Published papers within the ARENA project
The ARENA project

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

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

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

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

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

Swedish Road Administration

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

VINNOVA

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

During the ARENA 1 project many presentations were held. This report lists 7 published and presented papers connected to the ARENA project during April 2006 and October 2007.

Paper titles:
- **An integrated approach towards a national distance based road charging system for heavy goods vehicles**, presented at Transport Research Arena, Göteborg 2006, authors:
  - Eva Schelin
  - Inger Gustafsson
  - Jonas Sundberg

- **An analysis of road user charging trends in Europe**, presented at ITS World Congress, London 2006. Authors:
  - Eva Schelin
  - Inger Gustafsson
  - Phil Blythe

- **Demonstration of the Swedish approach to a kilometre tax system for heavy goods vehicles**, presented at ITS in Europe, Aalborg 2007. Author:
  - Thomas Sjöström

- **ARENA – Development of a national road user charging system**, presented at ITS in Europe, Aalborg 2007. Authors:
  - Michael Forss
  - Inger Gustafsson

- **A new approach to distance-based road user charges – The Swedish kilometre tax**, presented at ITS World Congress Beijing 2007. Author:
  - Jonas Sundberg

- **Micro-level effects of a kilometre taxation – modelling haulier categories**, presented at ITS World Congress, Beijing 2007. Authors:
  - Linda Ramstedt
  - Michael Forss
  - Inger Gustafsson

- **Evaluation of road user charging systems: the Swedish case**, presented at ITS World Congress, Beijing 2007. Authors:
  - Jan A. Persson
  - Paul Davidsson
  - Martin Boldt
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Presentation at Transport Research Arena
Göteborg 2006
An integrated approach towards a national distance based road charging system for heavy goods vehicles

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Abstract

This paper provides an introduction to the Swedish ARENA project that started in February 2006. The project is a co-operation between the industry, the authorities and the academia. Through joint actions, knowledge and competence will be built up with the overall aim of implementing a distance based road charging scheme for heavy goods vehicles in Sweden. Within the project the concept for the scheme will be developed and critical technical issues will be investigated. The paper will provide an overview of the integrated approach and present the starting point for the concept development, i.e. describe the Swedish situation and its requirements.

Background

In 2002 the Swedish Governmental Commission on Road Taxes was given the task to analyse the possibilities to implement a kilometre-based road charging system for heavy goods vehicles in Sweden. Several activities around Europe triggered this: Switzerland had introduced a distance-based road charging system for heavy goods vehicles in 2001, based on the tachograph technology. Germany was procuring a sophisticated system for distance based road user charging on its motorways, based on GNSS/CN technology (Satellite positioning and mobile communication), while Austria was planning for an introduction of road user charging for HGV:s (heavy goods vehicles) on its motorways, based on DSRC technology. Other European countries were also getting more active in finding new ways for financing the use of infrastructure, as the problems of the underfinanced infrastructure network was more clearly becoming a threat to the development of the European Union and its economy. UK and the Czech Republic were among these.

1 Vägtrafikskatteutredningen
2 DSRC – Dedicated Short Range Communication
In May 2004 the Swedish Governmental Commission presented its conclusions, recommending that a distance based road taxation system should be introduced around 2009 that should:

- encompass the whole Swedish public road network
- be applicable for heavy goods vehicles above 3.5 tonnes
- reflect the margin cost principle

At the same time period a rapid development took place in Europe, where non-interoperable EFC systems were being introduced in several countries. This was seen upon by the European Commission as a threat to the principles of free movement of people and goods. Consequently, in April 2004, an EFC-directive was accepted by the European Union, forming the principles of “one device, one contract” for Europe. The aim with this directive is to create the European Electronic Toll Service for heavy goods vehicles that should be interoperable on a contractual and procedural level, using one or several of the following technologies:

- GNSS
- DSRC
- Mobile communication

The overall goal with the Directive is to create a European service for road user charges (the EETS) including in its first phase heavy goods vehicles, and later all vehicles. The EETS is being defined in several European projects, among other the CESARE III project, in cooperation between ASECAP and The Stockholm Group.7

Work leading to the formation of the ARENA

In addition to the Governmental Commission on Road Charges and its conclusions, several other activities have taken place in Sweden during the last 4 years. This has shown the need for a more coordinated approach to how the Swedish activities within the field of road user charges and electronic fee collection should be handled in the future, if we want to introduce an electronic fee collection based road charging system that works well from both a national and a European perspective.

The Swedish national project Tango Collect (2003 – 2004) came to several conclusions regarding the need for a coordinated approach if a successful implementation of road user charges for heavy goods vehicles should be made. Tango Collect focused on providing decision support for a future implementation in Sweden, e.g. through the establishment of a network of stakeholders. The conclusions (Gustafsson and Schelin 2004) from Tango Collect include the views and needs of the stakeholders (the transport sector, the authorities and the system and service providers) and can be summarised as:

- Give us technology that supports us – not control us! is the message from the transport industry.
  They identify that the mandatory road charging application can open up for a platform to which other service applications can be added, thus speed up the use of telematics in a sector which

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3 EFC / Electronic Fee Collection
4 Directive 2004/52/CE
5 EETS – European Electronic Toll Service
6 ASECAP – The European Association with tolled bridges motorways and tunnels
7 The Stockholm Group – Informal association of European road authorities
today has a low use of telematics. The transport industry further has the opinion that a system for road charges should be easy to use, transparent, safe and protect the integrity of the users. The charging means should be designed to answer to the needs of both low-tech and high-tech users.

- Service providers and system suppliers identify an innovation potential if the value chain is attractive to all relevant stakeholders and they ask for open interfaces and a functional system specification as soon as possible. The system specification should be based on well defined interfaces to enable connections with other applications as well as charging systems in other countries.

- The system should be designed to support commercially added value applications, thus enabling larger acceptance by the users.

- The Swedish road network is large but not heavily used, and few roads are of motorway standard. The road operators wish to direct the heavy goods traffic to the main network, which is designed and built for carrying heavy traffic. A telematic platform provides possibilities to the authorities with regard to traffic management as well as other areas, such as improved traffic safety, tracking of hazardous goods, environmental aspects and capacity.

All stakeholders further emphasized the importance of involvement of all relevant stakeholders in the work as the way to reach a well-functioning system design as well as a successful implementation.

Latter development within the EFC-area has shown the importance of investigating and finding solutions on several issues. For example the Svinesund Bridge between Sweden and Norway opened in June 2005. Due to differences in legislation between Norway and Sweden, a suitable solution for how to charge the bridge users on the Swedish side was difficult to accomplish. Further on, the full-scale trial in Stockholm of congestion charging started on January 3rd, 2006 and will conclude on July 31st 2006. In order to get this trial running, several legal arrangements had to be made, as the legal framework in Sweden is not very suitable for the EFC development. (This relates to for instance the responsibility of the vehicle owner and that the charge is seen as a tax in Sweden).

Discussions are ongoing in Sweden about financing the building of new public motorways with road user charges, which has not been done before (Sweden has a long tradition of financing infrastructure through taxes). Several issues have to be solved before this can take place.

Coming to the characteristics of the Swedish road infrastructure and traffic, these differ a lot from Continental Europe, which calls for solutions that suits Sweden while they still fulfil the European goals of interoperability.

- The road network is large and not so densely used
- There are few roads of motorway standard
- There are several remotely placed border crossings
- There is not so much transit traffic
- A very large forest road network, often privately owned

Based on this, a Swedish system for road user charges must be designed to meet the Swedish design criteria, at the same time as it is interoperable with the European EETS! To address this need, the ARENA project has been formed in Sweden, which will coordinate EFC activities in Sweden and work towards bringing the Swedish needs into the European context. We foresee a Swedish distance based road user charge for heavy goods vehicles with the following characteristics:
• The service encompass the whole Swedish public road network

• It is applicable for heavy goods vehicles above 3.5 tonnes

• It reflects the margin cost principle

• In the future, the road user charge shall be able to distinguish between different classes of roads and different time of day

• The road user charge shall be able to distinguish between different types of vehicles. When the Swedish system start to operate it will have to account for a European EFC service.

• In the introduction phase, the tax should be differentiated solely on the basis of the vehicle’s properties (the vehicle combination’s total weight and environmental class)

• The technical solution proposed is focused on certain functions and not on certain specific technical methods, but should allow for an increased complexity with respect to the expected differentiation of the tax.

The ARENA

The basics of the ARENA is that it is a triple helix project, run as a joint effort between the academia, the industry and authorities. The ARENA shall bring existing competences from different sectors together and through joint actions build up knowledge and competence to enhance the possibility for Sweden to implement a distance based road charging system in Sweden around 2010. These joint actions will increase the efficiency and facilitate co-ordination of information and communication. The ARENA aims to open up possibilities for all actors and stakeholders and facilitate the implementation of new innovations based on knowledge and demand. The ARENA will plan for a test- and demonstration site open for all stakeholders, private as well as public. The distance based road charging application will be the driving force for innovation as well as regional and national development and growth. The project has a strong political support from Region Skåne and Region Blekinge, and started in February 2006 and will end in February 2008.

The ARENA aims at:

• securing that Swedish requirements are taken into account in the European EETS development

• the principle of margin cost is accounted for

• supporting an increased use of telematics

• creating opportunities for innovative Swedish solutions to find a larger market

• open up new markets for the industrial partners

• facilitate increased knowledge exchange on a European level

• preparing innovative demonstrations for the 2009 ITS World Congress in the area of e-payments
The ARENA is run by a Committee where all important partners participate; Netport, SWECO, BMT-ts, Blekinge Institute of Technology (BTH), Linköping University, Ericsson, Kapsch Trafficcom, Region Blekinge, Region Skåne, SRA head office, SRA Region Skåne, SRA Region Sydöst. As it is an open ARENA other partners are also involved, such as the stakeholder network formed during the Tango Collect project, the Swedish EFC Network, as well as the automotive cluster formed around Chalmers Lindholmen in Gothenburg. The goal is to form consensus around the issues discussed in the ARENA.

