ARENA Field Trials – Final report

Jens Löfgren, Sweco
Pia Larsson, Sweco

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ARENA REPORT 2010:03

2010-12-08

ARENA

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.

Abstract

In order to support a possible introduction of distance-based road user charging for Heavy Goods Vehicles (HGV) in Sweden, the R&D project ARENA has conducted field trials. The ARENA Trials have tested and demonstrated a road user charging concept, from November 2009 till April 2010.

The ARENA concept is adapted to both national requirements and harmonised with European legislation and standardisation and introduces a competitive environment, the Toll Service Provider, to stimulate effective and creative business solutions. The tariffs used in the trials were based on the marginal cost principle, with the charge being based on differentiation on time, place and vehicle characteristics.

The overall goal of the ARENA Trials was to test and demonstrate the ARENA concept's viability and attractiveness.

The ARENA Trials has been divided into two main parts; the Field Trial and the Test Track. The first part of the ARENA Trials, the Field Trial, was conducted on a day to day basis on the whole road network of the two Swedish southern provinces Skåne and Blekinge using trucks driving their ordinary routes. The Test Tack was a controlled blind test for the participating Toll Service Providers (TSPs) which consisted of a 45 kilometres long route exposing the TSPs' systems to different challenges to test charging accuracy, i.e. their ability to charge correctly in a challenging environment.

The ARENA Trials showed that good charging accuracy can be obtained and that the ARENA concept is a viable and attractive solution for distance-based road user charging - and a step to obtain interoperability throughout Europe.

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Introduction

The possible implementation of a distance-based road user charge for heavy goods vehicles has been discussed for many years in Sweden. The Swedish R&D project ARENA develops a feasible concept, an approach to distance-based road user charging (RUC) adapted to both national requirements as well as harmonised with European standardisation and legislation.

The ARENA project is funded by the Swedish Transport Administration, the Swedish Governmental Agency for Innovation Systems and European Regional Development Funds. The main goal of ARENA is to create Swedish competence and awareness within the industry and the political area for distance-based road user charging and its possibilities and limitations in a complex, international and competitive environment. Also, the project delivers a general and more specific functional concept description. The goal of the ARENA Trials was to test the viability and attractiveness of the ARENA concept, see chapter "*The ARENA Concept*" below.

The ARENA Trials, testing and demonstrating the ARENA concept, were operational from November 2009 to April 2010 and were divided in two parts; a Field Trial on a day to day basis during normal conditions and a test track conducted in a controlled environment. Participation was open to companies that were ready to fulfil the Field Trial requirements and obligations. The trials were conducted in the two Swedish provinces Blekinge and Skåne that are used as a test site for R&D projects with an initial focus on heavy goods vehicles and road user charging.

The ARENA Concept

The ARENA concept for distance-based road user charging distributes the responsibility for charging collection in three tiers, as Figure 1 illustrates; the Road User, the Toll Service Provider (TSP) chosen by the road user, and the Toll Charger (TC). The TSP is the collector of the charge acting on behalf of the tax and transport authorities. According to the concept the use of certified onboard equipment (OBE) is mandatory, and the road user is held ultimately responsible for reporting the road usage. The OBE is expected to be provided by the TSP. The TSP is also connected to the Toll Charger, to whom they report the Road Users' accumulated charge.

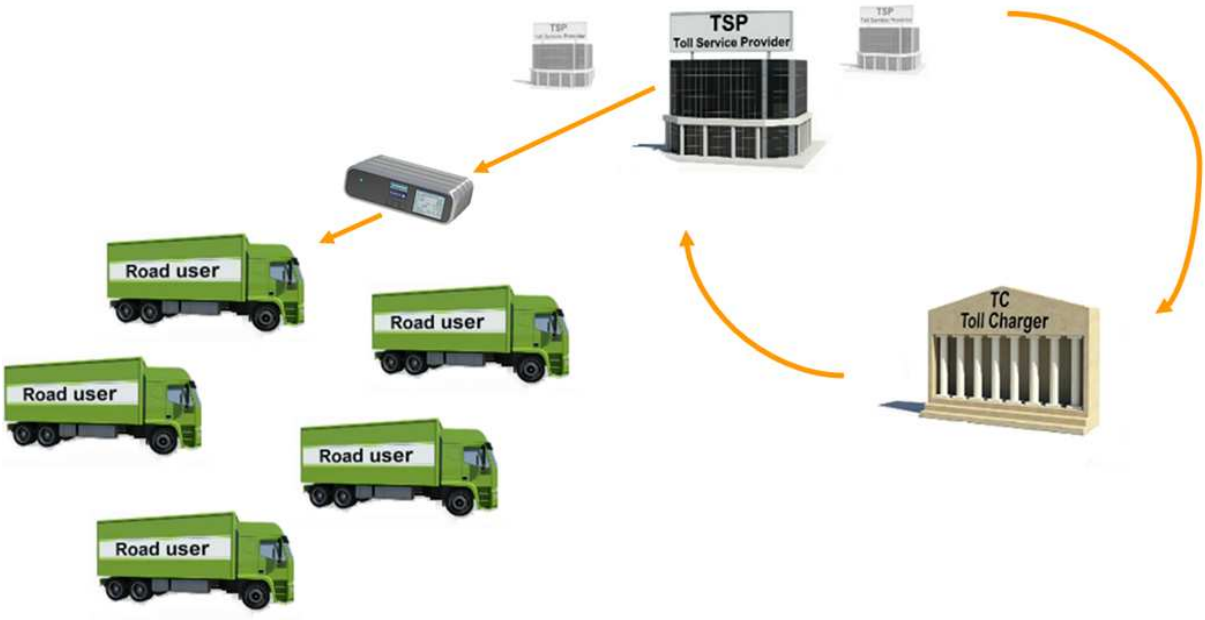


Figure 1. The ARENA role and task allocation model.

The separation in three tiers is familiar from the European decision on European Electronic Toll Service (EETS), about how to achieve interoperability between different road charging systems in Europe. In most schemes in place today, the users deal with a combined TC and TSP. In contrast, the ARENA concept envisions the TSP role to be firmly separated from the TC role.

The ARENA concept for a distance based road user charge includes all heavy goods vehicles with a total weight of 3.5 tonnes or more and covers the complete national road network. The tariff of the charge is based on the marginal cost principle and the charge is based on differentiation on the factors time, place and vehicle characteristics such as vehicle class and weight.

This division of responsibilities is in line with the EETS and is also designed to allow TSPs to make the best use of their technology and limits the prescriptions on what technologies to use. The multiple service provider approach stimulates effective and creative business solutions. This technology agnosticism has been prevailing throughout the ARENA Trials where there has not been any requirements to use any specific technology for the calculation of the road charge, only functional demands were applied.

The set up of the ARENA Trials

ARENA Trials test site was situated in the two southerly Swedish provinces Skåne and Blekinge. Together they constitute 11,000 kilometres of road divided on 65 000 road links. The first part of the trials; the Field Trial was conducted on the whole road network and the test track was limited to a small set of the road links on a limited area. Participation in the ARENA Trials was open to companies willing to personalize their On-Board Equipment

(OBE) and Back Office to the specifications provided by ARENA. The interest for the project in general and the Field Trial in particular has been satisfactory. Several potential Toll Service Providers (TSPs) has participated in the trials contributing with their knowledge and equipment.

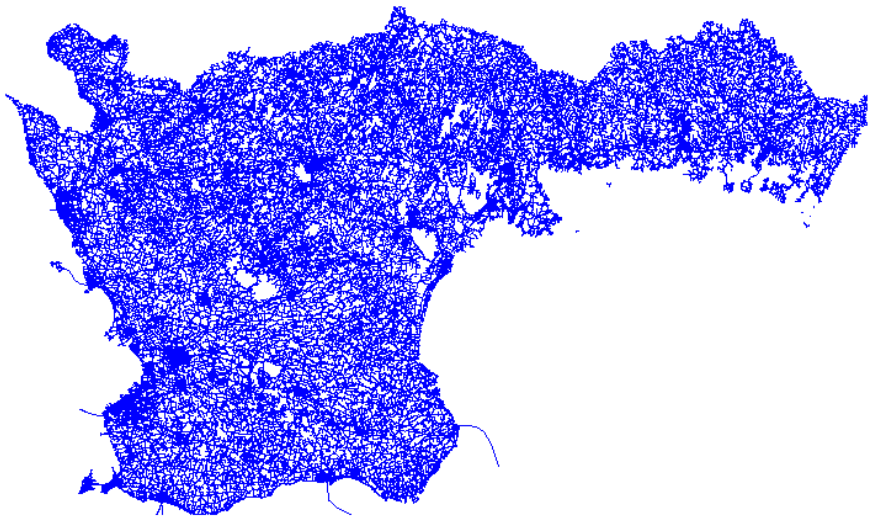


Figure 2. The two most southerly Swedish provinces Skåne and Blekinge

Communication Interfaces (specifications)

Prior to the ARENA Trials, three communication interfaces were developed, which will be briefly described below. These technical specifications were developed in coherence with contemporary versions of ISO-17575 standard and made available online in order to enable testing and compliance of the participating TSPs' technical systems. The three communication interfaces deployed and tested during the trials were:

1. Context Data Interface
2. Charge Report Interface
3. Compliance Check Interface

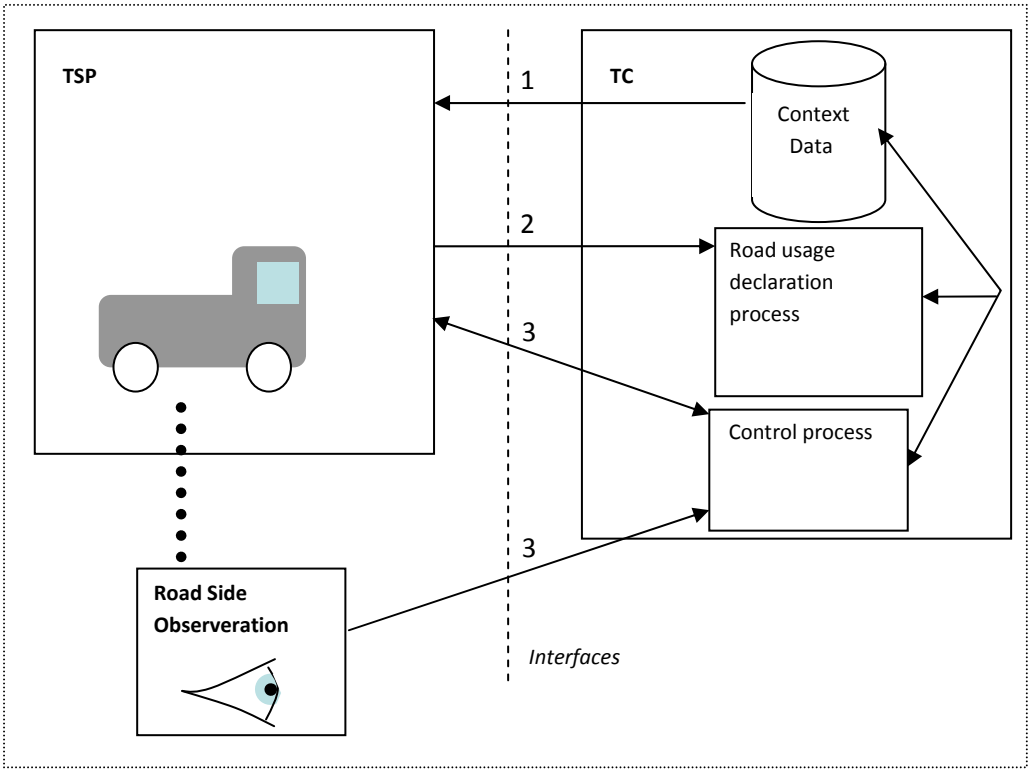


Figure 3. Information flows between TSP and TC over the three interfaces

Context Data Interface

The Context Data Interface consists of both map and tariff data. The map data is delivered in the data format Shape and contains information about the topology and geometry of the road network, where every road is represented by a road link. The map data consisted of approximately 11000 kilometres of road divided on 65 000 road links. Also, each road link has several attributes tied to it, for example road link ID, speed limit, direction, length and location class. The attribute location class points to the tariff data.

The tariff data was delivered in the data format XML and describes the tariff structure and contain rules for tax differentiation, depending on location class, time, vehicle class and maximum permissible vehicle weight. The tariffs will therefore change when the vehicle enters a road link with a different location class, or when a new time interval is reached.

Charge Report Interface

It is the responsibility of the TSP to collect and process detailed road usage data from its subscribed vehicles, for the road usage declaration process. The TSP will store the raw usage data and at regular time intervals aggregate this data into Charge Reports. Each Charge Report is then sent over the Charge Report Interface to the TC, who will use this information as base for the tax decision for the specific user. In the charge report, the TSP declares to the TC the fee calculated for a certain time interval. The road usage declaration process was used by the TSP issuing Charge Reports on XML format, through the dedicated back-end to back-end Charge Report Interface, to the TC.

Compliance Check Interface

As part of the control process, the TC might ask a TSP to provide the underlying raw usage data from a charge report. This can for instance be triggered by an observation from a road side camera. For that purpose, the TC uses the Compliance checking Interface. Through this interface it is possible for the TC to request raw usage data from the TSP. The TSP should respond with raw usage data for the vehicle that the TC requested. The request and response data are sent as XML messages.

Participation Levels

When the invitation to potentials TSPs was sent out in spring 2009 four participation levels were presented. The invited TSP could, based on their willingness to adapt their system to ARENA specifications, choose to participate on any given level. At first response nine companies enrolled on level one and one on level two. No enrolments were made for level three and ten for level four. However, the level of enrolment did, as the table above states, not equal the level of actual attendance in the trial due to different circumstances. The reason for not participating in the trials has been analysed and is presented later on in the report.

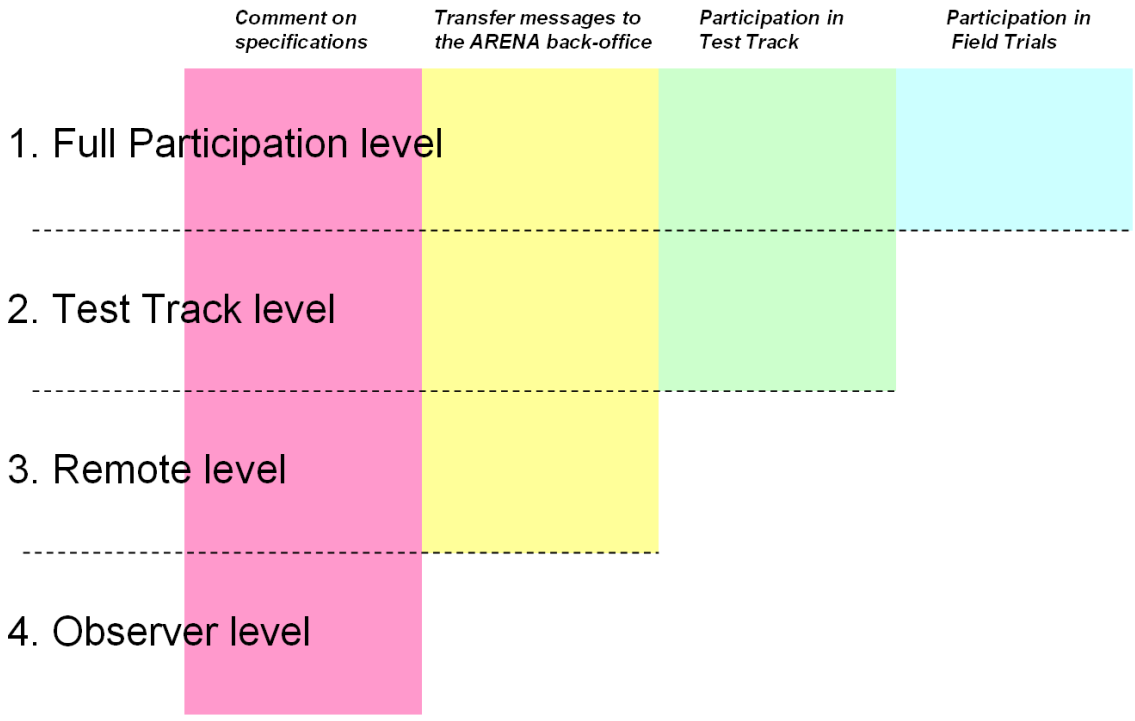


Figure 4. The four participation levels in the ARENA Trials

There were in total 13 potential TSPs taking active interest in the ARENA Trials' four participation levels, as Table 1 depicts below. In addition to these, representatives from additional ten companies have participated in ARENA's specification workshops.

Company name	Participation level
EROAD	1
FELA	1
GMV	1
Skymeter	1
Octo Telematics	1
Autostrade Tech	2
Eurotoll (SANEF)	2
AGES	4
DKV	4
Logica	4
Thales	4
Toll Collect (Satellic)	4
Union Tank	4

Table 1: Participating TSPs in the ARENA trials

1. Field Trial

The first level of the ARENA Trials, the Field Trial, began on the 16th of November 2009 and ended on the 12th of March 2010. Five TSPs participated and contributed with two On Board Equipments (OBEs) and back office system. The Field Trial was conducted on a day to day basis on the whole road network of Skåne and Blekinge using trucks driving their ordinary routes on a daily basis. Each participating TSP was to contribute with two OBEs and a Back Office which resulted in a test fleet of ten vehicles in total.

The main objective of the Field Trial was to test and demonstrate the ARENA concept's viability regarding the role and task allocation model. This has been carried out from a holistic point of view, to evaluate how the system functions and performs during everyday operations.

To be able to recreate a real environment, ARENA engaged Test Site NetPort with its partners; hauliers, drivers and workshops to participate in the Field Trial. The trucks represented a variety of driving patterns working on a regular day to day basis, performing local, regional and domestic transports enabling test of trucks entering and exiting the Field Trial area. Ten trucks from four hauliers were recruited, each equipped with one OBE supplied by a TSP, to be tested continuously when driving during normal conditions. Each truck was also equipped with a reference GPS device generating positioning data for the benefit of evaluation.

To ensure basic message and data delivery and to avoid technical mishaps that could venture the Field Trial result each participating TSP had to pass an integration test prior to the Field Trial to ensure that the TSPs were compliant with the ARENA specifications. The test was both a remote test checking the interfaces but also an on-sight test after installing the equipment in the vehicle to test the actual behaviour of the unit.

The participating TSPs were to send charge reports presenting a correct calculated charge, on a regular basis, to the ARENA back office to visualise an actual implementation. Drivers

and mechanics were also asked to answer questionnaires (before and after the start of the trial) in order to evaluate user experience and ease of installation.

The TSPs ability to calculate a correct user charge, i.e. charging accuracy, was tested and evaluated in the second part of the ARENA Trials; the Test Track.

