# ARENA 2 Concept – final report

arena

ARENA REPORT 2011:02

2011-03-31

Publication: ARENA REPORT 2011:02 ARENA 2 Concept - final report
Publishing date: 2011-03-31
Author: Jonas Sundberg, Sweco
Layout: ARENA project secretariat
Distributor: NetPort.Karlshamn, Biblioteksgatan 4, 374 35, Karlshamn, Sweden
Telephone: +46 454 572120, e-mail: info@netport.se

# Executive Summary

A main output from ARENA 1 was "The Concept" – a comprehensive solution for a distance-based road user charging scheme tailored for a Swedish kilometer tax.

In the ARENA 2.0 field trials the Concept was developed, implemented and operated as a technical system[1]. The development and test period provided important knowledge and experiences, and the preparations for and discussions during the test called for modifications of details of the concept.

However, the most important conclusion from ARENA 2.0 is that the fundamentals of the ARENA 1 Concept remain valid:

- The role model with a single TC and parallel competing TSP´s provided an efficient solution with very limited problems. It also provided important experience, e.g. the big differences in TSP performance.
- The tariff scheme, i.e. a link based price list based on NVDB, worked well in principle and could be managed by all TSP´s.
- The road usage declaration compiled and provided by the TSP worked very well.
- The key principles of the compliance checking mechanisms remain unchanged.
- The communication interfaces worked well, and the standards applied served well their purpose.

It shall be observed that these conclusions are based on discussions and field trials mainly focusing on autonomous Road User Charging. There are however no evidence that other conclusions should be drawn if DSRC based systems had been in focus during the project.

### Three revisions to the implemented Concept needed

If considering the ARENA 2.0 field trials as an implementation of the Concept, three revision needs have been identified:

Need for a tidier NVDB layer for distance based charging

The ARENA 1 Concept defined the NVDB as the solid base for the "price list". It was found in the field trials that the NVDB needs to be further processed to create a specific "pricing layer" as the basis for a distance based charging scheme.

Specifications left room for misinterpretations

The interface specifications used need to be further detailed than was foreseen in the concept.

Newer versions of the standards need to be taken into account

ARENA 2.0 was developed parallel to the ongoing interface standardization process. It has become evident that newer versions of the standards and new standards provide additional and appropriate information that should be accounted for in the future work.

### Three open issues identified

From the discussions in ARENA 2.0 also some issues have been identified where further discussion is needed:

[1] ARENA Report 2010:03 ARENA Trials final report

The level of detail in the road usage declaration

From the start of ARENA, the project has experienced a gradual move from a very Toll Charger oriented (centralized) to a TSP oriented (decentralized) procedure for fee calculation. The key question remains: How much information is really required to fulfil the needs and requirement of the Toll Charger (which could be the Swedish Tax Agency)?

Would an area based approach fulfill the Swedish requirements for exceptions to "all roads"?

A key requirement in the Swedish Concept is that a distance based charging scheme (autonomous tolling) should be able to distinguish between individual roads in the pricing mechanism. As far as publishing the price list (the NVDB layer) this is perfectly OK, but as was demonstrated in the ARENA Field Trials the use of the price list in this format puts limitations to the system due to the amount of data needed. Instead one could consider a price list where a limited number of roads are expressed as links (e.g. motorways) while other parts of the road network are simply classified as areas. This would reduce the problems with "missing roads in the database" considerably and limit the amount of data required for the TSP´s.

Will secure monitoring through the trusted recorder be the best solution?

Not only in Sweden but Europe-wide, the idea of secure monitoring through a trusted recorder prevails as a fundament for interoperable (in particular autonomous) road user charging. It contains a secure kernel that is standardized to such an extent that it will allow for Toll Chargers to retrieve and analyse raw data from virtually any European OBE, as is needed in the case of EETS.

Is this a feasible scenario, or are there better solutions that are more easily implemented? That will provide a more dynamic security solution that will allow for evolution? These questions will be in the centre in the near future in work on interoperable road user charging.

# Preface

The key deliverable from the first phase of the ARENA project was a concept for a national scheme for distance based road user charges[2]. This scheme was developed to meet specific requirements as expressed in the Road Tax investigation[3] and also fulfil the requirements following from the EFC directive[4] and its subsequent decision[5] and the CESAREIV recommendations[6]. The concept was also designed to fit with the EasyGo service in the Nordic countries[7].

In ARENA 2.0 the concept was developed into a full scale demonstration where all elements of the system were developed and tested[8]. This process, including specification of interfaces, workshops, dialogues with equipment manufacturers and system suppliers, provided a thorough analysis of the concept and helped to identify weaknesses and needs for development. This task is reported in this document.

[2] ARENA Report 2008:02 and ARENA Report 2008:03 A kilometre tax for heavy goods vehicles in Sweden – A conceptual design. Part 1 & Part 2
[3] Report from the governmental commission of road traffic taxation" (SOU 2004:63)
[4] Directive 2004/52/EC
[5] The EC decision (in 2009)
[6] CesareIV deliverables
[7] www.easygo.com
[8] ARENA Report 2010:03 ARENA Trials final report

# Table of Contents

# Introduction

ARENA, a Swedish R&D project, is developing a future-oriented road user charging concept for heavy goods vehicles and also establishes a Test Site to demonstrate practical solutions. The project is also a cornerstone for a research centre in the area of e-transactions.

The ARENA project serves as platform for stakeholders within the area of road user charging. The goal is to gather knowledge and skills in science, industry and public sector for opportunities and constraints of road user charging in a complex, international and competitive telematics environment.