**The work of the ARENA**

The work in this 2-year project is divided in 5 different Workpackages.

WP1 is overall ARENA co-ordination and evaluation  
WP2 Concept development and analysis  
WP3 Planning of test and demonstration site  
WP4 Network management and business development  
WP5 Information

The largest portion of work is done within WP2 Concept development. The picture below shows the major work issues within WP2 and 3.

![Diagram showing the workpackages where the major part of the ARENA's work take place, issues regarding the concept development and later test and trial of systems.](image)

The concept development is made with the approach of developing a national EFC service comprising as well DSRC based tolling systems as distance based charging using GNSS/CN. The concept will be developed around a number of scenarios, where each scenario represents a combination of solutions as regards:
· The timetable set for introduction
· The services included
· The distribution of functions and processes amongst components and actors
· The design of the control and enforcements systems
· The vehicle fleet concerned
· The design and implementation of the EETS

Key technical issues will appear concerning the distribution of functionality in the system (interfaces) and in the closely related design of the control and enforcement system. Industrial partners (Ericsson, Kapsch) will analyse and assess the realisation process from an industrial point of view, while researchers from BTH will validate the concept by simulations and early experimentation in preparation of the demonstration area planned.

References
· Commission of the European Union, Europaparlamentets och rådets direktiv om ändring av direktiv 199/62/EG om avgifter på tunga godsfordon för användning av vissa infrastrukturen, 2003
· Governmental Proposition (2006) SOU 2005/06:160 Moderna Transporter
· Gustafsson I and Schelin E (2005); Distance Based Road User Charges – Implementations aspects and Implementation Plan, Borlänge, (2005) SRA
· NORITS (2004); Nordic Interoperable Tolling Systems – Interoperability issues (for phase 2), Findings from Working Group Functionality in Phase 1, Draft version 0.91.
· Department for Transport, Feasibility study of road pricing in the UK – Report, London 2004
· Sjöström T, Myhrberg S.; Demonstration Site Description – Swedish Demonstration Site for Distance based Heavy Goods Vehicle Charging, Draft Version 0.9, SWECO, Stockholm 2006
Presentation at ITS World Congress
London 2006
An analysis of road user charging trends in Europe

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ABSTRACT
This paper provides a comprehensive overview and analysis on the trends, activities and planned deployments of road user charging systems across Europe. The paper stems from the transport policy for Europe and shows how the development is currently evolving; sometimes in line with the policy and sometimes away from the policy! The paper also contains an outline of the measures taken by the European Commission to prevent Europe from introducing national systems that are not interoperable with each other.

BACKGROUND
“Transport is crucial for our economic competitiveness and commercial, economic and cultural exchange. Transport also helps to bring Europe’s citizens closer together and the Common Transport Policy is one of the cornerstones of the building of Europe” [1]. These are the first lines in Europe’s Transport Policy Time to Decide, and it continues at pointing out the future challenges for Europe, if the building of Europe shall be successful.
Congestion, accidents and the underfinanced road network are some of the threats to this. The transport policy points out measures to be taken. In the last years several directives and decisions have been taken to achieve the goals of the Transport Policy, where road user charges are considered to be a helpful tool in tackling some of these problems [3]. Tolling as a way of financing the building of new infrastructure is also pointed out as a way of solving the financial crisis in the underfinanced road network [7]. Congestion charging as ways of managing demand in larger cities is also treated in a favourable way as a way forward to a sustainable Europe. The main thought to all this is that all fees introduced should reflect a socio-economic marginal cost principle.

As half the time span for the transport policy has now passed, the European Commission has produced a review of the policy [2]. This states that: **The objective of an EU sustainable transport policy is that our transport systems meet society’s economic, social and environmental needs. Effective transportation systems are essential to Europe’s prosperity, having significant impacts on economic growth, social development and the environment.**

Since the completion date of the Internal Market in 1992 the liberalised internal transport market and Europe-wide mobility is becoming a reality. Moreover, the transport industry has strengthened in this period and the Union has been able to maintain or develop its position as a world leader in many sectors. Successive enlargements have helped strengthen and consolidate this position.

The overall objectives of the European Transport Policy transport policy remain the same: a competitive, secure, safe, and environmentally friendly mobility, fully in line with the revised Lisbon agenda for jobs and growth and with the revised Sustainable Development Strategy. The transport policy toolbox needs to evolve to take into account the experience gained and to reflect the evolving industrial, political and international environment. Stronger international competition, but also weaker than predicted economic growth have made the task of ensuring sustainable mobility even more challenging.

This mid-term review argues for a comprehensive, holistic approach to transport policy. Whereas future policies will continue to be based on the White Papers of 1992 and 2001, in many areas European intervention will not suffice. Mutually complementary action will be needed at national, regional and local levels of government as well as by citizens and industry themselves. That is why a permanent dialogue is essential. The future actions, including the implementation of actions already announced in the 2001 White Paper and not yet followed up, will be based on a broad dialogue with all stakeholders concerned.

A European sustainable mobility policy therefore needs to build on a broader range of policy tools achieving shifts to more environmentally friendly modes where appropriate, especially on long distance, in urban areas and on congested corridors. At the same time each transport mode must be optimised. All modes must become more environmentally friendly, safe and energy efficient.

An improved EU framework combining regional and cohesion policies, an adapted framework for better and smarter charging for the use of infrastructure and differentiated solutions to deal with particular problems in certain cities, regions or along certain corridors could be the way forward. In this context the overall EU framework could help to enable differentiated and regionally more ambitious solutions whilst maintaining the necessary larger EU framework of mobility in a single market and confirming the EU’s presence as a global player.
The conclusion of this is that EU points out that a broad and holistic approach should be used to meet the goals set up for the Union in the future. This includes new types of financial engineering as well as user charges. These are seen as they should contribute more to the financing of the most commercially viable parts of the transport networks.

ROAD USER CHARGING

Within the field of road user charging, a rapid development has taken place in Europe during recent years, where electronic fee collection systems have been introduced in several countries. The problem is here, that several of these systems are not interoperable with each other. This is seen upon by the European Commission as a threat to the principles of free movement of people and goods within the Community. Consequently, in April 2004, the EFC-directive [3] was accepted by the European Union, forming the principles of “one device, one contract” for Europe. The aim with this directive is to create the European Electronic Toll Service (EETS) for vehicles that should be interoperable on a contractual and procedural level, using one or several of the following technologies:

- GNSS (Satellite positioning)
- DSRC (Dedicated Short Range Communication)
- Mobile communication

The overall goal with the directive is to create a European service for road user charges (the EETS) including in its first phase heavy goods vehicles and later all vehicles.

The directive lays down the conditions necessary to ensure a European electronic toll service that is interoperable at the technical, contractual and procedural level. The aim is to have a single contract between the users and all operators and a set of technical standards that allow the industry to provide the required equipment on a competitive market. The directive describes the essential principles of the system and a committee (Comité Télépéage) consisting of experts from all member countries are involved in the definition of the European Electronic Toll Service (EETS). Several European projects are set up to reach the goals outlined in the directive, among other the CESARE III project, in cooperation between ASECAP (The European Association with tolled bridges motorways and tunnels) and The Stockholm Group, which is an informal association of European road authorities.

All taken together the projects and expert groups working on these issues cover a wide spectrum of topics, e.g. technology, interoperability and enforcement. Several of the results from the projects and expert groups are now being discussed before they are to be agreed upon. However, since many countries have chosen different types of technical solutions to their road user charging systems, they also favour different solutions. It will be hard to reach a solution that is optimal for all Europe, as a system fitting one country doesn’t automatically fit another country, due to the diverse characteristics of the European countries.

IMPLEMENTATIONS ALL READY IN PLACE

Since the turn of the millennium, the European development has been fast, with several countries introducing or planning to introduce road user charges that are based primarily on the distance driven by the vehicle.
Switzerland introduced their road user charges for heavy goods vehicles above 3.5 tonnes in 2000. The whole road network is subject to the charges, and the fees are set in order to reach a modal shift from heavy goods vehicles to rail. The system is based on the tachograph, but uses the GPS for control functions.

Austria was second to introduce heavy goods vehicle charging, which was successfully implemented in 2004. All motorways of Austria are subject to the fees and technology used is DSRC. All heavy goods vehicles above 12 tonnes driving on Austrian Roads are required to have a DSRC transponder (on-board unit). The system was introduced mainly for financing purposes.

Germany introduced its technologically sophisticated system in 2005, after several delays. The whole German network of motorways (about 12000 km) are subject to charges and the system uses satellite positioning combined with a digital map, map-matching function, and mobile communication in the on-board unit. This also contains an Infra-red device for control purposes. All vehicles above 12 tonnes are subject to charging.

PLANNED SYSTEMS
In Eastern Europe, the new member states of the European Union are facing a tremendous growth in traffic. The transit traffic has also grown bigger as the countries bordering to them have introduced charges, which has made the traffic diverge to the still free road network of Eastern Europe.

Facing the facts of increased traffic and an under-developed road network, these countries need to 1) get financing for maintenance and construction of new roads and 2) get a tool with which traffic demand can be controlled. Therefore the Eastern countries are moving forward fast in the areas of road user charging, quickly adopting technologies and strategies from Western Europe.

The Czech Republic has recently procured a DSRC-based system, which will initially be covering the Czech highways and major roads, but later also cover the smaller roads. The system will be taken into use during 2007.

Also Slovakia is expected to procure a road user charge system in the near future.

Slovenia is following its neighbours in the Alpine region and is currently adopting an action plan that has been recently issued by the government and Ministry of Transport. It considers three steps and foresees a free flow tolling system by 2008 for commercial and by 2011 for all vehicles. Technical solution is not yet specified.

In Sweden the Parliament has recently agreed to the proposition Modern transports [4], where it is stated that a distance based road charging system should be introduced in Sweden in the future. The decision does not yet have a timetable connected to it.

UK has made several attempts at introducing a distance based road user charge system for heavy goods vehicles, where the procurement had come halfway when it was cancelled in June 2005 [8]. UK now envisages a national road-pricing scheme in the medium to long-term run, which will incorporate both heavy goods vehicles and private cars.