2. Test Track

The second participation level of the ARENA Trials, Test Track, was designed and planned to, from a Toll Charger's perspective; evaluate the charging accuracy for each TSP in a controlled test environment. With influences from the GNSS Metering Association for Road user charging, GMAR[1], a test track was designed in the vicinity of the city of Karlshamn. The Test Track was conducted between the 12-16th of April 2010 and six potential TSPs participated.

The objective of the Test Track was to evaluate charging accuracy of participating TSPs systems, based on the data generated from the OBEs on the Test Track when facing challenging but realistic conditions. ARENA was particularly interested in which situations the TSPs could handle and which situation they were not prepared for. Charging accuracy was during the ARENA Trials defined as the division between the fee reported in the Charge report, and the correct fee for the challenge.

$$\text{Charging Accuracy} = \frac{\text{Fee reported in TSP Charge Report for the Challenge}}{\text{Correct result for the Challenge}}$$

During Test Track, participating TSP's systems were exposed to five challenges, expected to make it difficult to create a correct charge report. The challenges were merely testing a set of worst case scenario rather than regular day-to-day use. More information about respective test follows, but briefly the tests included anomalies in map data, difficult geographical conditions and irregular driver behaviour. The character of the challenges and the exact location of the challenges were not made public before the start of the test this making it a blind test for all participating TSPs.

Basically, Test Tack consisted of an approximately 45 kilometres long route, on which the test vehicle circulated, see Figure 5 below. The route was divided into five different sections, where each section represented a challenge. For the Test Track, all OBEs from the participating TSPs were installed in the same Test Truck, thus reducing variations in external conditions and driving patterns to achieve better comparability. The route was driven 20 laps, four laps each day from Monday to Friday, and no deviations from the route were made during the week. Thus, every OBE was exposed to the same challenge 20 times and 100 challenges in total. In additions to these challenges, the compliance check interface was tested through spot checks made by road side cameras.

[1] GMAR's Performance Assessment Framework (GPAF) version 0.79, to be found at http://www.gmaruc.com as of 2010-08-13

Figure 5. A satellite picture over the Test Track area showing the five different challenges

During the week, 100 charge reports (five challenges per lap and twenty laps) were requested from each participating TSP, based on the time intervals in which the tests were driven. The calculated fees in these charge reports were then compared to the correct answer for the particular challenge. The "correct result" of each challenge has been compiled twice: First manually by adding the lengths of the road links and multiplied with current tariffs to get the fee, and secondly by using ARENA's Charge Calculation software. Each comparison resulted in a charging accuracy figure, which was obtained after dividing the calculated charge from the charge report with the correct answer for the challenge. If, for example, the correct answer for a certain test was 50 SEK and the calculated charge in the submitted charge reports was 51 SEK, the charging accuracy was 102 % and the user was overcharged. Likewise, if the charge was calculated to 49 SEK the charging accuracy was 98 % and the user ended up being undercharged. Thus, the goal for each TSP was to reach 100% of charging accuracy.

Six potential TSPs participated on the Test Track level and the five challenges during Test Track were following:

Challenge 1: Driving outside map

The idea of the first challenge was to evaluate the charging accuracy on a route where the vehicle partly drove on road links that were missing in the map data. In a future implementation there will always be a gap in time from the time when a road link is opened up for driving, until the time when the map data is updated and released by the TC. Scenarios like these will result in vehicles driving on roads that are not present in the map data, as Figure 6 illustrates.

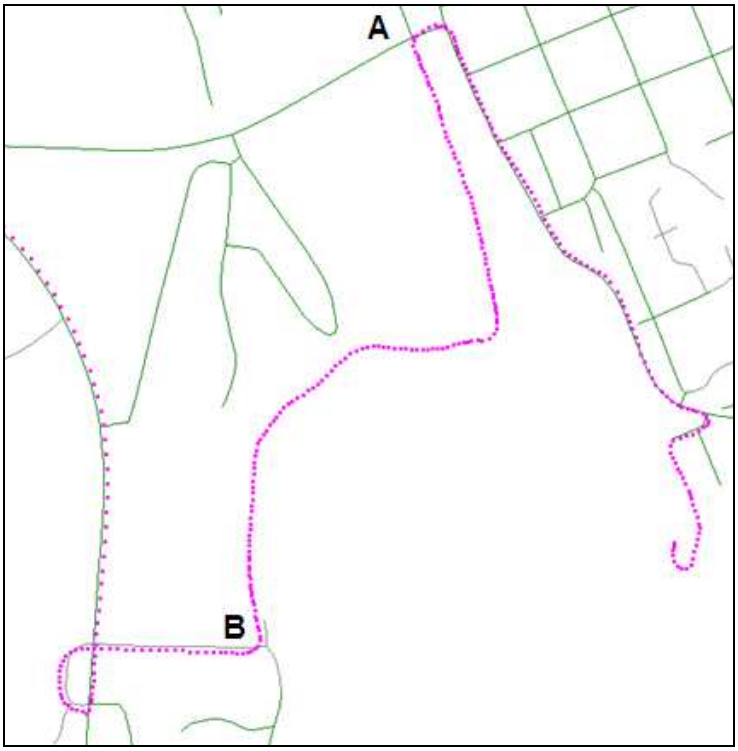


Figure 6. Driving outside the map, here illustrated by the GPS trajectory between A and B

In Figure 6 above, between A and B, there is no underlying road network, which may create difficulties in pricing the journey correctly. According to ARENA's specifications, all driving outside map should be considered free of charge and be left out of the charge report. ARENA's expectations of Challenge 1 were, if anything, that the TSPs perhaps would be likely to overcharge. For instance, if the GPS fixes could have been matched to the road links west of the vehicle's trajectory.

Challenge 2: Uncompleted road links

The second challenge was to evaluate how TSPs deal with a situation where a truck enters a road link, drives half of its length, stops and goes in reverse, i.e. not driving the entire road link from start node to end node, as Figure 7 illustrates.

According to ARENA-specifications, it is the continuously driven distance on road links that should be the basis for the road charge. The difficulty of Challenge 2 was to charge for the critical distance between A and B twice. TSPs who miss out on detecting driving on the critical distance will undercharge.

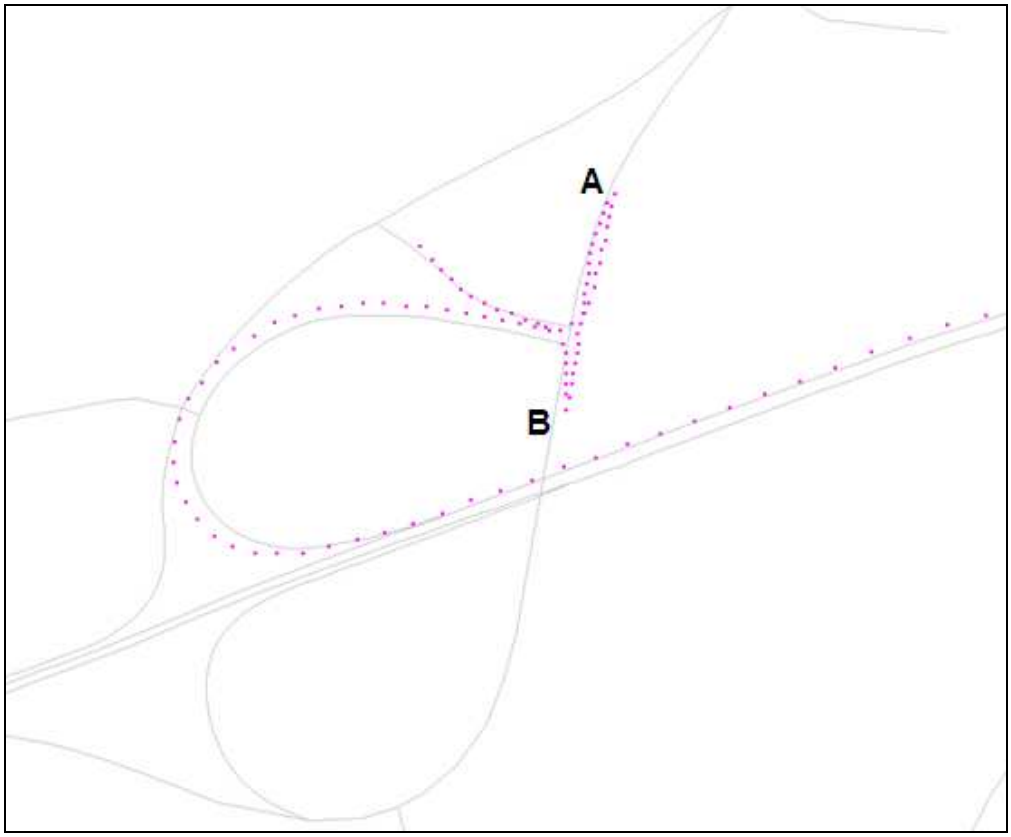


Figure 7. Uncompleted road links, as can be seen on the GPS trajectory between A and B.

Challenge 3: Parallel roads

The difficulty in challenge three, Parallel roads, consisted of detecting driving on two sections of parallel roads belonging to the tariff class free of charge, given in Figure 8. The challenge implies that if the TSPs fail to detect the turns into the parallel roads the first between A to B and the second between C and D, the TSP is likely to overcharge.