The project is managed by NetPort.Karlshamn in close cooperation with Sweco and Blekinge Institute of Technology. ARENA is funded by the Swedish Transport Administration, VINNOVA and the European Regional Development Fund.

## The ARENA Concept

The key deliverable from the first phase of the ARENA project was a Concept for a national scheme for distance based road user charges[10]. This scheme was developed to meet specific requirements as expressed in the Road Tax investigation[11] and also fulfil the requirements following from the EFC directive[12] and its subsequent decision[13] and the CESAREIV recommendations[14]. The concept was also designed to fit with the EasyGo service in the Nordic countries[15].

In ARENA 2.0 the concept was developed into a full scale demonstration where all elements of the system were developed and tested[16]. This process, including specification of interfaces, workshops, dialogues with equipment manufacturers and system suppliers, provided a thorough analysis of the concept and helped to identify weaknesses and needs for development. This task is reported in this document.

In parallel, policy development in Sweden and other countries, has called for an extension of the scope of the ARENA project to not only deal with distance based road user charges, but to treat these as a part of a comprehensive national scheme for road user charges. Including as well existing (e.g. the Stockholm Congestion tax and the Öresund bridge) as expected (the Gothenburg Congestion Tax, the Motala and Sundsvall bridge tolls) and discussed (a kilometre tax for HGV) charging systems.

Also, in the course of the project and following from the evolution of road user charging in Sweden and neighbouring countries, the basic scope of the project and the foreseen use of the Concept has been changed. The aim in ARENA 1 was to provide “technical support to procurement”, while the scope of the Concept developed in ARENA 2.0 was to support the authorities in the establishment of an integrated Swedish road user charge system that integrates Swedish needs with the international development and European legislation.

[10] ARENA Report 2008:02 and ARENA Report 2008:03 A kilometre tax for heavy goods vehicles in Sweden – A conceptual design. Part 1 & Part 2
[11] Report from the governmental commission of road traffic taxation (SOU 2004:63)
[12] Directive 2004/52/EC
[13] The EC Decision (2009)
[14] CesareIV deliverables
[15] www.easygo.com
[16] ARENA Report 2010:03 ARENA Trials final report

An overall presentation of this new concept is given in the document "RUC the Swedish Way[17]" which shall be seen as complementary to this report.

## This document

This document provides an overview of the revisions made to the concept in order to match changing requirements (following from field trials experiences) and a changed policy situation in Sweden.

**The first section** defines a basic terminology and description of entities actors and stakeholders in the system.

**The second section** describes, from different perspectives, the development of ARENA scope of works. The development accounts for changes in the national RUC policy and the anticipated use of the concept, new requirements on RUC systems following from this and their implications. The section furthermore iterates issues that were left to be resolved from ARENA, and discuss the need for integration with ANPR based RUC which is a cornerstone in current Swedish congestion tax development.

**The third section** provides a detailed analysis on each of the six main elements of the Concept that has been evaluated and identified for further development:

1. The overall business model
2. Tariff scheme applied
3. Road usage declaration to be
4. Compliance checking
5. Technical certification
6. Communication interfaces

**The fourth section** sums up the conclusions made and describes the need for further development.

[17] RUC the Swedish Way, ARENA report

# Terminology and reference model

The ARENA Concept describes the actors and their duties, and their interfaces. Understanding the concept, and hence this report, requires knowledge about actors and other entities that are essential for the system to work.

## Actors and Entities in the system

### The Toll Charger

The Toll Charger (TC) provides the transport service[18] related to the fee, and collects the revenue from the charging system. It may be an operator of a toll road or a national tax authority. The extent of the service is referred to as a Toll Domain. The Toll Charger has entered into a service agreement with one or more Toll Service Providers allowing their customers to use their electronic payment (EFC) facilities within the toll domain concerned.

### The Toll Service Provider (TSP)

The Toll Service Provider (TSP) supports the user / the driver with the facilities required to perform electronic payment of the road user charges. This includes the necessary vehicle equipment (OBE), an accounting and invoicing system and the necessary agreements with Toll Chargers. The user and the Toll Service Provider have a contractual agreement defining the conditions for their relation, which may include the TSP´s responsibility to act as an intermediary in the payment.

In case of autonomous systems (e.g. for a distance based charge) the Toll Service Provider will collect the data from the associated OBE´s and forward the required information to the relevant Toll Charger.

### The EETS Provider

The EETS Provider is a TSP working in accordance with the EFC Directive[19], offering a pan-European service; its clients have access to all European Toll Domains through the EFC OBE provided by the EETS Provider, and receive all costs on one invoice.

The EETS Provider will act as a proxy, and stands in place for its clients liable to pay the fees through a negotiated payment guarantee.

### The client, the EFC subscriber

The client holds the contract for the OBE and is responsible for payment of fees associated with the use of the OBE.

### The user, the driver

The user obtains the transport service and is responsible for the proper functioning of the OBE. In many cases (but there are several exceptions) the user is also the client.

[18] E.g. the right to use the network concerned
[19] Reference to the Directive 2004/52/EC

### The on-board equipment (OBE)

The OBE is an electronic device carrying the functionality and information required for EFC payment. There are two alternative and complementary solutions for the OBE:

a) Autonomous systems, where the OBE collects the information required for fee calculation through its own operation (using GNSS and CN), and forward the information to an associated TSP for further processing.
b) DSRC based systems (using microwave communication), used in traditional point passed toll stations, where the TC reads the information from OBE´s passing the toll station, compiles his claim and forward it to the appropriate TSP´s.