CLOSING REMARKS
Distance based road user charging is a hot topic in Europe, incorporating a paradigm shift from flat fees for vehicles using the road network to a more fair system, where several factors
can be taken into account when settling the size of the charges (distance, vehicle weight, axels, pollution class…). However, several technologies are competing to be introduced in the 25 member states of EU. The countries characteristics differ quite much, why some systems actually fit better or not so good in different countries. This is important to take into account when designing a national system, as Gustafsson and Schelin have shown in several reports [5], [6]. Further, if a consistent system should be introduced, the business model for the charges should clearly be reflecting the national policy to be well perceived by the market.

The European Commission is worried about the development in Europe, where national systems are introduced that are not interoperable with each other. This threatens the European policy of free movement of people and goods. To halt this development the Commission has introduced several Directives [3], [7].

As can be seen from this paper, Europe is facing enormous challenges in its aim at becoming one internal market, where the transport of people and goods is a significant part of the economy. The transport industry accounts for about 7% of European GDP and for around 5% of employment in the European Union [2].

REFERENCES


Presentations at ITS in Europe
Aalborg 2007
Demonstration of the Swedish approach to a kilometre tax system for heavy goods vehicles

Concept validation of system functionality in computer environment

FINAL PAPER
6th European Congress and Exhibition on Intelligent Transport Systems and Services
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ABSTRACT

Distance based charging for heavy goods vehicles (HGV) will probably be implemented in Sweden around 2011-2012. In order to support this implementation a demonstration facility will be set up in advance adapted to both national requirements and interoperability issues. The demonstration includes the infrastructure that will be operated by the authorities and cooperation with industry will allow for testing of in-vehicle equipment and communication.

The task ahead is now the changeover from years of theoretical system study to begin a practical implementation. How is the tax system demonstrated and visualised regarding functionality, interoperability and value added services?

To manage the situation a demonstrator with the first generation full scale demonstration facility digital infrastructure will be developed to simulate and visualise a road tax complete life cycle in the kilometre tax system for verification and validation.

INTRODUCTION

In 2004, a commission on road tax charges presented its final recommendations to the Swedish Government. The commission proposed the introduction of a kilometre tax for HGVs. Following additional investigations and a national hearing process the Government made a proposition to Parliament in May 2006. The Parliament voted in favour of the proposition, with one reservation: it had to be shown that the road tax would not bring any unreasonable consequences for regions (such as remote parts of Northern Sweden) or branches of industry (for example, the forestry industry).

A group of Swedish stakeholders has established an ARENA to coordinate activities for successful implementation of the kilometre tax and is managed by the Blekinge Institute of Technology and the Swedish Road Administration. A conceptual design describing the system is currently being shaped and suggests a functional, rather than specific, approach to the upcoming procurement which will be implemented in the full scale demonstration facility. The primary objectives with the full scale demonstration facility are to: visualise the basic principles of the kilometre tax for different groups of stakeholders; enable interoperability tests, allow for independent testing and validation of equipment and provide empirical input to the upcoming procurement.

These objectives are achieved by the development of a demonstrator with the main goal to support and strengthen the conceptual design and includes; applications for road tax calculation, road price data base and user friendly interfaces for Toll Charger, Toll Service Provider and On Board Equipment (OBE).
AIM WITH THE DEMONSTRATOR

Verify and validate the conceptual design developed within the ARENA project

Establish a demonstrator to simulate and visualise the functionality and first generation digital interfaces of the kilometre tax system in Sweden

Shall be developed in perspective to become a live demonstration at ITS World Congress 2009 in Stockholm, Sweden

Be part of and support the pre-study of the establishment of the full scale demonstration facility

Figure 1 Implementation time schedule of the kilometre tax system

SWEDISH KILOMETRE TAX SYSTEM FUNCTIONALITY

The conceptual design developed within the ARENA project is presented below with the fundamental functionality and actors:

Figure 2 Swedish kilometre tax system conceptual design for HGV
A contract is established (Function 1) between the user and a service provider, which may be Swedish (within Sweden only) or European (European Electronic Tolling Service including Sweden). The EETS Provider provides OBE’s to associated EETS Users, and SRA (Toll Service Provider) provides the same service towards Swedish users. The contract includes vehicle characteristics and other user information which are taken into account in the tax calculation and debiting process. The contract establishment includes issuing a security module which is installed in the OBE (tamperproof user identity certificate).

The decision whether a vehicle that have performed Track Data Registration (Function 2) is liable to pay tax is taken in Charge Payment (Function 3), based on the track log and user contract information. Charge Payment also takes into account possible discount based on vehicle characteristics, earlier registrations and performed payments. The SRA (Toll Charger) will provide information on applicable tariffs, and the kilometre tax is calculated and decided upon on the basis of track logs signed by the OBE.

The debit is made by invoicing Swedish users, or the associated EETS Provider for further claims towards the EETS User. The Control System (Function 4) is provided with reported declaration sequence numbers per vehicle, which are unique for each transaction.

The compliance control consists of several functions and uses existing infrastructure when possible (such as trip-meter). The most relevant control functions are to verify a serving OBE in real time and in post time control the submitted payment and that the positioning unit is providing correct information.

DESCRIPTION OF THE DEMONSTRATOR

The demonstrator is the first generation of the full scale demonstration infrastructure consisting of software applications, data bases and interfaces for kilometre road tax. These will be simulated in separate program windows to enable demonstration covering the complete life cycle of a road tax. The environment is based on the CESARE III model\(^1\) with Toll Charger, Toll Service Provider and OBE.

The demonstrator time stamped records positions (track log) from a GPS receiver and map matches the positions to a road link in a digital road map. The road tax is then calculated based on the vehicles travel path, maximum laden weight and Euro class and the information is sent to a central server using the communication channel GPRS.

**Demonstrator Environment**

The demonstrator hardware consists of a smart phone and a GPS device. The GPS device communicates via Bluetooth to the smart phone which can report to central server via a normal phone line or GSM.

D2.1 (v5.1), CESARE III (2006)
Basic server functionality is to manage several processes simultaneously, enable data storage and communication, receive and manage track log data. A fundamental requirement put on the server was the possibility to communicate via FTP protocol rather than HTTP, which is the most common communication protocol on the Internet, since it is more reliable to transfer files via FTP. However, FTP is an insecure protocol since transferred information is not secure and therefore communication security would benefit by using SCP protocol, which is somewhat cumbersome to implement, but since this a demonstrator full respect is not taken to integrity and security issues.

The demonstrator functionality was developed and implemented in a .NET server platform with an additional library from Franson GpsTools. .NET can read shape files from the Swedish National Road Data Base (NVDB) and supports file transfer by FTP but lacked routines so file transfer functionality was developed within the project. Franson GpsTools is well suited to develop applications with GPS and maps and with ease can manage input such as a road segments tax, speed limits.

Operating Interfaces
The developed software enables simulation of a data report (route declaration) submitted from an OBE to a Toll Service Provider and further forwarded to a Toll Charger. The interface is user friendly and information is accessible through a simplified and a detailed view, depending on the current need of information.

The OBE interface
The interface is equipped with an indicator (round green light top right corner visible in figure 3) showing if any system errors occur such as lack of GPS signal or unable to map match current position. Additional information is accessible through a menu such as previous routes and adjustments for vehicle data (weight, axels, emission). Before reporting a track log to a central server a driver must confirm the current track log data and accept to be liable for the performed transport. Figure 3 shows the split up view with accumulated road tax, current road tariff and a digital map showing the current position.

![Figure 3 OBE Interface with a split up view](image)
The Toll Service Provider interface
The interface includes the following information in a reported route declaration submitted from a HGV. When the Toll Service Provider has managed the route declaration it is forwarded to the Toll Charger as a basis for tax decision.

- HGV registration number
- Identity of the secure module in OBE
- Number of HGV axels
- Sequence (transaction) number
- Position information (GPS in this demo)
- Unique digital fingerprint
- HGV Euro Class

Figure 4 Shows the Service Providers display

The Toll Charger interface
The Toll Charger receives the route declaration from Toll Service Provider and performs a tax decision and calculates the due tax. Toll Charger can reproduce the digital fingerprint created in the OBE based on information in the route declaration. If the information has been tampered with along the way the digital fingerprint will not match and a road tax deviation is detected. The road tariff is differentiated (in time and space) and the travelled distance within each tariff class is separately calculated and accumulated to finally cover the complete HGV route.
Figure 5 Shows the Toll Charger interface

Road Price List and Map Matching

Road Price List
The digital road price map, based on NVDB, includes the entire road network where the kilometre tax is applicable (entire Swedish road network). Each road link is associated with a tariff and is differentiated in time and space. The road price map is visualised by showing the incoming track log from the OBE with the following map matching operation to establish the performed route and to calculate the due tax.

Map matching
Map matching is a method to match position information (time stamped coordinates) to road links in a digital road map. Position information submitted from the OBE often includes a deviation from the true position so methods, such as map matching, are developed to compensate the inaccuracy. The operation enables to recreate in post time the vehicles performed route which is fundamental in order to calculate the due road tax.

In this demonstrator a circle was created around each crossing and if a position did end up within the circle the crossing is stored in a data list. All reported positions are managed in a timely order which creates a natural sequence of positions and by adding the road links between the crossings the route is recreated.

Figure 6 Example of map matching
If there is no connection between the crossings Dijkstra's map matching algorithm is used.

Please observe that no large resources was spent on procuring a complex map matching algorithm since several exist on market today but regarded industry secrets and thus beyond our reach. However, in a situation of a full scale procurement of the kilometre tax system we expect several available and well working algorithms. Also preliminary tests with simpler algorithms show satisfying results for demonstration purpose.

Interoperability
The interfaces for the actors are open for maximum interoperability and flexibility. It is essential to use an open interface for the toll charger to enable one service provider to operate in several toll chargers areas. In addition, interoperability for registration of track log data and charge payment is demonstrated with a toll charger and on board equipment developed by Kapsch TrafficCom AB which is an external actor to the national ARENA project.

