. Clients who choose to use automatic payment (about 50%) are asked to turn to existing TSPs (within EasyGo). The lack of a local client base around Svinesund was an important reason for this approach. The experiences are extremely good and EasyGo has gradually expanded since the start with more services being connected through additional TCs joining the cooperation.

6.3.3 No exemptions for foreign vehicles
The proposal assumes that foreign vehicles are not exempt from the obligation to pay the road user charges. This demand requires improved legislation (c.f. next chapter) and is important for ensuring competitive neutrality between domestic and foreign road users. A general payment liability also emphasizes the principle that those who use the road transport system shall also contribute to paying the costs that arise. Equal treatment of all road users strengthens the acceptance of road user charges and will probably lead to less attempts of cheating, which reduces the operating costs of the system.

6.3.4 The Öresund and Svinesund connections are excluded from the proposal
The charging systems for the connections to Denmark and Norway are excluded from the presented proposal, although they adhere to its principles. The Öresund Bridge has tolling stations with bars and full payment obligation for foreign vehicles. The Svinesund Bridge is practically operated as a Norwegian Autopass system, and has also implemented payment obligation for foreign vehicles. Both Svinesund and Öresund are part of the EasyGo cooperation. Within the next couple of years, several new Toll Domains will be introduced (Motala, Sundsvall, etc.) within Swedish borders, but they will be in line with the proposal’s principles.
7 Legal and organizational needs

The proposed solution demands additions to and changes in the Swedish legislation. The key issues are the enforcement of road user charging of foreign vehicles and the establishment of a payment intermediary, the Toll Service Provider.

7.1 Foreign vehicles

Foreign vehicles are exempt from tax in the current legislation for congestion taxation. Payment obligation exists on the Öresund and Svinesund connections, and we can expect that foreign vehicles will have to pay in the planned toll systems of Motala and Sundsvall. Foreign vehicles can easily pay Swedish road user charges by being connected to either EasyGo or EETS.

The payment obligation for foreign vehicles will require that payment demands (e.g. congestion tax) can be directed towards the owner of a vehicle even if it is unknown. A connection to EETS or EasyGo may be missing or it might even be impossible to get the relevant information from the vehicle’s country of origin. The legislation must enable charging of such vehicles, even if the owner has not been identified.

7.2 Improving the road traffic registry

Applying sanctions against a foreign vehicle requires a continuously updated record with a balance of payments due, even if the owner is not fully identified. The record should be updated with information that is added through e.g. police controls.

The subscriber list of EasyGo is an important part of a national charging system. It has good coverage regarding Danish and Norwegian vehicles, and the information is available to the Swedish Transport Agency as a Toll Charger.

7.3 Registration of vehicles at border crossings

A national system for distance-based road user charging assumes registration of vehicles at border crossings, which is when the payment obligation arises or ceases. In practice, this happens when a vehicle passes through a station for registration with video/DSRC. It is appropriate to notify the vehicle at such a passage, in the case that it has old, unpaid fees, as well as informing the authorities in charge of enforcement that the vehicle has entered the Swedish traffic network with unpaid fees and sanctions shall be applied, on the spot, if possible.

7.4 Improving the legislation for congestion taxation

The legislation for congestion tax in Stockholm indicates that it is the owner of the vehicle who is responsible for paying the fee. Future demands, such as EETS indicate the needs of improved legislation, so that the claim will primarily be aimed at the account of a vehicle with a DSRC-based OBU. However, the owner of the vehicle is still responsible, if payment through an associated TSP is missing. In the case of foreign vehicles and DSRC or distance-based charges, this requirement is absolute since the road user can demand to pay through EETS.

7.5 EETS provider as payment intermediary

Vehicles that pay through an EETS TSP will pay in the currency used by the TSP, which means that the payment can be made in a foreign currency even if demands directed to the TSP are in Swedish crowns. Therefore, it has to be acceptable that the paid amount may deviate from the claimed tax amount if the payment is done through an EETS provider.
7.6 Roadside enforcement

The Swedish charging system is designed for free-flow passages and unmanned toll stations; thus, there is no alternative to pay in cash in connection to the toll stations.

Sanctions must be applied on the spot against foreign vehicles that are in debt when they are observed on the road network e.g. in connection with police roadside checks. The authorities responsible for roadside controls needs information in realtime of vehicle status from the road traffic register and should have the right to enforce sanctions on the spot.