# Development of Scope of work

## Changes in the policy context

The ARENA 1 Concept was developed in a policy context which was expressed as:

The Concept is "..an approach to a systems design for the foreseen Swedish kilometer tax for heavy goods vehicles, providing a platform for a continued analysis within the project concerning feasibility and viability, security etc.."

Following the investigations made by e.g. SIKA[20] in response to the parliament decision, the governing parties decided to remove the introduction of a kilometer tax from the transport policy. However, the government also made clear that a wider introduction of direct road user charges, for financial or policy purposes, should be expected. At the time of the start of ARENA 2, there were also strong movements for the introduction of distance based road user charges in e.g. the Netherlands and Denmark and studies were also made in e.g. Norway and Finland. Europe also saw the legal introduction of EETS, and ARENA 2.0 contributed actively to the CESARE IV project in order to ensure a good match between the Swedish view and the European.

Hence ARENA 2.0 decided to change the scope of the Concept to fit with the new policy situation, and the expression above was changed to:

The concept is "..an approach to a system design for a distance based road user charging scheme designed for interoperability with other national road user charging schemes and the EETS."

Or in short, the revised Concept should:

- Provide a generic solution for distance based road user charging instead of a solution for a kilometer tax
- Focus less on system design aspects
- Focus on integration and interoperability with other RUC schemes in Sweden
- Focus on EETS interoperability

## Changes in the expected use of the results

When ARENA 1 was initiated, the plans for introduction of a kilometer tax in Sweden were quite mature, and ARENA was expected to deliver results that could be used directly in an expected system procurement process for Sweden.

As the policy situation changed, also ARENA changed its view on the use of the results from the project. Given the revised Scope of the project, the results from ARENA 2.0 are intend to guide, at first hand, Swedish authorities in their process of establishing a comprehensive solution to road user charging in Sweden, taking into account different needs and objectives of different systems. ARENA 2.0 has delivered a specific report in response to this need; RUC The Swedish Way[21].

[20] Reference to SIKA Analysis
[21] ARENA 2.0 report RUC The Swedish Way

## Development of Concept Requirements

The requirements on a Swedish RUC system were initially (in the ARENA 1 concept) designed for the implementation of a kilometer tax. They were based on the Commission on Road Transport Taxations final recommendations for a kilometre tax[22], the investigation on alternative financing of the extension of motorway E6[23], the legal framework developed for the congestion tax in Stockholm[24] and the proposed tax for the Svinesund Bridge (never implemented) and other related legislation (e.g. video surveillance). The ARENA 1 list of requirements[25] was divided into six groups:

- System requirements set by the legislator
- User requirements
- Requirements regarding security and reliability
- Requirements on manufacturers of components
- Requirements on added value services
- Interoperability requirements

Given the new approach taken and the revised scope in ARENA 2.0, it is clear that the ARENA 1 list of requirements does not fit as these requirements were developed to guide in a technical implementation process.

It is however important to recognize that ARENA 2.0 has not identified any specific errors or mistakes in the original set of requirements, e.g. in the field trial development phase. The list of requirements is relevant for a process aiming at implementation of distance based road user charging.

To meet the revised scope of the project, ARENA 2.0 has developed a new high-level list of requirements as presented below:

### Requirements on the Swedish RUC System

The new approach is that each installation of road user charging will be based on its own specific local requirements reflecting local needs and restrictions. There is however a set of requirements that can be seen as universal for all systems in Sweden, and form the basis for a national road user charging system:

**The road user shall perceive an integrated system**

Road User charging in Sweden includes congestion tax, bridge and road tolls and possibly distance based charges in the future. A basic requirement is that the road users shall experience a single interface to the services received, and be able to use a singular electronic device for all payments.

**The customer shall meet a single point of contact**

[22] Skatt på väg (SOU 2004:63)
[23] Andra vägar att finansiera nya vägar (SOU 2006:33)
[24] SFS 2004:629
[25] ARENA Concept Requirements v1.0 2008-02-12

As a customer, you shall receive only one invoice including all payments due, and you shall be able to address a singular contact point with information queries, questions, complaints on invoices etc.

**The system shall be interoperable with EasyGo and EETS**

Travelers from abroad with contracts and equipment associated with the EasyGo or EETS service shall experience full interoperability in Swedish RUC installations.

**The system shall allow for equal treatment of all road users**

The EETS does not allow for discrimination between frequent and temporary users of a toll service. Similarly, the Swedish road user charging system shall include the components required to manage all vehicles, regardless of origin, using the different services. Whether or not to exempt a certain category of vehicles (e.g. foreign) shall be a policy decision and not follow from system limitations.

**The system shall be cost efficient**

All elements of the Swedish road user charging system shall be designed to operate at low cost, and there shall be a continuous strive for improved efficiency. An important task is to find appropriate performance indicators to be applied in the development and operation of a national RUC scheme.

**The system shall comply with standards and use open interfaces**

International standards shall be fully applied in the Swedish RUC system, and interfaces in the system shall be based on open specifications.

**The system shall be flexible and allow for evolution**

The Swedish road user charging system shall allow for competing technologies and suppliers within the agreed technical framework, in order to stimulate technical and organizational development of equipment and services.