Value Added Services
The OBE has additional functionality, apart from being used in the kilometre tax system for HGV, by implementing a value added service. Several services was evaluated and classified as public or private. Examples of public services are speed alert, alco lock, e-call, traveller information and road status monitoring and example of private services are road haulers management services, vehicle follow up services, driver support services and parking payment. The most suitable value added service to be implemented in an OBE used for distance based charging was found to be the public service road status monitoring by uploading vehicle position, time and place to a central server at given moments. The service was suitable due to the fact it is has not been developed and provides information without a warning functionality. Road status monitoring provides public authorities with traffic information useful when planning new road infrastructure or as traffic information to travellers.

Conclusion
The developed demonstrator is the first generation of a full scale demonstration facility digital infrastructure. The demonstrator shows a realistic possibility to combine and integrate value added services with an OBE used for distance based charging and a first approach to classify the most important parameters and interfaces at an OBE, Toll Charger and Toll Service Provider during a life cycle of a road tax.

However, the demonstrator is developed for demonstration purpose only and is somewhat unstable, the geographical demonstration area is limited and the map matching algorithm is too simplified to be used in a real implementation. But the demonstrator provides with an excellent knowledge base and empirical input to be further build upon to the second generation demonstrator and full scale demonstration facility.
REFERENCES


ARENA – Development of a national road user charging system

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ABSTRACT

Arena is a project that aims to develop a road user charging system for heavy goods vehicles (HGVs) in Sweden. The project has been initiated to support the Swedish plans for a kilometre tax for HGVs. In order to create a system that takes the needs of all parties into consideration, the charging system is being developed in cooperation with authorities, researchers, road users and private enterprises. The project is planning an independent trial and demonstration arena with focus on interoperability. This paper provides an overview of the project and presents some of the first findings.

KEYWORDS

EFC, Concept, Interoperability

INTRODUCTION

During 2002-2004 a Swedish commission on road traffic taxation investigated the possibility and suitability to implement a national road user charging system in Sweden [1]. The study was initiated by the introduction of HVF (Heavy Vehicle Fee) in Switzerland and the preparations for the charging systems in Austria and Germany.

The commission's proposal was based on the principles that charges will be collected for all public Swedish roads as well as some of the privately owned. The payment base should be the distance travelled in combination with vehicle characteristics (i.e. environmental class). Vehicles above a total weight of 3,5 tons should be charged. The overall objective for the transport policy in Sweden is that taxes and charges in road traffic should reflect the socio-economic marginal costs and contribute to achieving the transport policy objectives. For a distance based tax for HGVs this calls for internalisation of external effects like wear, maintenance costs, pollution and accidents.
The ongoing European development and the planned extension of the current EC directive concerning the Eurovignette [2] have started a political process in Sweden, where a proposition (Modern Transport [3]) was accepted by the parliament in May 2006. A vote was taken in favour of a kilometre charge for heavy goods vehicles and a decision on the needs of further studies concerning business impacts in different regions. SIKA (Swedish Institute for Transport and Communications Analysis) and ITPS (The Swedish Institute for Growth Policy Studies) were assigned to perform these studies. SIKA presented the results of their investigation, on how a kilometre tax would influence industry and regions in Sweden, [4] during March 2007. The investigation concluded that consequences for production and employment by introducing charges in general are small; in some cases business will be negatively affected. The investigation also concluded that in some business sectors the production will increase. SIKA is suggesting a careful implementation, starting with low taxes, and to further study how the charging system should be designed. They also highlighted that the introduced system should be socio-economically beneficial regarding its system cost. SIKA even opened doors for a less sophisticated system based on the tachograph, as in Switzerland. A political decision from the Swedish government regarding implementation is expected during 2008.

The initiatives regarding the Arena project were formed during the project Tango Collect, 2003-2004 [5]. Tango Collect focused on providing decision support for a future implementation of road user charges and the establishment of a network of stakeholders. The stakeholder’s different needs were identified and several conclusions regarding the need for a coordinated future approach regarding road user charges were made. In 2006 the Arena was initiated to help coordination and preparation for the presumed implementation of a charging system for HGVs in Sweden. The Swedish Road Administrator (SRA), would like to ensure competence development within the area of ITS and that the European development of the European Electronic Toll Service (EETS) meets Swedish needs.

Characteristics of the Swedish road infrastructure and traffic differ to some extent from the rest of Europe, which calls for a system that ensure consideration of Swedish needs, but still fulfil European interoperability.

- The road network is large and not so densely used
- There are few roads of motorway standard
- There are several remotely placed border crossings
- A very large forest road network, often privately owned

THE ARENA APPROACH

In 2006 the Arena project was initiated with the aim to build competence for the future road user charging system for HGVs in Sweden. The goal of Arena is to enable authorities, operators, users and suppliers to cooperate into the realisation of a solid and acceptable system and the work is divided into the following three areas:

- Coordinate and establish networks
- Develop a concept
- Prepare for a demonstration arena
The project is carried out in cooperation with authorities, industry, researchers and road users according to the Triple Helix concept (a joint effort between academia, industry and authorities).

The Arena brings existing competence together and prepares the presumed implementation of a road user charging system in Sweden. A plan for an independent trial and demonstration arena supporting development and procurement will also be made. Along with the work between project partners an international network with expertise knowledge is being created to help dissemination activities and influence European development.

The concept development has adopted an integrated approach in which overall system solutions, technology, communication opportunities and strategies are analysed and evaluated, with respect to the needs of the participating organisations. Everything is geared towards developing a system that is fair, simple and safe. Project partners are the SRA, Blekinge Institute of Technology, SWECO VBB, BMT Transport Solutions GmbH and the project coordinator NetPort.Karlskamn. The project is financed by SRA and VINNOVA (The Swedish Governmental Agency for Innovation Systems)

Purpose
One of the main scopes of the project is to develop and deliver a concept for a national distance based road user charge (kilometre tax) for heavy goods vehicles in Sweden. The development is to be made:

- In line with the European development, including the EETS (European Electronic Toll Service) [6]
- Using a holistic perspective, where the relationship between kilometre taxation, road tolls and congestion charging isn’t neglected

Other objectives are to:

- Secure that Swedish requirements and needs are taken into consideration in the European EETS development
- Support opportunities to use telematics services
- Create opportunities for innovative Swedish solutions to find a larger market
- Facilitate increased knowledge exchange on a European level
- Prepare innovative demonstrations for the 2009 ITS World Congress in the area of e-payment
ACTIVITIES

Concept development
An ongoing activity is the development of a systems design, in other words the conceptual design. The concept approach is to describe a system with the purpose of giving stakeholders:

- A common view of preconditions
- A common perception of the systems architecture ("What is it and what does it do")
- A method to build authorities and stakeholders knowledge in distance based RUC
- A reference document in discussions and while comparing alternative proposals in systems procurement processes.
- Identification and description of legal and institutional issues to be handled

The concept is built on knowledge and experience, requirements from policymakers and legal people, interoperability requirements and user requirements. The work is performed in workshops and with industry expertise interaction during separate forums. The draft concept is work in progress and currently has four key elements:

- The thin client
- The secure module
- Selectable position indicators
- Toll Chargers key interface

Besides industry interaction, researchers from Blekinge Institute of Technology (BTH) are involved to validate the developed concept. Based on applied research different criteria will be set up to be able to measure different concept approaches. The secure module is also being studied.

Industry forum
The project provides an arena where different actors can contribute to the conceptual development process on different levels. The industry forum is a process to establish a closer co-operation with the industry. The intention is to:

- Enable co-operation with industry
- Get feedback on concept realisation
- Enable networking for future projects
- Prepare for future demonstrations

The project arranged its first forum in February 2007. The concept was presented and six invited speakers commented the concept approach according to their experiences. Some questions, issues and considerations were brought up:

- Tax or fee, is important in systems design
- Purpose of a charge is important for acceptance
- Privacy issues
- Business model
- Thin client vs. Thick client approach
- Mandatory On-Board Equipment (OBE), is this feasible?
Challenging topics were discussed by the delegates after the presentations, such as trials, business models, enforcement, telematics and interoperability. The seminar made good contributions to the concept development process.

**Trial and demonstration arena**

To prepare a future procurement process and to prove the realisation of the concept that is being developed; there is a need of a demonstration arena. This activity isn’t included in the current project, but will be planned. Participating suppliers in the demonstration phase are to be given access to

- A server application with “authority-like” software, set up with an open interface
- Road side equipment sites
- Visualisation site – mainly for dissemination activities

Objectives with the demonstration:

- Interoperability, the main task is to make sure that a Swedish system can operate in a European context. OBE from different manufactures and different contracts must work according to EETS
- Enforcement, because of the size of Sweden’s road network it’s important that the enforcement can be made for the whole road network.

**Way forward**

The way forward is to build networks with countries involved with road user charging for HGVs. Especially countries which currently plan or consider nationwide systems, for example the UK and the Netherlands. Cooperation on European level is crucial for the development of the EFC directive and to achieve the European toll service (EETS). Members of the Arena project are represented in standardisation work and hope to contribute to the European development promoting innovative European solutions and to make Sweden well prepared when political decisions regarding charging HGVs are made.

**REFERENCES**


Presentations at ITS World Congress
Beijing 2007
A new approach to distance-based road user charges – The Swedish kilometre tax

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ABSTRACT
The Swedish parliament voted in May 2006 in favour of a national kilometre-tax for Heavy Goods Vehicles with the objective of internalising external costs. With this objective, solutions applied in other countries do not meet the Swedish requirements. Instead a solution is proposed with four key properties: A Thin Client OBU concept, selectable position indicators, a system security solution reduced to a secret kernel and a new approach to Toll Chargers interface. Also, the Swedish solution is open for parallel service provider interfaces, preparing for integration of OBU´s issued by European Electronic Toll Service (EETS) Providers.