7.7 A national Toll Charger

The ARENA proposal assumes that all road user charges associated to a certain vehicle are collected and administered by the Swedish Transport Agency, who is also responsible for sanctions against non-payers. The Swedish Transport Agency is also signs bilateral and multilateral agreements with other registrar authorities and TSPs in order to facilitate an efficient fee collection. Thereby the Swedish Transport Agency becomes the natural representative of Swedish road user charging systems in different European development and coordination activities regarding for instance, the EFC directive.

7.8 A national Toll Service Provider?

In a fully automatic Swedish distance-based charging system built on the availability of commercial and competing TSPs, there may be vehicles whose own-

7.9 Joining international agreements

Including non-paying foreign vehicles in a Swedish road user charging system requires an efficient system for enforcement. There are two main tracks for creating such conditions: Firstly, Sweden has to, in analogy with the EasyGo cooperation, sign bilateral agreements with foreign road traffic registries that give access to their vehicle license data. Sweden has a functioning exchange of license in formation with Norway and the EasyGo cooperation creates possibilities for solutions with Denmark. Bilateral agreements should also be made with other neighboring countries, primarily Finland and Germany. Additional agreements with a few other countries would then give access to license data for about 98% of the foreign vehicles on the Swedish network.

Sweden should also join important European initiatives, such as EUCAR that are under development. Register cooperation, according to the Cross-Border Enforcement Directive23, which is currently under development, is probably not applicable for unpaid road user charges, but the possibility should be investigated.

22 SIKA report 2008:22
23 https://www.eucaris.net/
8 Regional development through ITS – the test site in Blekinge and Skåne

One of the aims of the ARENA project is to participate in regional development and to use ITS as a tool to strengthen regional competitiveness, activity and employment. In order to meet this long term objective, ARENA is developing a research center with field trial operations as an addition to project activities and knowledge building. The research center and the field trial operations are closely linked and support each other in problem definition and result dissemination.

8.1 A strong partnership

In the start-up phase, the test area in Blekinge and Skåne had the advantage to be able to benefit from:

- A strong cluster within information and communication technology that can contribute with products, services and expertise, but also benefit from the results of the trials.
- A strong cluster within the transport industry that contributes with problem definitions and user demands, but also acts as a platform for the trials.
- A triple-helix structure, in the shape of NetPort. Karlshamn that can act as a neutral and non-profit coordinator and a driving force.
- An academic institution with an interest to improve ITS both as an academic subject and as an area for applied research.
- A supportive political environment, both locally and regionally, where ITS is regarded as a natural part of the region’s growth strategy.

8.2 A common history

The focus on ITS as a growth track begun as early as during the 1990s. The County Administration in Blekinge, the five municipalities and the former National Road Administration started an innovative traffic security project, called “Säkereken”. Safety-increasing measures were tested and evaluated. As a consequence, Blekinge was a natural testing area when the National Road Administration initiated attempts with variable speed limits.

Blekinge Institute of Technology (BTH) established a campus in Karlshamn in 2000, with ITS as an important activity. Soon thereafter, TFK also established an office in Karlshamn. A strategic plan for regional development and ITS in cooperation was created.

8.3 R&D projects in common

The work at the test site, which nowadays is called Test Site NetPort, has mainly been concentrated on R&D projects with national and international funding. The work, consequently organized as a triple-helix model, has benefitted from cooperation with regional, national and international manufacturing, transportation and ICT-industries. Examples of previous projects are “AIS 42”, for cooperation in transport chains using transport informatics, and “Mobile Pipelines”, which secured transport and handling of unpacked foodstuffs using RFID technology.

Extensive field trials with systems for road user charging have been completed within the ARENA project, with both extensive tests with trucks in day-to-day operations and with laboratory-like trials.

24 TFK – Transport Research Institute (www.tfk.se)
under uniform and controlled conditions. The trials have been completed in cooperation with companies from all over the world, and have shown that it is possible to create robust and interoperable systems for position-based road user charging that meet very high demands of reliability.

Field trials of road user charging and other mobile services based on positioning data were conducted through the GSC project\textsuperscript{25} during 2010 and 2011. Two different positioning techniques were compared by equipping 13 trucks with two OBUs each while driving in ordinary traffic in southern and central Sweden.

A platform for secure and neutral exchange of information between stakeholders in transport and logistics has been developed and implemented within the frame of the Green Corridor project “East West Transport Corridor”.\textsuperscript{26}

8.4 National test site cooperation

Four test sites in Sweden have, through ITS-Sweden, created a forum for cooperation under the name of “ITS Test Sites of Sweden”, an initiative for coordination and joint marketing, which has gained significant attention. The goal for Test Site NetPort is to respond to future needs for advanced trials, demonstrations and certification of mobile services within the ITS area.