## Issues from ARENA 1 to be resolved

As changes in the policy context called for a revised approach, there were also a number of issues from ARENA 1 that were left to be resolved in ARENA 2.0:

**The question about a thin or heavy client approach**

A key question in the international discussion during ARENA 1 was whether Europe was heading towards a thin or heavy client solution for Autonomous OBE. A thin client means a reduced OBE functionality, e.g. all maps and pricelists are resident in back-office systems, while a heavy client OBE carries the functionality and technology required for fee calculation. ARENA 1 was a strong proponent for a thin client approach, which was seen as a natural consequence of the EETS.

In the course of ARENA 2.0 it has become evident that the issue of a thin or heavy client approach is rather a “non-issue”: The approach taken in ARENA accommodates both solutions. Hence ARENA 2.0 does not need to pursue this issue further.

**The Secure Module**

This issue is discussed further in section 3, *Compliance checking*.

**The application of "virtual" (autonomous) on board equipments**

A virtual on board equipment means that the full functionality of the OBE is built into the standard equipment of a vehicle. It was a clear requirement from vehicle manufacturer to prevent the installation of additional devices in the driver environment, and as e.g. GNSS and CN capacity is available in most heavy vehicles there should be no need for duplicate equipment.

Following the shift of approach in ARENA 2.0, the question became less important. ARENA 2.0 clearly demonstrated that a TC does not need to interfere in this discussion as the key interfaces for the TC are not affected. In the ARENA field trials, the TSP´s decided themselves upon the approach taken. We can however see that the introduction of EETS makes virtual OBE´s more difficult to implement in a shorter time perspective, as this would require considerable harmonization efforts. It is also clear that the (expected) business model of the EETS provider is extending beyond the EETS, which also could complicate the use of virtual OBE´s.

But from a TC perspective, our conclusion is that this issue has been resolved in ARENA 2.0.

**Whether or not to report positions on the entire road network**

This issue is discussed further in section 3 under *Tariff scheme applied* and *Road usage declaration*.

## Integration with a national "fall back" ANPR system

Following the introduction of ANPR[26]-based Congestion Tax in Stockholm and Gothenburg, Swedish authorities have decided to use this system as a basis for all Swedish vehicles at planned domestic toll stations. The build-up of a national ANPR-system calls for the introduction of "an account register" which is a basic account system for all vehicles subject to road user charges in Sweden.

It is based on the national Swedish vehicles registry combined with observations and registrations of foreign vehicles subject to a Swedish road user fee to the extent where these are not equipped for EasyGo[27] or EETS DSRC registration. The register keeps record of vehicles on the national road network and their payment obligations, also including potential use in an autonomous tolling scheme.

[26] Automatic Number Plate Recognition
[27] A Swedish. Norwegian, Danish EFC interoperability scheme based on DSRC – www.easygo.com

## Elements of the ARENA 2.0 Concept

The analysis of the ARENA 2.0 Concept is focusing on six key components of the concept:

1. The overall business model
2. Tariff scheme applied
3. Road usage declaration
4. Compliance checking
5. Technical certification
6. Communication interfaces

These six elements of the Concept and how they have been developed in ARENA 2.0 are discussed below.

## The overall business model

With reference to the reference model presented above, the business model accommodated in the ARENA Concept can be described accordingly:

### ARENA 1 approach - Full compliance with EETS, the European Electronic Toll Service

EETS is based on the idea of independent Toll Service Providers (TSP) offering a solution for clients (users) which will give them a non-discriminatory access to "all" toll services across Europe. The clients will get all road user charges on one invoice from the TSP, and the TSP will act as an intermediary in the payment chain as claims from Toll Chargers (TC) will be directed towards the TSP´s.

Of particular importance is that a Swedish TC must open up its service for EETS Providers. This means that whether or not a "local" TSP is active, the system has to be designed to accommodate EETS. The ARENA Concept takes EETS into full account, and take full advantage of its potential. As the TSP´s will take full responsibility for providing OBE´s to the clients and its installation in vehicles, and settle a contract for the use of the equipment and associated payments, there is no need for a TC to build a business structure based on direct contractual relations with clients (end users).

Furthermore, EETS is based on the existence of parallel competing TSP´s. This means that the adoption of EETS brings in a dynamic element in the business model where TSP´s will compete with their business offerings and technical development.

This approach from ARENA 1 was tested in the ARENA 2.0 field trials and found viable. Hence the business model from ARENA 1 remains unchanged.

### Conclusion from ARENA 2.0

The field trials demonstrated the success of the approach taken. It was also concluded that a strict adoption of the EETS as a model for the fee collection drives efforts towards harmonisation, which is an additional benefit.

The conclusion from ARENA 2.0 is that the approach taken in ARENA 1 shall be retained, and even strengthened.

## Tariff Scheme applied

The tariff scheme developed in ARENA 1 was based on two key components: Vehicle characteristics and the "price list". The latter defines the toll rate for specific road links, taking into account road characteristics and time of day (potentially).

The foreseen basis of the price list was the NVDB, the official road network description (road database) of the Swedish Transport Administration.