BACKGROUND
Since 1972, internalisation of external costs has been a key element of Swedish transport policy. When a governmental investigation in 2002 was commissioned to make a review of the entire road and vehicle taxation system, this was an important aspect to consider. In 2004, the investigation reported its final recommendations to the government. Among others, the investigation proposed an introduction of a distance based tax for heavy goods vehicles – a kilometre tax. Following additional investigations and a national hearing process, the government made a proposition to the parliament. The parliament voted in May 2006 in favour of the proposition, with one concern: It had to be shown that a kilometre tax would not bring any unreasonable consequences for specific regions (e.g. Northern Sweden) or branches of industry (e.g. the forest industry).

The required investigations on this matter, conceptual design studies and preliminary work on legal matters and the implementation process, are now carried out in order to allow for the parliament to take a decision in the spring 2008 on the continued implementation.

This paper provides an insight in the key results of the conceptual system design study and describes some elements of the system design, which clearly distinguish the foreseen Swedish kilometre tax system from other distance based RUC schemes.
PARTICULAR REQUIREMENTS

The Government’s principal requirements on the system follow from the principle of internalisation of external costs:

- The kilometre-tax will cover all public roads (with minor exceptions in urban areas), and to some extent also private roads.
- The kilometre tax will be designed to stimulate the use of high class roads, i.e. allow for a lower tax on the motorways, higher on the secondary roads.
- The kilometre tax will cover domestic and foreign vehicles with a maximum laden weight above 3.5 tonnes.
- The kilometre tax will differentiate on vehicle characteristics, promoting vehicles of a higher environmental class.
- The kilometre tax shall be prepared for differentiation also on time of day, i.e. a higher tax in rush-hours.

If these requirements are considered when looking at existing and operational schemes for distance based road user charges – Germany, Austria, the Czech Republic and Switzerland – it is easy to see that there are big differences. The most important being the inclusion of the entire road network, which brings in particular new challenges to the design of the control system. The Swedish requirements are in fact fairly similar to those applied to the LRUC scheme in UK which was abandoned.

In addition to these requirements, Sweden has also decided to ensure that the kilometre tax system is compliant with existing and planned road toll schemes in Sweden and Europe. Of particular importance is the Swedish-Danish-Norwegian interoperability agreement NorITS, which enables full interoperability between all DSRC based toll schemes in these countries through the EasyGo service. We also have to take into account that the Swedish kilometre tax will have to comply with the European legislation that follows from the EFC directive 2004/52 aiming at European interoperability.

KEY ELEMENTS OF THE CONCEPTUAL SYSTEMS DESIGN

Following the requirements analysis, the conceptual design study has been carried out within the ARENA project, involving a comprehensive group of stakeholders: Road haulers and their interest organisation, the Swedish Road Administration, the Technical University of Blekinge, industrial actors within ICT and EFC and other experts in the area of EFC. In the autumn of 2006 and spring 2007 a number of national and international workshops have also been carried out to gain international feedback on the proposed conceptual design.

Of primary interest are the characteristics of the system that distinguish it from the German Toll Collect system which is so far considered to be the closest related. This paper focus on four such characteristics:

- The Thin Client architecture
- The secure kernel
- The position indicators
The key interfaces

The paper will in addition present a control system approach which takes into account the specific requirements of the Swedish kilometre tax.

**THE THIN CLIENT ARCHITECTURE**

Similar to the Toll Collect system, the Swedish kilometre tax system will see HGV’s equipped with an OBU that continuously register the vehicles positions and communicate these to a central system.

Sweden has however decided to call for a Thin Client solution, meaning that the resulting fee is not calculated within the OBU, but in the Central System. This means that the OBU needs to have neither road network characteristics nor the “price list” information downloaded.

It is important to understand that from a functional perspective there is little difference between thin and heavy client architectures. Imagine a module performing the required map matching and fee calculation. This module can be located either inside the OBU or in road side equipment. The real difference is whether an air interface or an internal OBU interface is used to feed the module with information. If the road side system receiving the information is under control of the OBU Issuer, the module performing map matching and fee calculation can be seen as a “proxy” to the OBU, and the air interface used for the communication can be regarded as internal to the system. Hence, thin and heavy client OBU’s may co-exist in a system, which is an important aspect in the design of the European Electronic Toll Service (EETS).

**THE SECURE KERNEL**

There is a strong request from Swedish haulers as well as vehicle manufacturers (Volvo, Scania) to allow for a long term solution which enables the kilometre tax functionality to be implemented in vehicles standard ICT platform. In order to enable this, the kilometre tax system is proposed to be based on a secure hardware module (e.g. an IC card issued by the tax authority, or a SIM-card) which will cater for the secrecy and security of the system. The remaining parts of the system, e.g. the GNSS or other positioning function and the communication unit, will then not have to be secured by the system owner. This architecture fits well with the requirement that the conceptual design also has to take into account interoperability with EETS on-board units.

**SELECTABLE POSITION INDICATORS**

The system will allow for supplier defined solutions on how the OBU shall register positions. We can foresee a mix of methods, allowing for e.g. the OBU to use GNSS (e.g. Galileo) where no other position indicators are available, and DSRC to supplement this when appropriate (as used in the Toll Collect system) or even replace the GNSS at certain parts of the network (e.g. when driving in tunnels). Imagine a list of consecutive positions retrieved from different sources and stored in the secure kernel.

By allowing the supplier to select combinations of position indicators, and also allow for OBU’s of different origin to co-exist, we believe that we have also created a potential for innovations – new solutions may be brought in without requiring exchange of old elements.
THE KEY RELATIONSHIPS
A kilometre tax system for Sweden must be regarded as a long term engagement, which must be open for gradual development and improvement as time goes. We cannot already now know what technical conditions that will prevail in 2011-2012 when the system is expected to get into operation. Also for this reason, the Swedish approach is to expect that service providers will take the full responsibility for as well provision of the OBU’s as the collection of uploaded information. Hence they will be in full control of the interface between the vehicle and the central system. This brings two advantages: We can allow for multiple suppliers, in competition, to offer their solutions allowing for a continuous evolution of the system. We can also see that this solution fits best with the principles of the European Electronic Toll Service (EETS) currently being developed within the European Union. The Swedish architecture implies that the Swedish Tax Authorities needs not to engage in the interface between the EETS OBU and its associated Central System, other than defining quality criteria for the trip declarations that will submitted by the EETS Provider to the Swedish Tax Authorities.

THE SWEDISH APPROACH TO CONTROL
The approach to control is a key to successful implementation of an EFC system for HGV kilometre tax in Sweden. A well designed control system will bring reasonable costs and ensure user confidence and acceptance.

A “traditional” approach, with physical installations in the road network as the main real time control component, is found to bring too high costs in relation to the foreseen revenue from the system. In addition, it does not really solve the problems associated with road transport on the secondary road network – a national road network is too large to be covered by installations and physical observations for real time control.

To overcome these problems, a new approach to the real time control function has been developed. This new approach could best be described accordingly:

- Much more focus on control mechanisms related to business processes – more intelligence and less hardware
- The line of control should follow contractual relations – more responsibility to the Toll Service Provider in his relation to the user
- The scope of the Toll Charger has been focused
- Adaptation to the existing legal base for road side control and enforcement authority – as tax authorities are not mandated to stop vehicles at the road side

ACTORS IN A “TRADITIONAL” CONTROL MODEL
The “traditional control model” reflects a relation between actors in EFC operation where the Toll Charger controls the users of the transport service to verify that they have carried out proper payment. In fact, the control function is normally integrated with the debiting function and carried out in real time.

The key point reflected in the traditional approach is the effort to detect users that are not equipped with accepted equipment for the EFC service – the unknown and violating user. This focus is clearly relevant if the primary threat seen is about unequipped and unknown
users. As the Toll Charger in traditional tolling also often is issuer (TSP) of EFC equipment for his service, it is a rational approach.

**Figure 1. Control and information flows in “traditional approach”**

**ACTORS IN A REVISED CONTROL MODEL**

In a distance based charging system, as in the concept developed for the Swedish kilometre tax, the debiting and control functions are in general not simultaneous. Also, in interoperable EFC payment, the TC is often not issuer of an OBU appearing in the system – it could be any EETS Provider.

The revised control model reflects other relations between the entities. Instead of exercising direct control of the users, the Toll Charger will build a control mechanism that follows contractual relations. Hence, the Toll Charger will exercise his primary control towards the TSP, and the TC furthermore expects the TSP to exercise thorough control on his associated user/OBU. There is also a mechanism maintained that include the Toll Challengers direct monitoring of vehicles. This control has however a scope that differs from the traditional model: The responsibility of the Toll Charger is to measure the level of fraud/anomalies rather than to catch violators and execute enforcement.

In this model, there is of course no evident solution to the case of “unequipped users”, i.e. vehicles that do not carry an OBU / have no contract with a TSP. As the role of enforcing authority is outside the scope of the Toll Charger, and shifted to other public authorities that are in command of the necessary tools: The right to stop vehicles at roadside, the right to issue fines etc.

A clear advantage of this model is that it fits better with the roles and responsibilities that are established in Sweden in relation to e.g. tax evasion and fraud related to the use of the tachograph.
As long as the detected (measured) level of fraud is below a certain threshold (let’s say 2%) there is no need to upgrade the enforcement system. If a tendency to a raising level of fraud in general is observed, or if the level of fraud is found to be unacceptably high amongst a certain category of users, the Toll Charger will call for increased enforcement (more road side control, higher fines etc.).

Fraud related to manipulated information from vehicle OBU’s is not expected to be a major problem. It will clearly be in the interest of the TSP to ensure correct and timely declarations from associated vehicles, as this is regulated in the contract between the TC and the TSP concerned.