8.5 A complete offer

Perhaps the most vital resource for the test site is the various expertise at hand to run development, demonstrations and trials. Expertise includes everything from traffic, transports and logistics to ICT and project management. The communication between the experts is facilitated by co-location and by a well organized triple-helix cooperation. The field trials within ARENA, with actors from all over the world, verify the expertise to plan and complete complex trials.

The field trials area within ITS, that has been established in southern Sweden under the name of Test Site NetPort offers a platform for extensive test operations within e-transactions, user charges, intelligent logistics and other mobile services. Expertise, software, hardware and IT-platforms are offered by the partners who are currently involved with the test site and support the whole chain from research, development, tests, demonstration and pilot installation to full-scale implementation.

A future goal is to expand the activities to include also certification of equipment where it is required by authorities or by the market. EETS, the European service for interoperable road user charges may require this type of service to ensure that the Toll Service Providers conform to the European specifications.

\textsuperscript{25} GSC = GNSS-enabled Services Convergence. www.ertico.com/GSC

\textsuperscript{26} EWTC II-project, www.etwc2.eu
9 BLITS – a research center for broad cooperation within ITS

9.1 Focus on mobile solutions and e-transactions

ARENA has begun a long-term work to establish a research center for ITS with focus on mobile solutions and e-transactions located at the BTH campus NetPort Science Park in Karlshamn. The center will handle obstacles and issues that practitioners and researchers of today encounter within the ITS area. The issues are often complex, sometimes diffuse and span many different areas of expertise, but are often handled as isolated tasks with no relation to each other.

Addressing these tasks in continuous cooperation would increase the understanding of surrounding limitations and possibilities, reduce duplication of work and make the whole picture of the problem much clearer. Technical problems would however still be regarded and solved as such, but with an improved understanding of surrounding conditions which may affect potential solutions’ relevance and feasibility.

Such a cooperation is promoted by a research center providing a wide range of supplementary expertise with a good joint knowledge and understanding of the needs of authorities and industries, the power of market forces, the technical options and the users’ needs. This is the objective of the research center named BLITS (Blekinge Logistics and ITS) where currently 19 part-time researchers are cooperating.

A major activity in the ARENA project has been to identify the issues that we want BLITS to focus and specialize on. The starting point was that the research shall be relevant from the perspectives of society, industry and academics. The research shall also complement work done at other universities and research centers in Sweden and be in line with the profile and the vision of BTH.

Internal workshops and experiences from different seminars and conferences have indicated that there are a number of concrete issues which need to be addressed in relation to road user charging and congestion taxation as these measures are becoming more and more frequent all over Europe. Research topics relate to the impacts of introduction under different conditions and the design of technical solutions that are feasible both nationally and internationally. BLITS has contributed to ARENA with several exploratory studies and PhD projects that are briefly described below and are also presented in more detail in a separate report.

9.2 Critical questions for road user charging systems

Methods for identification of vehicles and calculations of road network usage are central in every road user charging system. ARENA does not specify the design of the OBU (e.g. suitable positioning technology) as long as it delivers sufficiently reliable data for the charge reports. Evaluation of the reliability of OBUs while taking a number of other aspects into account is thus important. Paul Davidsson and Jan Persson have developed and applied a framework, which specifies the criteria that such an evaluation should be based on. The criteria are grouped in categories related to e.g. precision in charge declaration, flexibility and adaptability, system costs and socio-economic gains, performance while operating under different conditions as well as security and integrity.

In certain road user charging systems, the identification of vehicles is completely based on (or for back-up) optical readings of the vehicle’s license plate and there are well-proven methods for this. In systems with foreign vehicles, the technique becomes less reliable because the system has
problems to interpret what it sees. Plates from different countries can have similar, or even the same structure on their license plates, which can lead to misleading identifications. It is thus important that the identification system is self-learning and that it has a wide variety of attributes that it can use to categorize different plates depending on important traits of a license plate. Sina Tamanna, Niklas Lavesson and Mikael Nilsson have structured the identification problems in an exploratory study and have mapped existing methods within the area. Possible hybrid techniques that combine different existing methods are being discussed because no existing method can solve the problem on its own. They intend to implement and evaluate these alternatives in their continued research.

9.3 Integration of the market needs

A distance-based road user charging system opens for the creation of different kinds of complementary ITS services. If hardware and information for fee collection could also be used for other applications, then premium mobile services could be created to a substantially lower cost than if separate systems for these services would be required. Gideon Mbiydzenyuy has studied the possibilities of such co-utilization of hardware and information in his licentiate thesis and has mapped the dependence and synergies between different types of services as well as their needs for information and technical platforms. The work has shown the potential of synergies, but also the difficulties of finding a good basis for quantitative comparisons between different clusters of services with similar needs.