### ARENA 1 approach

In ARENA 1, the idea was to publish a "price list" as a "layer" of the national Road database (NVDB) which includes a link-based description of the road network. In the database, each road link is associated with a "tariff band" expressing the price per kilometre (road type dependant) for different vehicle categories during different times of day (optional).

| | Location Class ID 3 - Highway | | | | |
|---|---|---|---|---|---|
| Location Class ID | Time Class ID | Weight ID Min | Weight ID Max | Vehicle Class ID | Tariff (milli-SEK per meter) |
| Highway | Low Traffic | ≥ 3.5 | < 12 | Euro 0 | 0,528 |
| Highway | Low Traffic | ≥ 3.5 | < 12 | Euro 1 | 0,48 |
| Highway | Low Traffic | ≥ 3.5 | < 12 | Euro 2 | 0,432 |
| Highway | Low Traffic | ≥ 3.5 | < 12 | Euro 3 | 0,384 |
| Highway | Low Traffic | ≥ 3.5 | < 12 | Euro 4 | 0,336 |
| Highway | Low Traffic | ≥ 3.5 | < 12 | Euro 5 | 0,288 |
| Highway | Low Traffic | ≥ 3.5 | < 12 | EEV | 0,24 |
| Highway | Low Traffic | ≥ 12 | < 22 | Euro 0 | 0,968 |
| Highway | Low Traffic | ≥ 12 | < 22 | Euro 1 | 0,88 |

*Figure: ARENA 2.0 Field Trial Tariff Scheme*

### Conclusion from ARENA 2.0

The "price list" was made available for the field trial TSP´s as an unambiguous description of the tolls due as a specific layer of the national road database. Basically this approach has been retained in the concluding Concept.

However, the price list shall be seen as a way to publish the information required for fee calculation rather than as a strict basis for the fee calculation. From this price list, other types of maps (e.g. areas / zones) can be developed and applied to the liberty of the TSP. In the concluding concept of ARENA 2.0, the TSP Route Declarations (see below) do not need to refer back to the "price list".

## Road Usage declaration

In traditional (DSRC) road tolls, the TC operates the system required to collect customer information as a basis for claims. In autonomous EFC, the TSP collects all user data and transforms it into a Road Usage Declaration[28] which is forwarded to the TC.

### ARENA 1 approach to Road Usage Declaration

In ARENA 1, the idea was to describe each journey as a discrete series of road links according to "the price list", i.e. the national road database extended to include a "toll layer" where each link is given a specific road class indicator[29]. This description was defined as the "road usage declaration" and formed the basis for fee calculation. In the fee calculation, the trajectory of the vehicle (with its char-

[28] A Charge Report in the ARENA 2.0 Field Trials
[29] A road class defines a basic price per km

acteristics) is mapped against the “price list” and translated into a series of road links with their associated tolls. The approach also accounted for start and end points “in the middle of links” by always eliminating the first link and charging the full price of the last. This would ensure that two journeys along the same route (given the preconditions) would result in the same fee. In the ARENA 1 Concept the Road Usage Declaration included the identity of the full sequence of road links.

An argument behind the idea of “link sequence” was that it allowed for the TC to make an unambiguous fee calculation. This followed from the principle applied in Swedish Congestion Tax Systems where the TC has the responsibility to calculate and settle the tax (a “tax decision”).

### ARENA 2.0 experience

It was found in the ARENA 2.0 field trials and discussions that the approach taken created certain problems:

- The link structure of NVDB was not designed for the purpose. A huge variation in link characteristics (in particular length) made it difficult to provide a precise enough calculation of the tax due.
- It was also found that implementation of zones in the charging scheme would bring a considerable simplification to the system, and in particular in the design of the price list. A zonal approach would also facilitate the use of heavy clients in the system as it could limit the size of “the map” considerably.
- The idea of a “road usage declaration” to include all physical links was considered to be an infringement to personal integrity as it included a very detailed description of the vehicles movement to be sent to the authorities, and potentially to be defined as public information.

### Conclusion from ARENA 2.0

It is sufficient that a road usage declaration includes the amount of driven kilometres on different classes of roads during different time intervals (if relevant for the fee calculation). All references to the precise location of the journey can be removed from the declaration. The possibility to control remains through the compliance and control system (see Compliance checking / Trusted Recorder below). This is also how the declaration was designed and tested in the ARENA 2.0 field trials.

It can however be argued that also this amount of information is more than required in order to fulfil the task. Considering that the TSP has developed the Road Usage Declaration, it is evident that the TSP has the capacity to also calculate the tax. This means that the Road Usage Declaration could be reduced to the vehicle identity, the time period covered and the amount of tolls due.

In this question, the conclusion from ARENA 2.0 is that requirements from the TC´s will be crucial for the amount of information required to be included in the road usage declaration.

## Compliance checking

### ARENA 1 approach to Compliance Checking

During ARENA 1, a considerable development took place where the focus shifted from technical measures to control compliance to administrative and qualitative measures. The basic reason for this

was the high costs associated with full road network coverage of technical control system with appropriate quality.

ARENA also adopted the use of a Trusted Recorder as the technical basis for compliance control, where travel paths are cryptographically committed (frozen) on the OBE (through a Trusted Recorder) allowing for later matching against spot checks on the road network.

### ARENA 2.0 experience

ARENA 2.0 fully implemented a Trusted Recorder application and operated it during the field trial with good results. An important lesson learned was that the frequency in the recording in the trusted recorder needs to be in the order of at least 1/100 meter or 1/5 seconds to allow for control. ARENA also demonstrated parallel use of speed enforcement cameras[30] for spot check recording of passing HGV´s and concluded that images of appropriate quality can be retrieved also with temporary installations.

ARENA 2.0 did not further engage in the development and testing of qualitative control measures.

### Conclusion from ARENA 2.0

The global conclusion from ARENA 2.0 is that the comprehensive and multi-facetted approach taken to compliance checking seems to be a workable solution. It is however evident that Sweden not single-handedly can develop and implement a Trusted Recorder solution. There still remain some important technical issues to resolve, and here international standards and practises need to be developed.