**SUMMARY ON CONTROL PHILOSOPHY**

The traditional control philosophy applied in road user charging is characterised by:

- The Toll Charger control everything
- Do it in real time – integrate the debiting and control functions
- Do not trust anyone
- Toll Charger is also in command of enforcement

The Alternative Control Philosophy developed for the Swedish Concept is characterised by:

- Trust until security is under threat

- Toll Charger keeps track on level of fraud and violations - use random check to measure violations
• Focus Toll Charger control on business processes and quality systems of transport operators
• Delegate to the TSP to have control of associated subscribers
• Synchronize and use parallel control mechanisms
• Focus on non-real time control measures, separate the debiting and control functions
• Other authority than the Toll Charger is in command of enforcement

Important input to the control systems approach, was received from the Swedish customs, and its work on e-Customs. The Swedish customs have a long tradition of building customs procedures based on trust, where trusted companies may perform their customs declarations in two seconds if they can demonstrate a sound business model.

**EFFECT ON CONTROL SYSTEM COSTS**

The cost estimate of a traditional control system approach indicated initial investment costs in the order of 185 M€, and operational costs in the order of 40 M€ /year. The major cost was installation of roadside control equipment, which alone corresponded to approximately 55% of the investment costs, and together with mobile control units to approximately 70% of the operational costs.

The new approach means a reduction of fixed installations with approximately 90%, and a reduced need for staff and systems dedicated to the management of control transactions. It will also bring down the investment costs with at least 50%, and also bring a considerable reduction of the operational cost.

Taking into account an estimated annual depreciation during the first years, it is reasonable to estimate that the new approach will reduce the system cost to half during the initial years.

One must however understand that costs will increase in other sectors (e.g. the police carrying the responsibility for road side control), and that the level of fraud most likely will increase slightly which will bring down the revenue from the system.

**REFERENCES**

(3) Sundberg J; A New Approach to Control in the ARENA concept for HGV kilometre tax in Sweden, ARENA report, May 2007

All documents available through: [www.arena-ruc.com](http://www.arena-ruc.com)
Micro-level effects of a kilometre taxation – modelling haulier categories

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SUMMARY

This paper is focusing on how an introduction of a kilometre tax in Sweden will influence the transport industry in general and the hauliers in special. The paper is describing an attempt to categorise different types of hauliers which exist in the Swedish haulier market, and haulier companies are interviewed to validate the categorisation. To facilitate the prediction of the effects of road user charges, the categories can be used in decision support systems.

Keywords: Road user charges, logistics, modelling.

INTRODUCTION

The European systems for charging heavy goods vehicles are currently undergoing a change to make the users pay more correct external costs that are caused by transportation, i.e., internalisation of external costs. Until now, most systems for charging heavy goods vehicles have been based on a yearly flat fee, which gives the right to use the roads for transport purposes. The current developments are towards systems that charge the users for the distance used, i.e., a distance-based taxation with the potential to differentiate between road type, time of usage, environmental performance of vehicles, etc. Charging for the use of infrastructure is not a new concept. New, however, is the increased ability to reflect the socio-economically marginal costs and thereby contribute to achieving general transport policy objectives and the principles set by the European Commission on fair and efficient pricing. Studies have been made of how the transport industry will be influenced, e.g., [4] where the effects on different segments of the forest industry are studied, but the knowledge of how hauliers will be influenced of a kilometre taxation is low. To be able to study the influence on the heterogeneous haulier market, we suggest using categories and examining the potential influence of kilometre taxation within the categories.
To predict the effects of governmental control policies, or transport policies, such as a kilometre taxation on transport chains, decision-support systems, e.g., simulators, can be used. With simulation it is possible to capture effects on individual transport chains, such as logistical issues for instance concerning load capacity utilization [10]. Categories of different types of hauliers, as well as other actors within transport chains, are useful when simulating transport chains since predictions therefore can be made on certain market segments. Hence the issue of generalizability which appears when individual transport chains are studied are dealt with.

The purpose of this paper is to suggest how it is possible to categorise the Swedish haulier market in order to better predict the effects of an introduction of kilometre taxation in Sweden. The paper also includes results from interviews with a number of Swedish hauliers on their views on a future kilometre tax system. Furthermore, we discuss how it is possible to extend the haulier categorisation. The usage of the categorisation when performing simulation experiments of possible policy effects on transport chains are also discussed.

**CURRENT SITUATION IN SWEDEN**

In Sweden, 4.2 billion vehicle kilometres are performed with heavy goods vehicles. Of this, 10% are performed by foreign vehicles [13]. In southern Sweden, in the counties of Skåne and Blekinge, the amount of foreign vehicles is higher. A study from the Swedish Road Administration shows that roughly 78% of the total number of heavy goods transport via the ports constitutes transit traffic passing through the two counties [16]. This is regarded as an unfair situation since foreign vehicles do not pay Swedish taxes (although they are obligated to pay a vignette fee for specific roads), such as the vehicle tax and the diesel tax, aimed at internalising the external costs of heavy goods vehicles. Since 1972, internalisation of external costs has been a key element of Swedish transport policy. When a governmental investigation in 2002 was commissioned to make a review of the entire road and vehicle taxation system, this was an important aspect to consider. In 2004, the investigation reported its final recommendations to the government. To fully cover the external costs of heavy goods vehicles, the investigation proposed an introduction of a distance based tax for heavy goods vehicles – a kilometre tax. A kilometre tax is possible to differentiate, which facilitate to cover the external costs on a more detailed level. Following additional investigations and a national hearing process, the government made a proposition to the parliament in May 2006. The parliament voted in favour of the proposition, on condition that it had to be shown that a kilometre tax would not bring any unreasonable consequences for specific regions (e.g., Northern Sweden) or branches of industry (e.g., the forest industry). The required investigations, conceptual design studies and preliminary work on legal matters are now carried out [15]. A study performed by the Swedish Institute for Transport and Communications Analysis (SIKA) is positive to a kilometre tax and concludes that the marginal cost based tax levels - proposed by the institute - would have limited impact on production and employment [13]. SIKA raises the question whether a kilometre tax system is socio-economically viable or not. Further investigation and a cost-benefit analysis are to be performed in near future.

**PREVIOUS KILOMETRE TAXATION STUDIES**

Existing research indicates that changes in modal split and route choice are limited as a consequence of kilometre taxation, but greater utilisation of the vehicle capacity have been noticed [2], [9]. However, there are different views of how an introduction of a kilometre taxation in Sweden will actually influence the transport industry. Some studies show rather poor effects as a consequence of a kilometre taxation [2], [9], while other studies show more
significant effects [6]. It is expected that the impacts of a kilometre taxation will decrease closer to the end-consumer. Liechti and Renshaw [7] show that the consumer prices have not increased significantly in Germany, Switzerland or Austria as a consequence of a kilometre taxation. Moreover, it is expected that the influence of an introduction of a kilometre taxation will be higher when the transport cost is large in relation to the overall cost.

Little research is conducted of how the haulier industry would be influenced by kilometre taxation. To better predict the effects of a possible introduction of a kilometre taxation, we believe that it is important to carry out an analysis on how the haulier industry, i.e., the users of the system, would be affected by a kilometre taxation. This can be useful when making use of micro-level models.

**AVAILABLE STATISTICS AND CATEGORISATIONS**

The transport market is heterogeneous, why there exist several attempts to categorise it into market segments, which can be used when historical data (statistics) of goods flows is presented. Categorisations can be used when predictions of potential changes are made, for instance with transport models. The focus of existing Swedish statistics is mainly on the goods flows and its characteristics, not different haulier segments. Consequently, existing statistics does not fully cover the different cost structures, types of transportations, etc., of different haulier market segments.

The Swedish haulier organisation uses a categorisation of the Swedish hauliers where certain assumptions are made regarding vehicle usage, cost structure, etc. However, this categorisation is outdated and does not match the current situation very well.

Enarsson and Lindblad [1] have made a review of the Swedish freight statistics. They define some shortcomings of the available statistics, for instance, foreign transports are not included. Moreover, it can also be difficult to couple product groups to transport flows. As an example, it is difficult to know what is loaded in containers which arrive to the ports.

Liedtke and Schepperle [8] define other shortcomings in the European transport statistics. For instance, the NST/R (Standard Goods Classification for Transport Statistics) product categories which are used in Europe does not successfully take handling and packaging categories, sector relations and good-type relations into account. Moreover, often products are not categorised in a consistent way, since the categories are not disjoint. Liedtke and Schepperle argue that there is a need to make a more consistent segmentation of the transport market, and therefore present a suggestion of a categorisation of the transport market [8]. The authors claim that there is a need to continue the work of categorising the transport market.

**SUGGESTED SWEDISH HAULIER CATEGORIES**

Since the market of hauliers is heterogeneous and should not be treated as a single market segment, we try to capture different market segments of the hauliers by defining groups of hauliers with similar characteristics. We want to cover the main part of the Swedish haulier market for heavy goods vehicle with suitable categories for analysis purposes to make realistic predictions of possible effects of a kilometre taxation since we believe that different categories will react differently on taxation. The categorisation has a base in current categories used by the Swedish haulier organisation, as well as a categorisation made in a previous project called Tango Collect [3].
Table 1. Overview of haulier categories. LTL – Less-than-TruckLoad. FTL – Full-Truck-Load.