The market prerequisites are another important aspect for the development and usage of different ITS services. An exploratory study by Emil Numminen and Jennie Blomqvist shows a need to investigate this more thoroughly and to clarify what ITS services that the transport industry deems necessary and under what premises (e.g. willingness to pay).

Åse Jevinger’s and Shoaib Bakhtyar’s PhD projects are both related to this topic. Åse’s research focuses on identifying what services the transport industry needs for so-called Intelligent Cargo and the design of those services. Services for Intelligent Cargo aim to improve the possibility to intervene in the logistics process when the need for action arises, e.g. a delay or a major temperature change. If, for example, a container can communicate directly with the AGV27 or the staff at the terminal the possibility to rapidly solve potential problems increases. Services for intelligent cargo are greatly influenced by what other ITS services and ways of communication are available and vice versa.

Shoaib’s research focuses on eFreight, which is about paperless flow of information connected to the flow of goods (and associated services) with the intention of facilitating seamless transports. Central questions in his work are the design of seamless transport based on the eFreight concept (without paper documents). The design also affect the possibility to effectively realize different kinds of supplementary ITS services.

27 Automatic Guided Vehicle
9.4 Smarter information management

The amount of data, and as a consequence the costs of data traffic, for vehicles using ITS services that continually send/request information, such as positioning and map data, can be really high. There is thus a clear incentive to try to reduce the amount of data and the costs for the transmissions. This can be done in multiple ways, such as compressing data, sending data less frequently or finding a more efficient data representation. The data transmission reduction must not compromise the reliability, regardless of method. For example, the OBU can choose to send every second position, which halves the data transmission, but, depending on where the vehicle is and its speed, it may be difficult to reconstruct its actual route. Different strategies to reduce the data transmission have been analyzed in an exploratory study by Mattias Dahl, Johan Holmgren, Efrain Laksam and Håkan Lennerstad, and first attempts to implement and evaluate a number of algorithms have been carried out.

The availability of large amounts of information provided by different ITS solutions and services are not only bringing positive effects. The requirements for integrity and the risk for misuse are also important to consider. Positioning data (with GPS positioning) from vehicles transporting high-value freight could facilitate criminal acts such as theft or hijacking. These risks were analyzed in an exploratory study by Stefan Axelsson. According to this, other strategies than the current pseudonymization are necessary for protecting this type of data. A proposal is to use random and repeated pseudonymization (transcoding) of the identity of the vehicle during its trip.

9.5 Better understanding of implementation problems

Understanding the problems of implementation and user acceptance of ITS solutions and services in society and industry is a challenging task. The expectations that ITS shall provide more efficient, environmentally-friendly and safer traffic and transports have been high ever since it was introduced as concept. However, a large part of these expectations have not been fulfilled. The possible reasons for this have been explored in a preliminary study by Johan Hedin on cooperation with Jonas Sundberg. The study concludes that the introduction of ITS has been significantly slower and less extensive, both in relation to expectations and in comparison to the introduction of IT systems in other sectors, and this is not due to the lack of technical solutions. The study will serve as a basis for continued research with the aim to facilitate the introduction of IT in the traffic and transport sector.

It is also important to understand the effects of implementation, both expected/unexpected and desired/undesired, as well as what factors affect the outcome over time. One way to highlight different important aspects is to model and simulate the intended system. BTH, with Johan Holmgren in the lead, have thus developed and applied the simulation tool TAPAS. TAPAS is based on optimization and multi-agent technology, and has been used in several experimental studies, including the East West project.
10 ARENA 3 supports the development of a national strategy

In the continued work during the period of 2011 to 2014, “ARENA 3” has the goal to support the development of practical solutions of electronic road user charging systems for current and future Swedish needs. Thus, ARENA also meets the needs that are identified in the Swedish strategic plan for ITS:

- The establishment of a national road user charging system in Sweden with a cost-efficient verification system that includes foreign vehicles.
- Continued Swedish international cooperation regarding the implementation of EETS – the directive (2004/52/EC) and the Commission’s decision about electronic road tolls (2009/750/EC).

The aim is to continue the national development of competence in the field of ITS, which has also been an important goal in the previous ARENA projects. The technical and commercial concept of ARENA makes room for innovative combinations with commercial ITS solutions. ARENA 3 will be able to provide concrete solutions to this innovative process as conditions for European solutions are gradually stabilized. The goal is to create an inspiring innovative environment, with the international focus of the test site and through R&D cooperations with academic institutions around the Baltic Sea.