[30] In cooperation with Sensys Traffic and Kapsch TrafficCom.

## Technical Certification

### ARENA 1 approach to Technical Certification

The ARENA Concept, also after the ARENA 2.0 evaluation, is promoting competition and parallel TSP´s to operate on the same network. This approach implies two things:

- Vehicle equipment must be the responsibility of the TSP´s, and, as evolution is favoured, the technical requirements from the Swedish TC must be very restricted (to interfaces and security). The OBE´s themselves shall be considered as "black boxes" from the Swedish TC perspective.
- This means that verification of "suitability for use" must be subject to a thorough testing procedure and prior to that a comprehensive technical certification.

This approach was brought into ARENA 2.0 as the motivation for the field trial scheme.

### ARENA 2.0 experience

The ARENA 2.0 field trial scheme was developed with the specific purpose of representing a "suitability for use testing" scheme. An important ARENA 2.0 experience is that the difference in quality of operation between different TSP´s is more related to their capacity and performance in relation to data management (including map matching, filling gaps in trajectories etc.) than on the technical performance of the OBE´s. The latter seems in general to have worked quite well, while the TSP´s ability to interpret received data and provide a correct tax calculation showed very big differences when the equipment was made subject to more complicated challenges in terms of vehicle movements and OBE management.

### Conclusion from ARENA 2.0

The main conclusions from ARENA 2.0 underscore the need to distinguish between the capacity of the TSP and the capacity of the OBE:

1. There should be a generic (European) requirements specification on OBE´s concerning their technical performance. This requirement specification should, at first hand, be directed towards manufacturers of equipment.
2. OBE certification: There is a need for a **generic technical certification of On Board Equipments** that will demonstrate their technical ability to perform according to the technical requirements. This is the responsibility of the OBE manufacturer.
3. TSP certification: There is a need for procedures leading to **certification of the TSP-OBE combination**, i.e. the TSP´s capacity to operate his interface with selected OBE´s. This is preferably done through a harmonised test bed which includes a dedicated, well known, road network and pre-defined vehicle (OBE) movements including specific challenges[31]. The test will focus on TSP-TC interface compliance and security system verification (e.g. a correct implementation of a trusted recorder). It should also allow for a generic charging accuracy verification through known parameters of the network and test facilities concerned.
4. Also, each TC (or a group of interoperable TC´s in cooperation) needs to develop its own specific test bed (road network plus vehicle movements including specific challenges) for verifi-

[31] Not necessarily a physical road network, also simulated environments could be used

cation of TSP-OBE operation as part of the suitability for use testing. This testing is specifically aiming at verification of a correct route declaration and fee calculation (charging accuracy) in the specific Toll Domain concerned. It can not be recommended to allow for operation based on only points 2 and 3 above, as the local characteristics may put very specific requirements on the TSP-OBE system.

## Communication Interfaces

### ARENA 1 approach

The ARENA 1 Concept were based on parallel and competing TSP´s where, as a consequence, the TSP-OBE interface[32] has to be the responsibility of the TSP, while the TSP – TC interface need to be open and harmonized as far as possible, and under the responsibility of the TC.

It needs to be underlined that the ARENA 1 Concept was limited to autonomous road user charging where direct communication between the OBE and the TSP is considered to be a typical feature. It was also this interface that was developed and tested in the field trials.

### ARENA 2.0 experience

The ARENA 2.0 experience is limited to the application of autonomous RUC. In the field trial ARENA developed interface specifications based on the draft ISO 17575 standards.

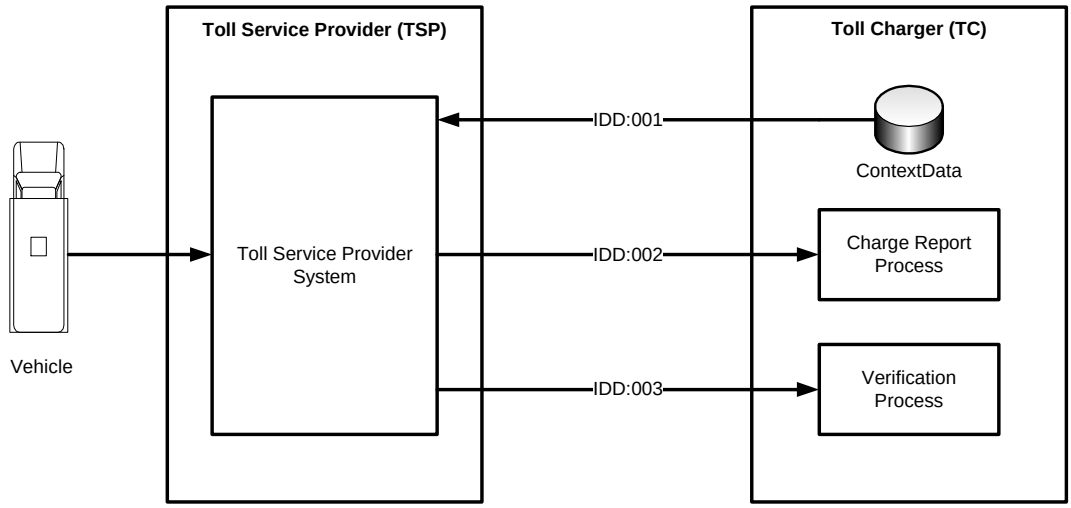


Figure: ARENA 2.0 Interfaces for data exchange between the TSP and TC [33]

The TC-TSP interface is managed via three types of data, where the data exchange is based on the exchange of XML documents. The definition of these XML document is based on draft versions of the ISO-17575 standard, especially when it comes to the charge reports.