<table>
<thead>
<tr>
<th></th>
<th>Martin</th>
<th>Åsa</th>
<th>Kevin</th>
<th>Piotr</th>
<th>Olle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total weight (ton)</td>
<td>60</td>
<td>18</td>
<td>50</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Vehicle age (years)</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Type of transport</td>
<td>Long distance, often timetabled, LTL</td>
<td>Regional distribution, LTL</td>
<td>Construction, FTL</td>
<td>Long distance, foreign vehicle, FTL</td>
<td>Wood, routed tour, FTL</td>
</tr>
<tr>
<td>Distance/year (km)</td>
<td>180 000</td>
<td>40 000</td>
<td>50 000</td>
<td>180 000</td>
<td>180 000</td>
</tr>
</tbody>
</table>

The categorisation was an iterative process, which started with a workshop together with hauliers and the haulier organisation of southern Sweden. The haulier groups are described according to distance driven per year, type of vehicle used, type of transport, etc., see Table 1 above for a brief overview. These five segments are estimated to represent a large share of the overall road transport market in Sweden, at least the majority of the haulier market, according to the haulier organisation of southern Sweden, experts of the Swedish haulier market and national statistics [12]. Based on the haulier categories and its characteristics, cost evaluations were made based on statistics (mainly from [12] and [14]) and own assumptions, see Figure 1. To validate the categorisation, interviews were made with eight haulier companies representative of the included categories. The interviews contained mainly open-ended questions and the following issues were brought up in the interviews:

- The interviewed hauliers were asked to validate the categorisation, as well as describe how well their company fitted into the categories.
- The interviews included discussions of the cost structure for each segment concerning fixed cost, distance-based and labour cost as well as total cost per year and return of investments.
- A future kilometre taxation as suggested by SIKA [13] was added on the existing cost structure of the companies to facilitate an analysis of what impact the tax would have on the different segments.
- A number of defined statements concerning the possible impact of kilometre taxation were discussed.
- Liedke and Schepperle have found a clear relationship between transport market segments and shipment size, handling categories and from-sector [8]. Therefore we tried to extend the description of the categories by letting the companies describe their logistical operations in more detail.
RESULTS AND ANALYSIS

The defined haulier categories were validated towards the interviewed haulier companies. The categories represented the situation of the haulier rather well; however, we had to make some modifications of the categories:

- The distance driven by Kevin was increased to 50,000 km per year. Our first assumption was lower.
- The salary of Piotr was increased, since Eastern European countries recently have had an increase of salary.

Moreover, often Martin and Åsa exist in the same company since the different categories complement each other.

From Table 2 it can be seen that the largest cost increase as a consequence of the kilometre taxation will be noticed by Piotr, because Piotr is not included in the assumption that the vehicle tax will be lower when a kilometre tax is introduced in Sweden. The haulier types which do not drive many kilometres are naturally less sensitive to kilometre taxation.

<table>
<thead>
<tr>
<th></th>
<th>Martin</th>
<th>Åsa</th>
<th>Kevin</th>
<th>Piotr</th>
<th>Olle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per year (kSEK)</td>
<td>2383</td>
<td>700</td>
<td>1032</td>
<td>1180</td>
<td>2644</td>
</tr>
<tr>
<td>Cost per year (kSEK) km tax</td>
<td>2628</td>
<td>743</td>
<td>1077</td>
<td>1427</td>
<td>2888</td>
</tr>
<tr>
<td>Cost increase (kSEK)</td>
<td>245</td>
<td>43</td>
<td>45</td>
<td>247</td>
<td>244</td>
</tr>
<tr>
<td>Cost increase per cent</td>
<td>10.3%</td>
<td>6.2%</td>
<td>4.3%</td>
<td>20.9%</td>
<td>9.2%</td>
</tr>
</tbody>
</table>

Table 2. Effects on the cost structure as a consequence of a kilometre taxation.

The results from the statements are:

1. **The cheapest route is always used.**

The time aspect is generally more important than the cost aspect, especially for Kevin and Olle. When it is possible, the cheapest route is chosen. However, there is always a trade-off between cost and time.
2. A kilometre taxation, based on vehicle characteristic differentiation, gives incentives to invest in new vehicles more frequently. Yes.

3. The price for the end-customer will increase as a consequence of kilometre taxation. Most hauliers agreed on this. Crucial when letting the customer pay for increased costs are open relations between the partners. If detailed price information is given to the customer it is easier for the haulier to justify an increased price. Typical for the hauliers which do not believe that it is possible to let the customer pay for the kilometre taxation is a fixed price with no transparency and that the customer dominates the haulier, for instance that the haulier is a part of the customer company.

4. The transport resources will be better utilized. Most hauliers agree that it is possible to utilize the resources more efficient. However, not everybody believes the suggested kilometre taxation levels will have an effect on this. The greatest potential for a better utilization is an increased co-operation with other hauliers and with the customer since the customer has an important influence on how it is possible to plan the resource utilization.

We have tried to find patterns connected to the haulier categories and we have got some indications for some of the statements. However, in order to find more specific characteristics, a more structured survey including more information probably has to be done, with a much larger sample. We have also tried to extend the haulier categories to include more detailed logistical characteristics, such as product value, load consolidation. This also needs to be further examined for a larger sample.

The findings from our study concerning vehicle utilization correspond to what has been observed after an introduction of kilometre taxation in other European countries [9] [2]. The hauliers we interviewed believe it will be a cost increase for the end-customer; however, it is possible that the cost increase will not be significant, like the findings in the previous studies.

From the haulier interviews some wishes were expressed concerning the implementation of the kilometre taxation which can be regarded as guidelines, or aspects to consider:

- The purpose of the tax is important to state very clearly.
- The system has to be fair, e.g., cheaters should be stopped directly, few exceptions of included vehicles and equal tax levels for everybody.
- There has to be a European interoperability
- The collected tax should pay road maintenance and investment

**DISCUSSION**

As mentioned in the introduction, categories of hauliers can be appropriate to use when making simulation studies of the effects of for instance an introduction of kilometre taxation. If the categories are related to current statistics, it is possible to make predictions of certain market segments. In Sweden, detailed statistics exist concerning the product flow [14]. The product flow is for instance connected to industries, load carriers, transport modes, product values, and product flows between regions. When the haulier categories have been further examined, the haulier categories can be connected to this product flow statistics to indicate which segment of the national statistics the categories belong to.
The hauliers can belong to different types of transport chains with different types of customers, suppliers, etc., therefore it makes sense to extend the categorisation to also include other actors within transport chains to better capture different types of relations. A characteristic that is relevant to capture for typical customers is, e.g., ordering behaviour; for typical transport buyers the importance of the reliability of transports could be relevant to capture. It is also possible to define categories of typical transport chains based on the relations between actors in a transport chain. As an example, Ramstedt and Woxenius [11] have made a suggestion of typical transport chains, based on the dominance of the customer, supplier, or logistics service provider. It is possible to extend this with other characteristics such as product types, transport distance, etc.

There are several shortcomings of the study. Only a few hauliers have been interviewed and only hauliers in the southern Sweden have been interviewed. Therefore it is difficult to draw any general conclusions from the study; it should rather be seen as a first step towards a full categorisation of the Swedish haulier market. Another issue is the way the categories have been defined. Categorisations can be done in several ways. Liedtke and Scheppele [8] suggest that hauliers are connected to haulier categories with fuzzy clustering. Another way of making categories is to search for common patterns in large amounts of data by making use of clustering techniques/algorithms. However, such methods require a larger sample which was not possible in this study. Moreover, to cover a larger share of the haulier market, more categories probably need to be included. We have got indications from hauliers and other experts that categories such as hauliers belonging to a company (e.g., a producer), dry bulk, farming transports and intermodal transports, also could be included in an extended categorisation.

CONCLUSIONS AND FUTURE WORK

In this paper we have made an attempt to categorise the Swedish haulier market. The categorisation has been used in a small study of how it is possible that Swedish hauliers will be influence by an introduction of a kilometre tax for heavy goods vehicles.

There is a need for future work, for instance the categories need to be further validated and examined to fully cover the market. A larger sample of Swedish hauliers representing the whole country need to be examined, for instance a questionnaire can be sent out to cover a larger share of the Swedish haulier market. Also, the usability of the haulier categories need to be further studied in simulation experiments when making predictions of for instance policy effects.

The relationship between the transport buyer, forwarder and the haulier is very interesting to further study since this has an important influence on how the transports will be performed. Especially if the possibility of a modal split as a consequence of a kilometre taxation will be examined, it is important to further study how the mode choice actually is made.

ACKNOWLEDGEMENTS

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REFERENCES


Evaluation of road user charging systems: the Swedish case

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ABSTRACT

This paper identifies a set of important criteria to consider when evaluating potential road user charging (RUC) systems, grouped into charging accuracy, system costs and societal benefits, flexibility and modifiability, operational aspects, and security and privacy. These criteria are then used in a comparative analysis of four RUC candidate systems for heavy goods vehicles in Sweden. We conclude by pointing out a number of important issues needing additional attention in the process of developing a Swedish Road User Charging (RUC) system.

INTRODUCTION

In order to make the road users compensate for the external costs that are caused by their transportations, i.e., internalisation of external costs, the European systems for charging Heavy Goods Vehicles (HGV) are currently undergoing a change. Until now, most systems for charging heavy goods vehicles have been based on a yearly flat fee, whereas the current developments are towards systems that charge the users for the distance driven with the potential to discriminate between road type, time of usage, environmental performance of vehicles, etc.

The Swedish Road User Charging (RUC) system, as proposed by the Swedish Government, is to be distance-based and cover both domestic and foreign heavy goods vehicles above 3.5 tonnes. The kilometre tax should cover all public roads, and in order reflect the marginal costs principle, it should be possible to differentiate between different types of vehicles (e.g., environmental performance classes), time of the road usage, and between different roads. This makes a Swedish RUC system more complex than the RUC systems in operation at the moment, e.g. in Germany only motorways are considered. Moreover, the Swedish system should be harmonized with other European systems existing and under introduction. This implies that system should adhere to the EFC-directive 2004/52/CE with the purpose of achieving a European Electronic Toll Service for heavy goods which is interoperable.

The purpose of this paper is to identify important aspects or criteria to consider when evaluating different solutions to the RUC problem and to illustrate how these can be used to make a structured assessment. Most RUC systems are complex systems involving many actors, a lot of functionalities, hold sensitive information etc., which makes it important to consider additional criteria than just the cost of meeting the system requirements and objectives. Meeting such criteria is important in order to achieve acceptance among the
involved actors. In the next section we identify a number of important criteria for evaluating road user charging (RUC) systems and their parts.