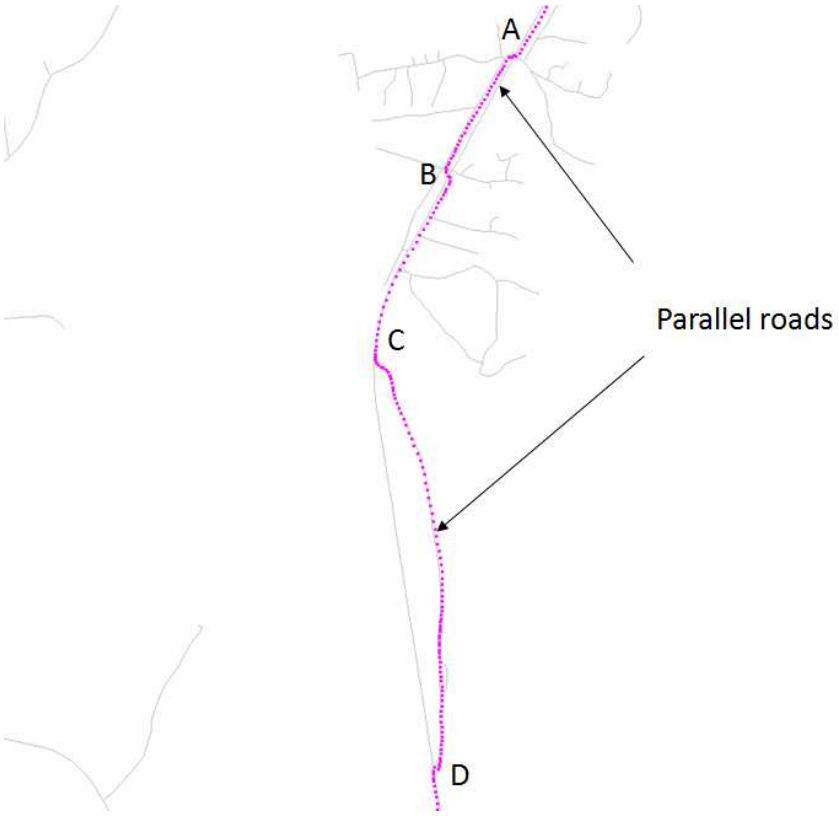


Figure 8. The challenge Parallel roads

Challenge 4: Power outage while stopped

During Challenge 4 the vehicle performed two stops in the verge, where one power outage per stop was performed, see Figure 9. The power outages were carried out using a switch between the OBEs and the power supply and the purpose was to evaluate how well the TSPs systems perform after start up, and how they manage to “fill in the gaps” and price journeys featuring time to first fixes (TTFFs). The reason behind this challenge was to evaluate how irregular driving behaviour with short pauses or incidents with detached cables affect the charging accuracy.

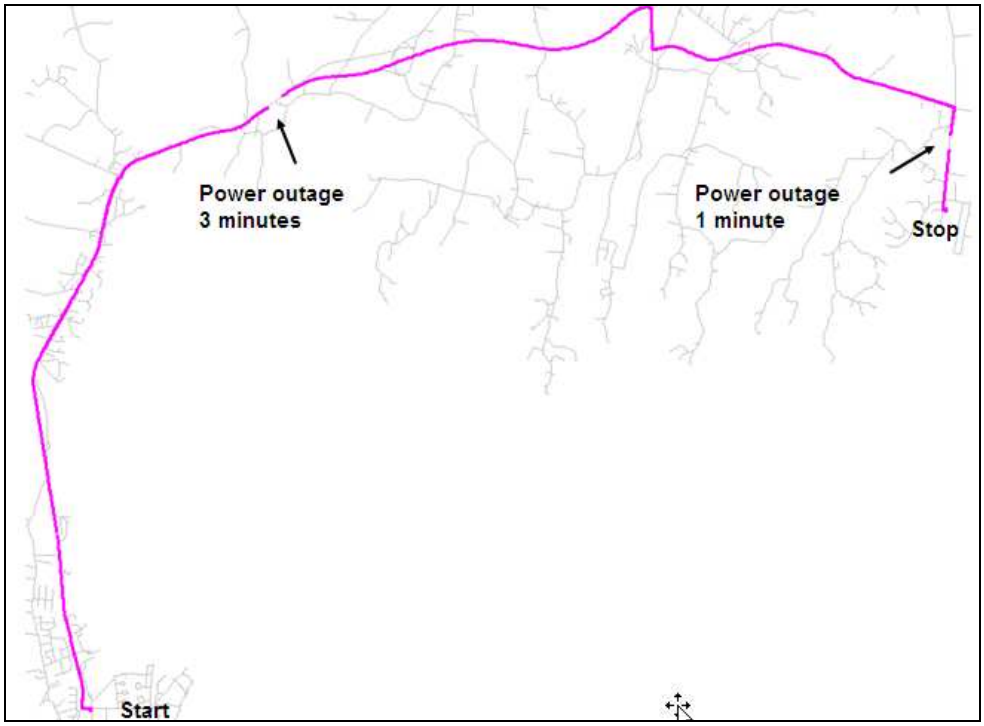


Figure 9. Power outage while vehicle standing still, illustrated by two TTFFs.

Challenge 5: Power outage while driving

In challenge 5 the vehicle was driven while the TSPs OBEs had no power supply, as illustrated by Figure 10. This challenge was designed to evaluate the TSPs' systems robustness against irregular driving behaviour and potential cheating. When planning the Test Track, Challenge 5 was expected to be the most difficult of the five Challenges, and undercharges were expected. The first power outage lasted around 900 m, with no alternative route to take, and the second power outage lasted for 1, 2 kilometres with alternative routes to choose.

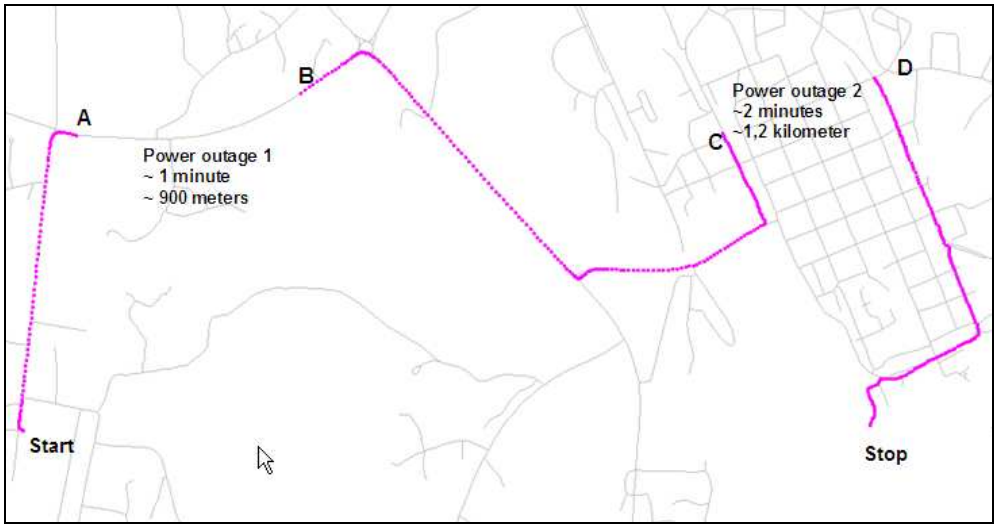


Figure 10. Power outage while driving, illustrated by gaps in the GPS trajectory.

3. Remote Level

The third level of participation in the ARENA Trials was the *remote level* which was an opportunity for TSPs to develop their systems according to ARENA specifications and to test the system against the ARENA server without taking part in the Field Trial or Test Track. Also this level aimed at testing and validating the technical specifications developed in the ARENA project.

In case of remote testing on other sites than Test Site NetPort (Skåne and Blekinge), the TSP had to define their own Toll Context Data and provide it to the ARENA project team.

4. Observer Level

The *observer level* included the possibility of participating in the process as an outside observer and evaluator. It also meant receiving notifications and requests to provide comments when new results were published. ARENA carried out three workshops where the ARENA concept and ARENA interface specification have been. Observers actively participated in these workshops and submitted written comments on our specification drafts.

ARENA's Software Developments

When conducting a trial aiming at measuring accuracy based on newly developed specifications, it is fundamental that the participating parties have understood the specifications correctly. Furthermore, in order to determine the accuracy it is paramount to know for sure what the accurate result is. So, in order to enable a fair evaluation of TSPs performances, ARENA has developed two software applications:

- A charge report evaluation software
- A map matching and charge calculating software

Charge Report Evaluation Software

The charge report evaluation software was used in the early stages during the Field Trial. It was a relatively simple application which endeavoured to check the consistency of a random sample of charge reports from the operators. The software helped ensuring that TSPs had made a correct interpretation of the context data and charge report specifications when submitting the charge reports, so that, given that the correct distances are recorded from the OBE, the correct fee is calculated. The charge report evaluation software first loads the context data and, according to the context data's tariff rules, recalculates the fee for TSPs' submitted charge report, given journey parameters as distance driven, location class, time and vehicle characteristics, and compared the correct charge to the fee submitted in the charge report. If there is a deviation between the two fees, the software reports it. Similarly, if the results are the same, the software announces that the recalculated fee is 100.00% of the fee stated in the TSP's charge report.

While simplistic it was successful in identifying a number of inconsistencies that were rectified at the operator level. Further, the development of the software revealed a number of problems with the integral structure of the charge report which caused difficulties with the calculations. What is best described as backtracking was necessary in order to calculate results. It was determined that a better and more logical structure would most probably reduce the possibility for calculation errors and misinterpretation. The program was found to be useful in identifying a number of initial problems in both the charge report structure and operator errors in calculations.