The main experience from ARENA 2.0 field trials is that the interfaces well served their purpose and XML was easy to implement and well suited for the system. However, as the specifications left room for misinterpretations, considerable work had to be done to refine the specifications during the implementation of the trials. As ARENA 2.0 was carried out in parallel to the ongoing standardization, it

[32] This refers at first hand to an assumed CN interface. Also DSRC interfaces may be in operation for specific functions which require a TC-OBE interface standard.
[33] From the ARENA 2 Interface Specification

became also clear that in future work specifications need to be updated to cater for newer versions of the standards and in particular ISO 12855, Electronic fee collection - Information exchange between service providers and toll chargers, which is a key standard for interoperability, by now available in a complete draft. It includes the messages and attributes to be used in the back office communication between Toll Chargers and EETS Providers and was not available when the ARENA 2.0 specifications were developed.

### Conclusion from ARENA 2.0

The conclusion from ARENA 2.0 was that the approach taken in the development was correct and that the idea of open interfaces provided a workable multiple TSP solution as planned. The ARENA 1 Concept remains unchanged in this respect.

In future work new standards and newer versions of the standards needs to be taken into account as the standards have now reached a much higher level of maturity. Also further technical development is needed (rule-based translation of specification to XML, potentially a binary code interface as well to provide increased scalability) in order to develop a Swedish solution to the application of the ISO 17575 and 12855 standards.

# Final Conclusions

## The key elements of the ARENA Concept remain valid

The most important conclusion from ARENA 2.0 is that the fundamentals of the ARENA 1 Concept remain valid:

- The role model with a single TC and parallel competing TSP´s provided an efficient solution with very limited problems. It also provided important experience, e.g. the big differences in TSP performance.
- The tariff scheme, i.e. a link based price list based on NVDB, worked well in principle and could be managed by all TSP´s.
- The road usage declaration compiled and provided by the TSP worked very well.
- The key principles of the compliance checking mechanisms remain unchanged.
- The communication interfaces worked well, and the standards applied served well their purpose.

It shall be observed that these conclusions are based on discussions and field trials mainly focusing on autonomous Road User Charging. There are however no evidence that other conclusions should be drawn if DSRC based systems had been in focus during the project.

## Three revisions to the implemented Concept needed

If considering the ARENA 2.0 field trials as an implementation of the Concept, three revision needs have been identified:

### Need for a tidier NVDB layer for distance based charging

The ARENA 1 Concept defined the NVDB as the solid base for the “price list”. It was found in the field trials that the link model applied in NVDB is to disparate to allow for direct use as a price list where map matching is used. NVDB needs to be further processed to create a specific “pricing layer” as the basis for a distance based charging scheme.

### Specifications left room for misinterpretations

The interface specifications used need to be further detailed than was foreseen in the concept. Also, rule-based instead of manual translation of specifications to XML (XER) should be applied to facilitate implementation.

### Newer versions of the standards need to be taken into account

ARENA 2.0 was developed parallel to the ongoing interface standardization process. It has become evident that newer versions of the standards and new standards provide additional and appropriate information that should be accounted for in the future work.

## Three open issues identified

From the discussions in ARENA 2.0 also some issues have been identified where further discussion is needed:

### Legal requirements on the level of detail in the road usage declaration

From the start of ARENA, the project has experienced a gradual move from a very Toll Charger oriented (centralized) to a TSP oriented (decentralized) procedure for fee calculation. In the initial concept, each complete trajectory expressed as road links were sent to the TC for fee calculation, in the field trial this was replaced by a matrix providing distance travelled within each tariff band (type of road and time of day), while the final recommendation is rather to let the TSP calculate the tax and send a minimum of information to the TC.

As ARENA 2.0 has demonstrated the technical and functional viability of a decentralized approach, the key question remains: How much information is really required to fulfil the legal needs and requirement of the Toll Charger (which could be the Swedish Tax Agency)?

### Would an area based approach fulfill the Swedish requirements for exceptions to "all roads"?

A key requirement in the Swedish Concept is that a distance based charging scheme (autonomous tolling) should be able to distinguish between individual roads in the pricing mechanism. As far as the price list (the NVDB layer) concerns this is perfectly OK, but as was demonstrated in the ARENA Field Trials the use of the price list in this format puts limitations to the system due to the amount of data needed. This is particularly critical when considering international traffic in combination with the use of a thick client carrying the price list information, as all information needs to be exchanged when Toll Domains are shifted.

As ARENA decided to implement a strict distance traveled approach (see section *Road Usage Declaration* above) and the road usage declaration does not refer back to the price list, it is in practice free for the TSP to transfer the price list to other formats, e.g. area based solutions. As we can expect a very limited number of road types as the basis in the price list, large areas can be assumed to belong to the same price level. If this is accounted for already in the definition of the price list, one could construct a price list where a limited number of roads are expressed as links (e.g. motorways) while other parts of the road network are simply classified as areas. This would reduce the problems with "missing roads in the database" considerably and limit the amount of data required for the TSP´s.

This issue should be further elaborated in the development work prior to implementation of distance based charging schemes.

### Will secure monitoring through the trusted recorder be the best solution?

Not only in Sweden but Europe-wide, the idea of secure monitoring through a trusted recorder prevails as a fundament for interoperable (in particular autonomous) road user charging. It contains a secure kernel that is standardized to such an extent that it will allow for Toll Chargers to retrieve and analyse raw data from virtually any European OBE, as is needed in the case of EETS.