ARENA provides the expertise to analyze and evaluate different solutions and the results can be used as a basis for the decisions of responsible authorities. ARENA also offers a forum for industry representatives and IT system providers to discuss common questions with representatives of the authorities. Given the importance of European coordination, specific Swedish issues are combined with international activities in ARENA 3, with a focus on promoting general solutions within the EU and its concrete (Swedish) applications. The work demands a close cooperation, nationally and internationally, with suppliers of both technology and systems, e.g. for standardization and trials.

WP1 - Communication and cooperation
A serie of workshops and seminars supporting the work in the other WPs and bringing together a wide range of stakeholders with the objective to address common challenges and provide additional knowledge.

WP2 - A national road user charging system
Contributions to practical solutions for a rapid introduction with flexibility to cope with future national and international development.

WP3 - Baltic Sea Forum for heavy goods vehicles
Cooperation in a stable network of responsible national authorities and technical experts for exchange of information, identification of challenges and joint activities.

WP4 - EETS development
Contributions to and cooperation with the European development and standardization activities.

WP5 - NetPort Test Site
An extensive and technically well equipped test area for practical trials of road charging systems, mobile services, e-transactions and EU certification.

WP6 - Development of an innovation center
Continued development of an innovative environment in cooperation with BTH.

AP 7 Project management
The experiences from the work in the previous phases of ARENA show the significance of national and international networks to coordinate initiatives and create consensus. ARENA cannot make any formal decisions regarding technology or organization, but concentrates on contributing with knowledge for relevant decisionmakers. Thus, the activities in work package 1 (WP 1) become an important instrument to reach the goal of the project. The work package is both a conduit to gather and concretize needs, and an instrument to distribute different approaches for solutions as preparations for operative decisions, especially within the Swedish Transport Agency and the Swedish Transport Administration.

ARENA 3 contributes in WP 2-4 with studies and analysis of themes and questions to discuss and communicate. In WP 2, the national strategy is further developed in coordination with the development in the neighboring Nordic countries and the framework of EU regulations. Recommendations regarding the design of the system and the technology to be used are expected, especially concerning foreign vehicles as well as contributions to the practical organization of toll charging and tolling service provisions.

The perspective is widened in WP3 to include the countries around the Baltic Sea, with focus on heavy vehicles. International road transport is rapidly increasing and the transport companies are asking for a coordinated solution of the different electronic charging systems. Starting in WP 3, ARENA 3 is aiming to develop a cooperation around the Baltic Sea with the intent to increase the efficiency of road transport in the Baltic Sea region by coordination of charging systems, demands for hazardous goods declarations, traffic information services etc.

WP 4 addresses the development of the basic technical conditions for interoperable EFC systems within the European framework. Important issues are secure transactions and certification of operators who wish to provide EETS services. Issues related to system deployment will become more and more important, nationally and internationally during the next couple of years, and WP 5 offers possibilities to test solutions under realistic conditions in the NetPort Test Site in Blekinge and Skåne.

WP 6 intends to further develop the BLITS research and innovation center for intelligent transport systems, which was established during ARENA 2.0, in cooperation with the Blekinge Institute of Technology (BTH). The activities in WP 6 support the activities in the other work packages through applied research with focus on challenges regarding e.g. security, risks, system capability or smart calculation methods.
11 Abbreviations

**Toll Charger**

The Toll Charger can be an authority or the operator of a tolled road or a bridge. In Sweden, the Transport agency

**Toll Service Provider**

An organization that on behalf of a vehicle owner is responsible for information handling and payment of road user charges

**BLITS**

Blekinge Logistics and ITS, a R&D center at campus Karlshamn

**DSRC**

Dedicated Short Range Communication

**EasyGo**

A Nordic cooperation for road user charging regarding DSRC

**EETS**

European Electronic Toll Service

**EFC**

Electronic Fee Collection

**GNSS**

Global Navigation Satellite System

**GPS**

Global Positioning System

**GPRS**

General Packet Radio Service

**HGV**

Heavy Goods Vehicle

**ICT**

Information- and Communication Technology

**ITS**

Intelligent Transport Systems

**OCR**

Optical Character Recognition

**OBE**

On-Board Equipment

**OBU**

On-Board Unit

**RFID**

Radio Frequency Identification

**RUC**

Road User Charging

**TC**

Toll Charger

**Test Site NetPort**

A test site for ITS in Blekinge and Skåne

**TSP**

Toll Service Provider

**Toll Domain Statement**

Toll Charger’s conditions for traffic in the Toll Domain

**Toll domain**

Road Toll network defined in the Toll Domain Statement
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