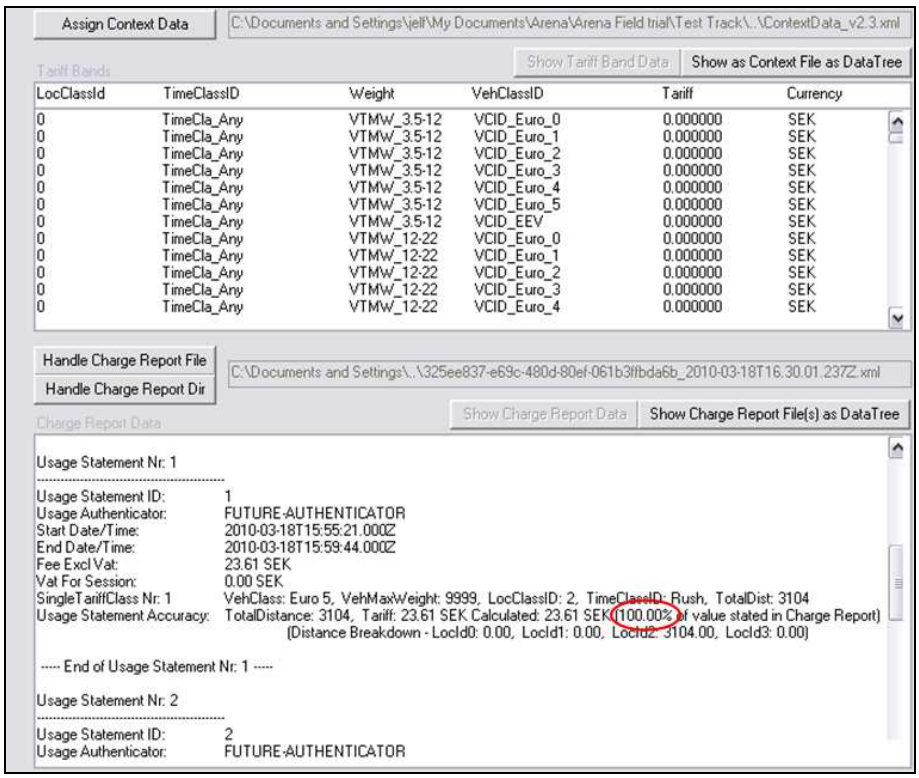


Figure 11. Screenshot of Charge Report Evaluation software

Map Matching and Charge Calculation Software

The second software developed, the map matching and charge calculation program, use positioning data from ARENA's reference GPS device. It was a more advanced program that was based upon the concept of mapping GPS coordinates and the corresponding timestamps from a logger onto the Swedish National Road Database in order to generate the same data as charge reports, thereby making validation possible. The software loads the context data and the vehicle's trajectory and map matches the GPS positions to the road links and calculates the road charge. Although the map-matching functionality was relatively crude it performed well in a number of tests and demonstrated the principles for road kilometre charging visually in a pedagogic way. The program that was developed was restricted by problems in the database which included a large number of short links particularly as junctions, some less than 5 metres long. These short links were shorter than the distance between two consecutive GPS-coordinates and were often at critical points in the network where turning movements occurred. This caused a number of problems for longer routes where the probability for map-matching problems was higher.

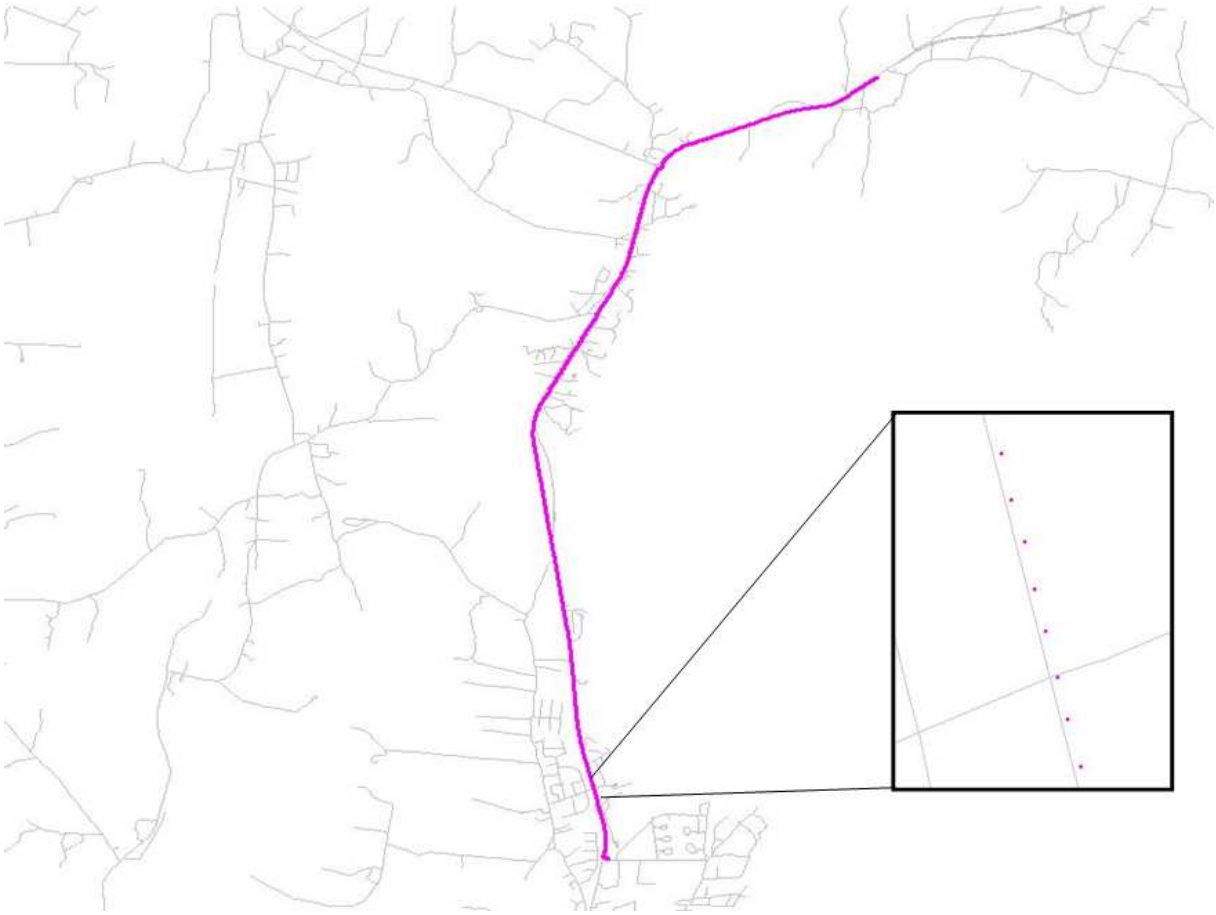


Figure 12. A vehicle's GPS trajectory plotted in the map matching and charge calculation software

This software was used to calculate the correct charge for the test track challenges, to lay the basis for determining charging accuracy (the correct charge for test track challenges have then been double checked by "manual" calculations, adding the lengths of the road links and multiplied with current tariffs to get the fee). The development of the map matching and charge calculation software has also provided useful knowledge to the ARENA project team. While many of the problems were solved, there were insufficient resources to rectify all of the different types of map-matching problems making the program less useful for wide-scale testing. The program served however, a useful purpose in demonstrating the main concepts involved.

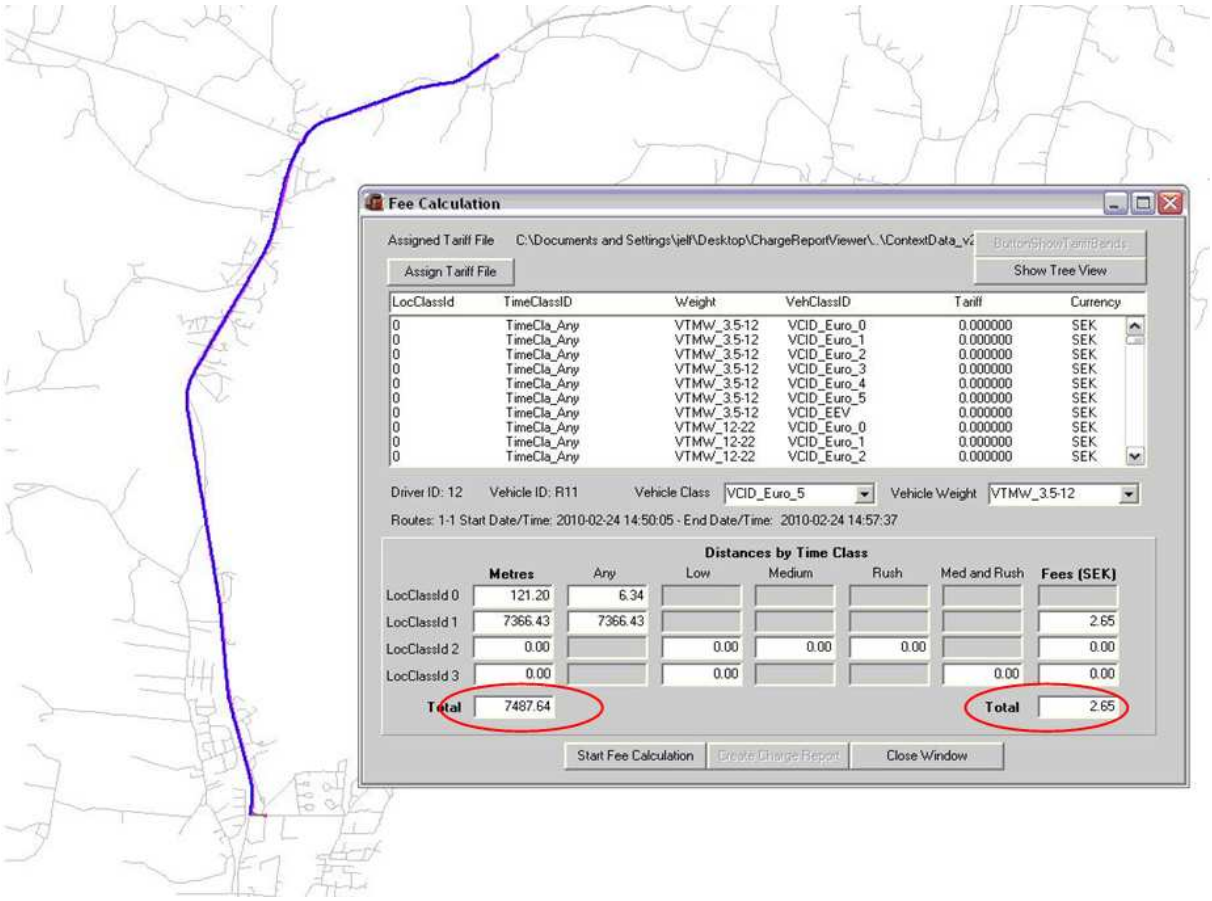


Figure 13. The GPS trajectory has been map matched and the charge calculated accordingly