Is this a feasible scenario, or are there better solutions that are more easily implemented? That will provide a more dynamic security solution that will allow for evolution? These questions will be in the centre in the near future in work on interoperable road user charging.

# Annex: Terms and definitions

**Kilometre tax system:** All systems needed in order to collect road charges (but not to perform payment) according to distance travelled by vehicles.

**Central system** – Collection of terms including all technical systems not included in the OBU or on road side.

**DSRC** – Direct Short Range Communication[i]

**Driver** – A person actually driving the vehicle.

**EasyGo –** A cooperation on interoperable EFC between Sweden, Norway, Denmark (under extension to include also Austrian users)

**EETS** – European Electronic Toll Service. An interoperable ETS-service defined by the European Commission.

**EETS Provider** – An actor providing equipment and contracts enabling a user to pay a road charge. CESARE III project has defined the terms as "The EETS Providers are offering EETS by issuing OBE, contracts and payment means to the Service Users. They guarantee the payment of the services consumed by their customers the proved by genuine claims from the Toll Chargers. They will claim payment from the Service Users."

**GNSS** – Global Navigation Satellite System. Generell term for satellite positioning.

**PKI** – Public Key Infrastructure[ii], a structure of asymmetric cryptographic keys allowing binding of private/public identities with pairs of keys by a Certificate Authority.

**MAC** – Message Authentication Code[iii], a cryptographic one-way function used to prevent tampering of message contents. Mac supports a secret symmetric key as input and the message integrity can not be verified without access to this key.

**Transaction** – Continuously messages follows after one another according to the communication protocol, e.g. a report.

**TSP – Toll Service Provider** - A generic denomination of an actor providing equipment and contracts enabling a user to pay a road charge.

# Annex: References


Hedin J., Eriksson O., Sundberg J., Lindqvist M.; Handbok för Systemarkitekturarbete inom ITS; Förutgåva Vägverket (2003).

Karlsson Ulrik (2005); Handledning för systemarkitekturarbete inom vägavgiftsområdet

Löfgren, J., Larsson, P (2010). ARENA Report 2010:03 ”ARENA Trials final report”.

Sundberg J., Karlsson U., Sjöström T.; Kilometerskatt för tunga fordon i Sverige, Etapp 1 – Generisk arkitektur (2005)

Sundberg, J., Janusson, U and Sjöström, T (2008). ARENA Report 2008:02 “A kilometre tax for heavy goods vehicles in Sweden – A conceptual design. Part 1”

Sundberg, J., Janusson, U and Sjöström, T (2008). ARENA Report 2008:03 “A kilometre tax for heavy goods vehicles in Sweden – A conceptual design. Part 2”.

Statens Offentliga Utredningar, Finansdepartementet: SOU 2004:63 Slutbetänkande, Skatt på väg; Vägtrafikskatteutredningen (2004)

Skadsheim Arild, An overview of NORITS, version 1.2, Document 801 (2006)

D2.1 (v5.1), CESARE III (2006)

Karlsson U., Myhrberg S.; Vägavgifter för tunga fordon i Sverige - Etapp 2: Tekniska förutsättningar (2005)

Directive 2004/52/EC of the European Parliament and of the Council of 29 April 2004, on the interoperability of electronic road toll systems in the Community (2004)

Ulrik Karlsson och Stefan Myhrberg, Vägavgifter för tunga fordon i Sverige - Etapp 2: Tekniska förutsättningar, sektion 3.2.1 (2005)

http://en.wikipedia.org/wiki/Public_key_infrastructure, visited March 15 2011

http://en.wikipedia.org/wiki/Message_authentication_code, visited March 15 2011


[i] Ulrik Karlsson och Stefan Myhrberg, Vägavgifter för tunga fordon i Sverige - Etapp 2: Tekniska förutsättningar, sektion 3.2.1 (2005)

[ii] http://en.wikipedia.org/wiki/Public_key_infrastructure

[iii] http://en.wikipedia.org/wiki/Message_authentication_code

## ARENA reports

ARENA REPORT 2010:01 “Transport policy vs. distance-based road user charging tariff scheme design”. Karlsson, M. Sweco Infrastructure.

ARENA RAPPORT 2010:02 ”PM Hantering av utländska fordon i svenska vägavgiftssystem”. Sundberg, J. Sweco Infrastructure. (English translation not available)

ARENA REPORT 2010:03 ”ARENA Field Trials – final report”. Löfgren, J. och Larsson, P. Sweco Infrastructure.

ARENA RAPPORT 2011:01 ”PM Distansbaserade vägavgifter”. Forss, M. NetPort.Karlshamn. (English translation not available)

ARENA REPORT 2011:02 ”ARENA 2 Concept - final report”. Sundberg, J. Sweco Infrastructure.

ARENA RAPPORT 2011:03 ”Test Site NetPort - ett försöksområde för ITS”. Clemedtson, P. NetPort.Karlshamn. (English translation not available)

ARENA RAPPORT 2011:04 ”Sammanfattning av pågående forskning inom ARENA”. Krasemann, J., et al. Blekinge Tekniska Högskola. (English translation not available)

ARENA RAPPORT 2011:05 ”Vägavgifter i praktiken”. Källström, L., Sundberg, J., Forss, M., Clemedtson, P.O., Törnquist, J och Löfgren, J.


www.arena-ruc.se

Project Owner:

Cooperation partners:

Financial partners:

Investing in your future

EUROPEAN UNION
European Regional
Development Fund