Results

The overall vision for the ARENA Trials was, as previously mentioned, to test and demonstrate the ARENA concept's viability and attractiveness regarding role model, task allocation and interoperability. The overall results from the ARENA Trials show that the ARENA concept has proven to be viable, which we will go deeper into below. Furthermore, the ARENA Trials has been a way of gaining knowledge of the RUC industry and experience of current state of the art systems regarding charging accuracy, user experience and ease-of-installation and to analyse how the companies that participated in the trials and their technical solutions and services can work in conjunction with a possible future Swedish distance-based road user charging scheme. It has also been an opportunity for participants to develop, test and validate their road user charging solutions and to verify the ARENA concept's viability and attractiveness. ARENA has served as a platform for cooperation within the area of road user charging.

Field Trial

The result of the Field Trial has demonstrated that the ARENA role and task allocation model are viable. The Field Trial showed that any TSP from anywhere in the world applying technology which meets the functional demands, can adapt to the ARENA concept and start delivering road user charging services to hauliers using Swedish roads. The verification of ARENAs multi-service provider role model is good news, since it is one of the prerequisites for EETS and Europe-wide road user charging interoperability.

In addition to testing the ARENA concept, the evaluation of the Field Trials also included an evaluation of the user experience and ease of installation to get a comprehensive view of the system. This was done by handing out questionnaires to the truck drivers and workshop assembly fitters. It was shown that there was no negative user interaction throughout the trial and that the installation was easy and took between one and two hours per unit. This is comparable with the installation of any other OBE. When asking the users about any negative driver interaction they replied that they did not experience any at all.

Moreover, all TSPs participating on the observer level contributed to the marketing of the ARENA project and to valuable discussions and cooperation within the RUC industry.

Interfaces

The communication interfaces defined for the ARENA Trials has been proven to work as desired. All communication has been performed over the three interfaces specified by ARENA:

- The TSPs have received both map and tariff data over the Context Data interface, and then implemented both map and tariff structures to respective systems.
- The Toll Context Data has been used to measure the road usage and price the vehicle's journeys. This road usage data have then been submitted to the Toll Charger over the Charge Report interface.

- The Toll Charger have performed spot checks via road side cameras followed by Compliance Checks requests, with the TSPs responding with the raw usage data from the time of the spot check.

In total, ARENA has from the start of the ARENA Trials in November 2009, until the end in April 2010, received about 380 000 requests to the Toll Charger back office. However, the Field Trial also showed that there is a need for more detailed technical interface specifications, featuring more examples of the messages to be sent over the interfaces.

The choice of open web technologies such as REST web services and XML seems to have made it easy for everyone to develop and debug the integration. Another lesson learned was that live data sent from vehicles gives a realistic situation which in turn facilitates the integration test. The integration of Charge Reports was easier than the integration of compliance check which took a little longer to perform.

Problems of technical nature that occurred were mainly:

- Linked to the use of TSP self signed SSL certificates, that made it difficult for the TC server to verify the domain chain of the TSP server URLs
- Charge Reports that were not validated with the, by ARENA provided, XML validation scheme (XSD) before being sent out, caused the Charge Reports to be rejected

The TSPs participating on all levels contributed with valuable input, developing and improving ARENA's interface specifications, through their written feedback. The updated interface specifications can be found on the ARENA Field Trial website.

Test Track

The aim of Test Track has been to evaluate charging accuracy in a controlled test environment. Some TSPs managed to handle the demanding challenges very well resulting in very high results of charging accuracy, as the frequency diagram in Figure 14 illustrates below.

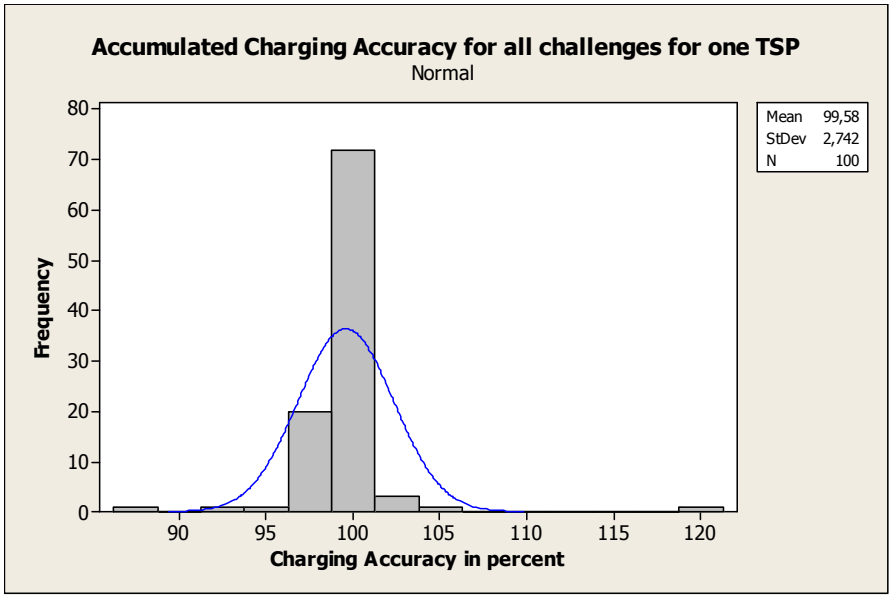


Figure 14. Accumulated Charging Accuracy for the TSP who generated the best result

Figure 14 shows the charging accuracy for all Test Track challenges for one of the TSPs. The figure reveals a mean value of 99.6 % and standard deviation of 2.7 %, with the pricing well gathered around 100 percent charging accuracy, except for some outliers. This result shows that it is possible to achieve very good charging accuracy, which in turn indicates that the ARENA concept is viable and that there is technology available on the market which meets very high demands. However, not all TSPs managed to deliver such accurate results, which Figure 15 illustrating the accumulated charging accuracy for all TSPs for all Test Track challenges reveals.

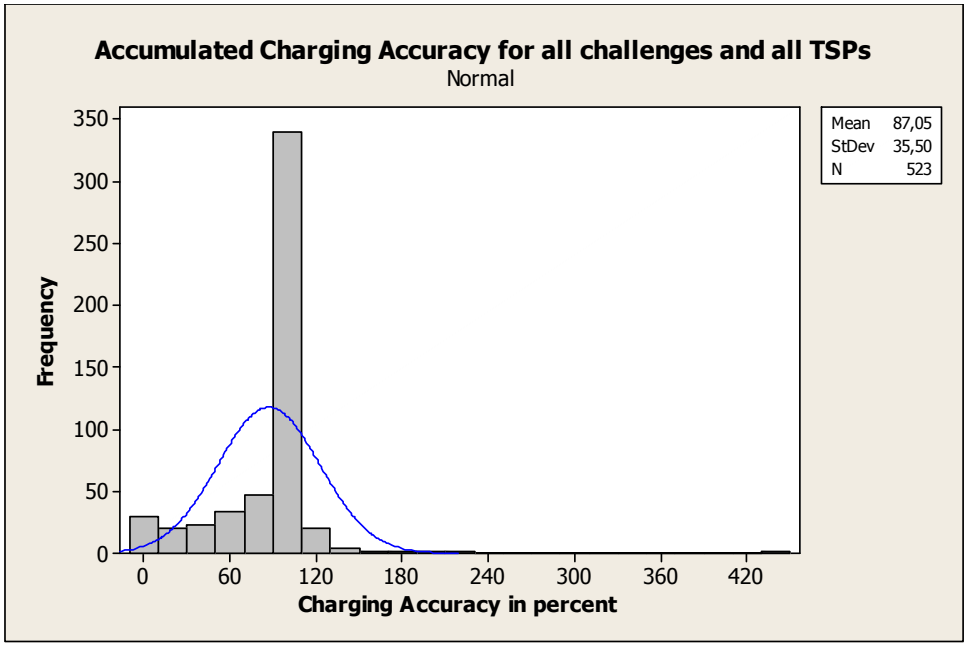


Figure 15. Accumulated Charging Accuracy for all TSP and all challenges

Figure 15 reveals varying charging accuracies, telling us that some TSPs experienced difficulties with the Test Track challenges. For example, there are several low outliers, many of them stemming from substantial time to first fixes and instability issues from the challenges featuring power outages. Due to the difficulties of the challenges, the TSPs are prone to undercharge, which the mean charging accuracy of 87 % tells us.

ARENA has analysed the reported trajectories from the TSPs via compliance check response data. This has revealed that some inaccuracies have been caused by data management problems for at least one TSP. These data management problems can be understood by the fact that the TSP has reported GPS trajectories that do not match the position of the true route at all. This leads to the conclusion that the data management after the collection of the data can partly be blamed for some of the inaccuracy, instead of other issues like the accuracy of the OBU itself.

Furthermore, the fact that some systems experienced varying charging accuracy can also be explained by Test Track being designed as a blind test consisting of a demanding set up of worst case scenarios difficult to price correctly. This, in combination with low thresholds; all companies interested were welcome to participate, there were no financial remuneration for the time and efforts made, as well as concurrent RUC trials in Europe. Another factor might be that some of the OBEs used where prototypes, not production units. All these factors may have influenced the result.

However, the Test Track result specifies the need for a careful certification process prior to an eventual implementation. In ANNEX 1, the results from the Test Track challenges can be found.

Conclusion

To conclude, the ARENA Trials were a success showing that the ARENA concept is a viable and attractive solution for multi service provider distance-based road user charging. During late 2009 and early 2010 ARENA has:

- Conducted trials involving several potential TSPs and mobile units (OBEs)
- Drafted a couple of transport companies and equipped their vehicles with different OBEs
- Made observations through road side cameras and requested raw usage data for compliance check
- Tested and verified necessary interfaces for distance-based road user charging

Simultaneously, the participating Toll Service Providers have:

- Further developed their back office system
- Complied to the ARENA specifications
- Measured and calculated the road charge
- Submitted charge reports and responded on compliance check requests

The ARENA Trials showed that, although the charging accuracy varied for the Test Track, it is possible to produce charge reports with very good charging accuracy, even during demanding worst case-scenarios. However, the trials also stress the need for a certification process prior to implementation, a process that might contain these types of worst-case scenarios.

The ARENA Trials also showed that both the role- and task allocation model is successful and thus that the ARENA concept is viable. The trial has validated that several TSPs, with different technologies, are able to implement the ARENA specifications and make it work. The ARENA concept does not exclude a specific type of technology and the ARENA scheme is in line with the European Electronic Toll Service (EETS). Since ARENA's multi-service provider role model has been verified to be a feasible RUC approach, the industry has come one step closer to EETS and interoperability throughout Europe.

References

ARENA Specifications January 2010 Available: http://arena-uc.se/includes/download.asp?info=Arena%20Specifications%20Jan%202010.zip Accessed: 2010-10-15

Decision EC/2009/750 on the definition of the European Electronic Toll Service and its technical elements

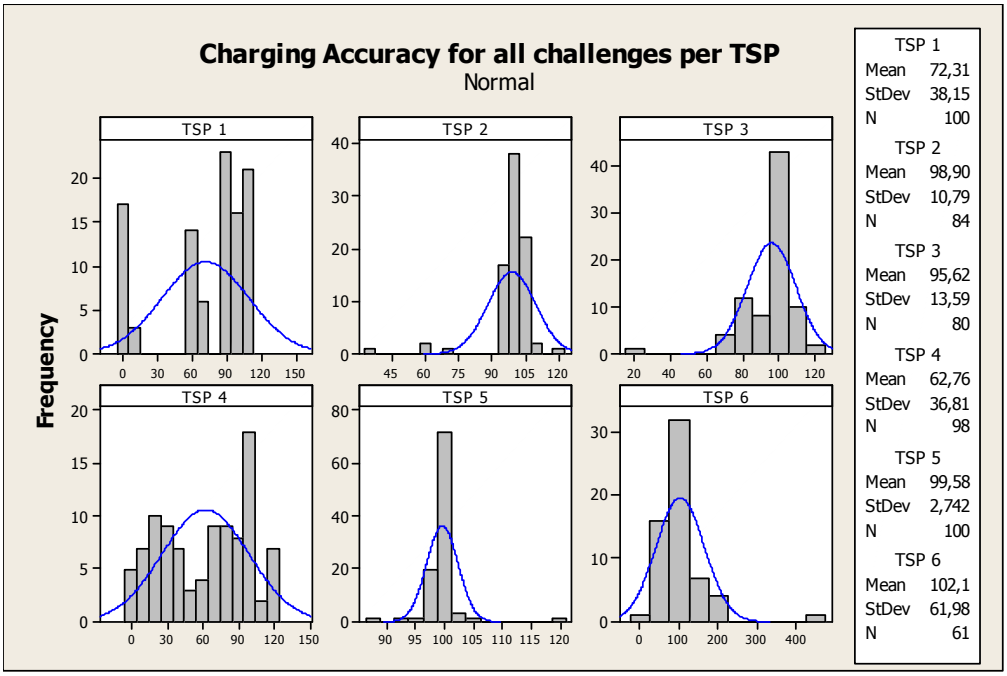
Directive EC/2004/52 on the interoperability of electronic road toll systems in the Community.

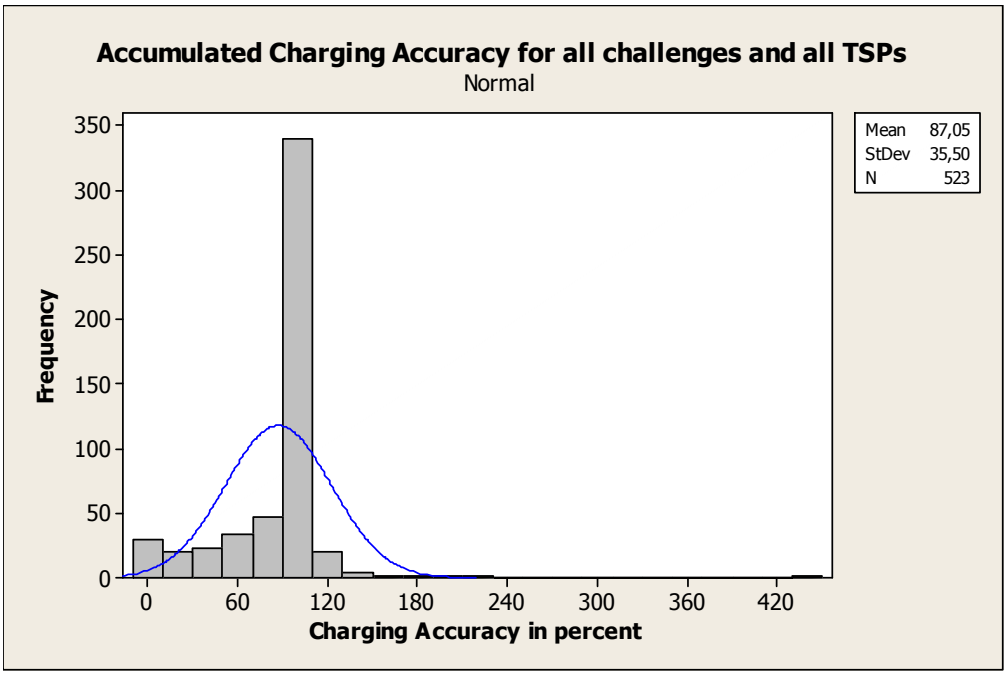
Forss, M., Gustafsson, I., Källström, L. & Sundberg, J. 2008. Kilometre tax for heavy goods vehicles in Sweden - a proposal for a functional concept. ARENA Report 2008:1 Available: http://www.arena-ruc.se/includes/download.asp?info=ARENA_REPORT_2008_01_KilometreTaxInSweden.pdf Accessed: 2010-10-15

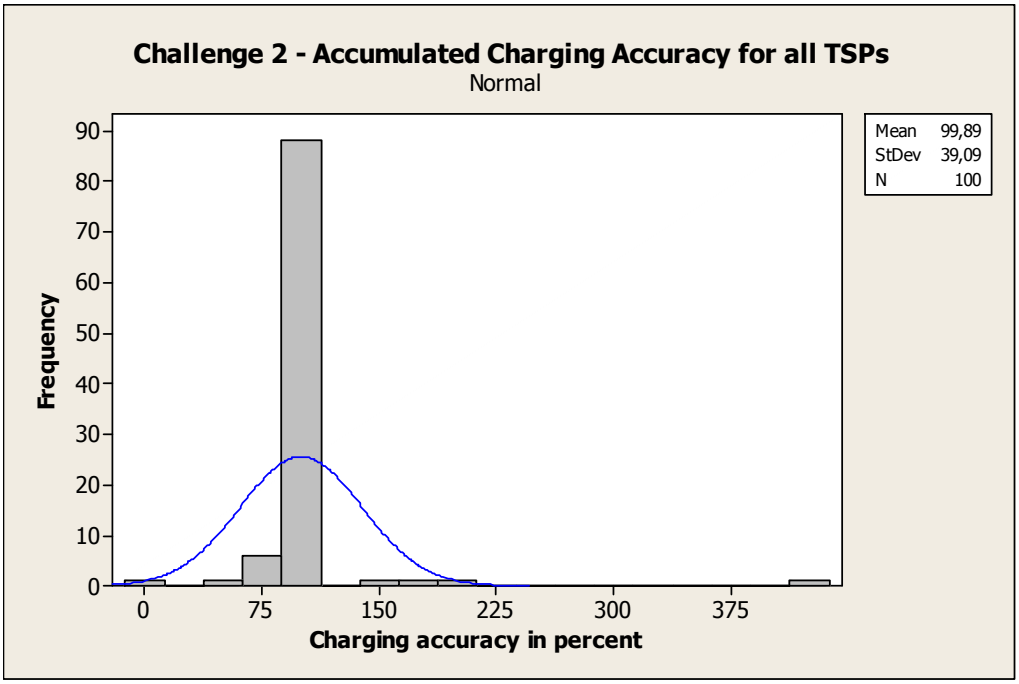
Annex 1

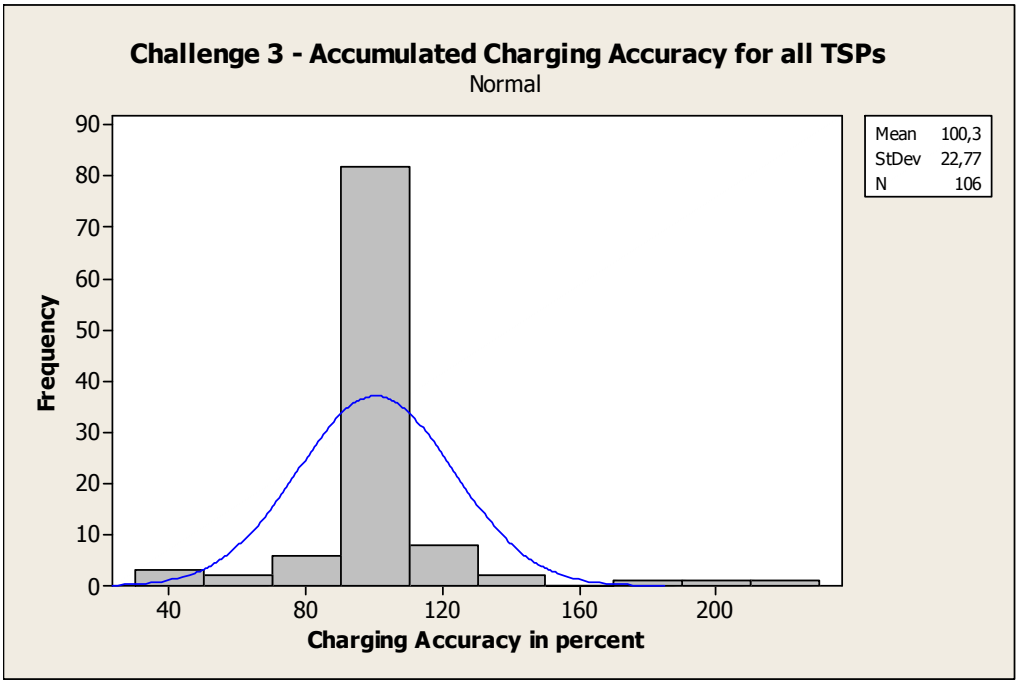
Charging Accuracy diagrams from Test Track

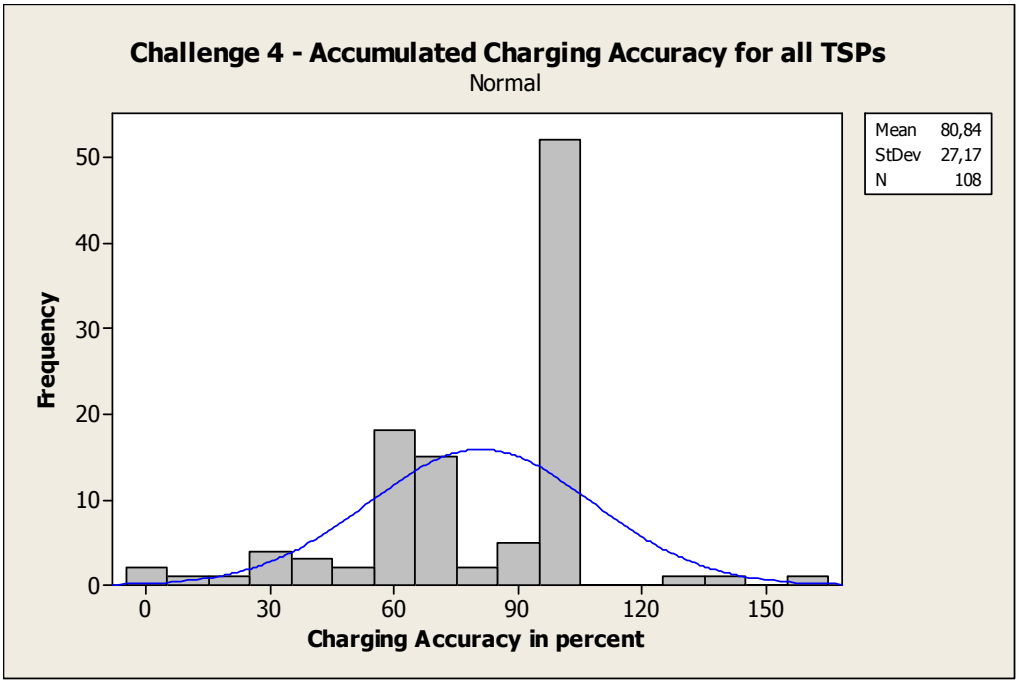
Note that the numbering of each TSP do not have anything to do with the order of the companies in chapter “The set up of the ARENA Trials”.

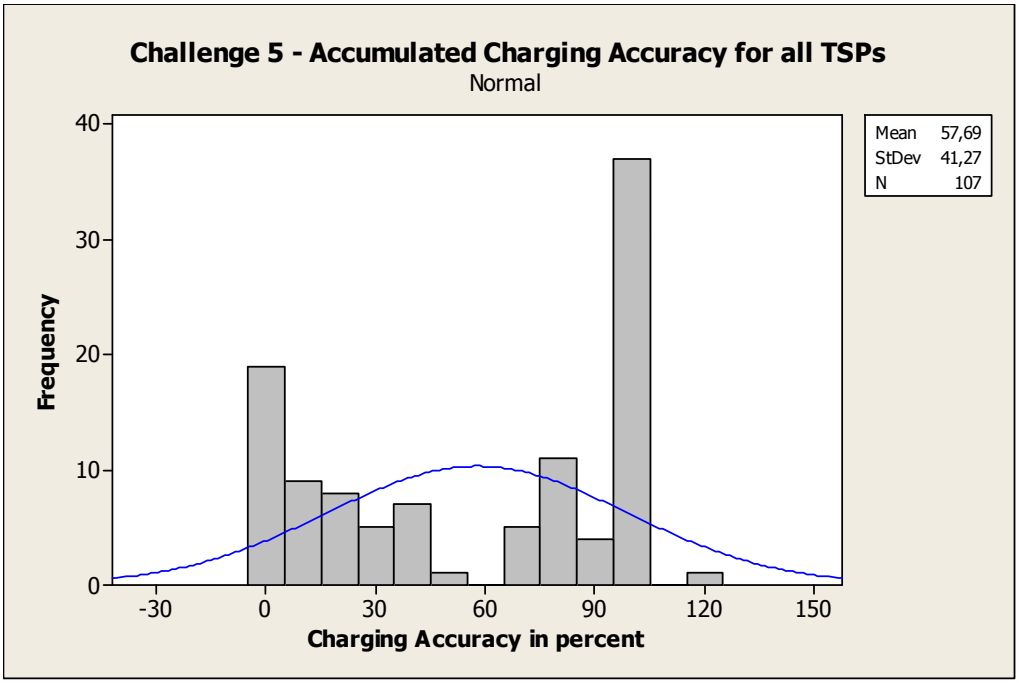





Challenge 2 - Accumulated Charging Accuracy for all TSPs
Normal
Mean 99,89
StDev 39,09
N 100
Frequency
0
10
20
30
40
50
60
70
80
90
0
75
150
225
300
375
Charging accuracy in percent


Challenge 3 - Accumulated Charging Accuracy for all TSPs
Normal
Mean 100,3
StDev 22,77
N 106
Frequency
0
10
20
30
40
50
60
70
80
90
40
80
120
160
200
Charging Accuracy in percent


Challenge 4 - Accumulated Charging Accuracy for all TSPs
Normal
Mean 80,84
StDev 27,17
N 108
Frequency
0
10
20
30
40
50
0
30
60
90
120
150
Charging Accuracy in percent


Challenge 5 - Accumulated Charging Accuracy for all TSPs
Normal
Mean 57,69
StDev 41,27
N 107
Frequency
0
10
20
30
40
-30
0
30
60
90
120
150
Charging Accuracy in percent

Annex 2

Other major partners of the ARENA Trials

The ARENA Trials would never have been possible without the participation from our cooperation partners. The lists below complement the list in chapter “The set up of the ARENA Trials”.

Participating Road Side Camera Operators

In order to perform road side observations of vehicles and to test and demonstrate the Compliance Check interface, road side cameras have been used. ARENA has cooperated with following two suppliers of road side camera equipment:

- SENSYS Traffic
- Kapsch TrafficCom

Table 2: Suppliers of road side camera equipment

Participating Hauliers

For the ARENA Field Trials a vehicle fleet of total ten vehicles have been used. Vehicles to the ARENA Field Trials have been provided by the following four hauliers:

- Blekinge Budtjänst AB
- AB Karlshamns Express
- FoodTankers AB
- Karlshamns Transport & Hantering AB

Table 3: Participating hauliers

Each OBE was equipped with a SIM-card enabling the TSPs to transmit road usage data to their back office. The SIM-cards have been provided by the following Mobile Network Operator:

Participating Mobile Network Operator

- Telenor Sverige AB

Table 4: Participating Mobil Network Operator

ARENA reports

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

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

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

www.arena-ruc.se

Project Owner:

NETPORT KARLSHAMN

Cooperation partners:

SWECO

BLEKINGE TEKNISKA HÖGSKOLA · BTH ·

Financial partners:

TRAFIKVERKET
SWEDISH TRANSPORT ADMINISTRATION

VINNOVA

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Development Fund