**EVALUATION CRITERIA**

Potentially, there are many solutions that match the functional requirements described above. To choose between these potential solutions, there are a number of relevant criteria that can be used. We have identified a set of criteria which have been discussed with participating stakeholders in the Arena project (http://www.arena-ruc.com/). Some of the criteria presented below are similar to the ones described in the report by Expert Group 9 (1), which is supporting the European Commission on the work on Directive 2004/52/EC:

Charging accuracy – How good is the system at charging the road user the correct tax?
- **Distance accuracy** – How exactly can the distance a vehicle has moved be computed?
- **Vehicle differentiation** – How well can the system differentiate between different types of vehicles, such as, weight class, emission class, etc.?
- **Time differentiation** – How exactly can the time when a vehicle has used a road be recorded?
- **Road differentiation** – How good is the system at identifying which route a vehicle has used?
- **Fairness** – Are all road users (liable for the tax) equally treated, e.g., foreign and domestic users?
- **Target accuracy** – Are all of the, and only the, intended users targeted?

System costs and societal benefits – How large are the system costs and societal benefits?
- **System cost** – What are the costs for government, haulers, and other actors?
- **New equipment** – How large is the need for introducing and installing new (non-standard) in-vehicle equipment?
- **Communication need** – How much communication is needed, e.g., between vehicles and central servers?
- **Time to deployment** – How long time does it take to develop and deploy the system?
- **Fostering competition** – To what extent does the system offer incentives for a multitude of system providers?
- **Support technological development** – To what extent does the system provide incentives for development of new (efficient) technologies?

Flexibility and modifiability – How are the possibilities to adapt the system to future requirements?
- **Ability to adapt** – To what extent could the system be adapted to changing requirements, e.g. refined differentiation?
- **Scalability** – How well does the system handle large increases in the number of users, the road network, etc.?
- **Support for additional services** – How easy is it to add new services (to the basic road user charging functionality)?
- **Integration with services** (interoperability) – How well does the system cooperate with other relevant systems such as toll services?
- Technological lock-in: communication – How well does the system avoid technological lock-in with respect to communication technology?
- Technological lock-in: positioning – How well does the system avoid technological lock-in with respect to positioning equipment?
- Enforcement possibilities – What are the possibilities to implement different type of control and enforcement schemes?
- Update effort – How much effort is needed when new road sections are introduced, the tariff is changed, equipment update is needed, etc.?

Operational aspects – What are the effects of the system during operations?
- Availability – How robust and reliable is the system (for instance, is their a single point of failure)?
- Maintainability – How easy is it to maintain the system?
- User friendliness – How easy is it for the end-user to use the system, e.g., in terms of the manual procedures necessary and the installation? How good is the system at providing information to the user regarding, e.g., the fee/tax to be paid and where to find support in case of problems?
- System complexity – How complex is the system, e.g., in terms of number of and complexity of the equipment needed?

Security and privacy – What risks exist with regard to security and privacy within the system?
- Risk of sabotage – How large is the risk of system sabotage, what motives exist, and how easy would it be to sabotage the system?
- Fraud resistance – How difficult is it for users to circumvent security measures to escape taxes, e.g., by manipulation of equipment?
- Risk of information theft – How easy is it to steal information from the system?
- Integrity protection – How well does the system protect reliable information?
- Privacy protection – How well does the system protect user sensitive information?

By using these criteria it is possible to evaluate the strengths and weaknesses of different solutions. Below we present and evaluate four potential solutions.

**POTENTIAL SOLUTIONS**

In the proposed Swedish system, it is implied that a good approximation of external costs requires the possibility to differentiate between different types of vehicles (e.g., environmental performance classes), time of the road usage, and between different roads. However, there are proposals (2) for systems which are not able to fully differentiate between road usage and time of usage. One approach is to use the digital tachograph and another is to simply use a fuel tax. The fuel tax option is relevant for comparison, since it at least has the potential to capture the CO2 emission effects accurately. Below four proposals are introduced:

A. The “thin client solution” is a proposed solution for a Swedish road user charging system for Heavy Goods Vehicles (HGVs) (3). It is based on that vehicles report their positions to a central system (an EETS-provider), whenever the mandatory On-Board Unit (OBU) knows that the vehicle is in Sweden. It is similar to the solution 1 (which is not the one denoted “thin client” in their proposal) in the “Report of Expert Group 9” (1). The basis of the system is an OBU, able to record Global Navigation Satellite
Systems (GNSS) positions and to transmit them to a central server (not necessarily in real time). Also, Dedicated Short Range Communications (DSRC) between OBU and roadside equipment should be possible. The solution builds upon delivery of signed track logs including position data from the On-Board Unit (OBU), towards the EETS provider, using Public Land Mobile Networks (PLMN). Communication between two parties will be carried out by securing identity of the parties and that the messages are secured against message modification and fabrication; a secured kernel is used for this purpose. This solution allows for a rather open system structure in terms of different solutions for retrieving position data and sending these to the central server, either as a stream or in bulk transfer. Control functionality is carried out by real time communication using DSRC and by control of reported position data in comparison with other sources of information (e.g., tachographs, company tax declarations, etc.). Border crossing is dealt with by DSRC registration and stored information in the OBU of country borders in GPS format.

B. The thick client solution, is similar to the thin client, but with the addition of that maps and tariffs are included in the OBU, which needs to be possible to update. Further it includes a tax calculation capability, and hence, the tax calculations are communicated (not the positions per se). It is similar to the solution 3a in the “Report of Expert Group 9” (1). This solution is based on an OBU that is secured from manipulation and an important part of the control functionality is to make sure that no manipulation has occurred. Hence, it is based on a closed structure of the system, where the used OBU need to be certified and tamper proof. Border crossing is dealt with by using the maps in the OBU and possibly DSRC communication at the border.

C. The digital tachograph, see Kågeson (2) for a proposal. The core of the system is to use electronic devices (the digital tachograph) for recording vehicle movements. Originally, these were mainly motivated by the need to ensure that the time regulations for lorry drivers are obeyed. This type of electronic system is mandatory on new lorries in Europe (see http://www.eu-digitaltachograph.org/). The suggested control is carried out at regular vehicle safety checkups and possible road-side control. Border crossing can be dealt with by letting drivers making registrations of this, either electronically or as in case of the analogue tachograph by a picture taken by a camera. The exact dealing with foreign trucks and the enforcement in Sweden is not specified in the proposal (2).

D. The Fuel tax system, a special tax for fuel diesel usage in Sweden. Fuel sold in Sweden is simply taxed and fuel brought in by HGVs is taxed if not taken out again. The system based on fuel tax need to consider alternative possible usage of the fuel, i.e. need to consider potential exemptions for fuel usage for other purposes than HGV. The control is by controlling the fuel distributors in Sweden. Further, the control needs to be carried out through declarations of trucks entering and leaving Sweden. We have assumed that there can be rather efficient ways of handling this declaration, e.g. electronic devices which can measure and declare the fuel can be developed.

Next we will analyse the four candidate solutions using the different criteria presented above.

**PRELIMINARY EVALUATION**
With respect to distance accuracy, the solutions A, B and C, all have good potential for computing correct distances. However, for A and B, the accuracy depends on the frequency of position reports and the corresponding map matching, whereas C is sensitive to systematic errors in the tachograph. D is dependent on the fuel consumption per kilometre which is difficult to estimate accurately. The ability to vehicle differentiation is rather good in A to C, but there may be some difficulties with identification of a potential trailer. Solution D cannot handle this differentiation unless it is closely related to fuel consumption, but it may in fact estimate the environmental effects of an additional trailer rather well through increased fuel consumption. Solutions A to C should be able to handle time differentiation rather well. However, C cannot perform time differentiation in combination with road differentiation. Road differentiation can only be handled by solutions A and B. Fairness between foreign and domestic vehicle transports can only be fully achieved in A and B (assuming EETS-providers exists for both foreign and domestic users), whereas fairness cannot fully be expected for C and D due to the expected extra work at border crossing for in particular foreign HGVs. As a fuel tax will probably affect others than the intended target group who are using diesel for other purposes (e.g. light trucks, cars and other types of machinery), the target accuracy is the lowest for solution D and high for the other solutions.

The system cost is anticipated to be the highest for A and B, since these solutions require development of central computing facilities and heavy use of the communication infrastructure, as well as the introduction of new equipment in vehicles either on a permanent basis or when entering the country. Moreover, we anticipate their operational and enforcement to impose cost increases due to their advanced structures, whereas the solution C has the potential to use equipment already in existence and included in the vehicle. We believe that solution D has the lowest costs since no new equipment is needed in the vehicles and no new ICT infrastructure needs to be developed and deployed. We anticipate a higher need of new equipment in cases A and B in particular, where existing in-vehicle equipment cannot be used to the same extent as in A. The communication need is the highest for A, since the amount of position data that needs to be communicated to a central server is significant. Solution A communicates the majority of information in upstream direction, which in general offers less capacity as compared to the downstream. The majority of traffic in case B is assumed to be related to updates in downstream direction, thus competing for resources with other users’ downloads. Furthermore, B has the potential to aggregate the position information into tax calculations in the upstream communication. The communication need between a vehicle and a central server is marginal for D (only declarations of fuel at borders). Limited information needs to be reported from the digital tachograph for tax computations in C. We estimated the time to deployment to be in favour of D (no equipment in vehicles needed) and C (equipment in existence). For A, interfaces need to be developed, and for B, more complex equipment needs to be developed. The highest degree of fostering of competition is achieved in A (due to an open structure) and C (well defined units which can be produced by a number of providers), whereas B has the characteristics of a complex and closed system raising the bar for those planning to enter the market. We believe that A is supporting technological development the most due to its flexibility in technology choices, while neither C and D support any significant development of new technology.

The ability to adapt is the highest in A, since it has a more open structure allowing the use of different technologies. Solutions C and D are hampered by the inability to adapt to new requirements, e.g. road tolls. Solution A has limits with respect to scalability, due to the need of communication and the fact that computations are done centrally, potentially in a single-point-of-failure structure. B imposes slightly less computational needs on central level. D has
no problem with respect to this whereas some limits exist for C due to the central processing of information from tachographs. Solution A has good support for additional services due to its open architecture and positioning capability. B is also good due to the inclusion of both positioning capability and maps. Solutions C and D have strong limits on additional services, which often requires position information. Integration with services, for instance road tolls, is naturally only possible with A and B, but not easily with C and D. In comparison, solution B has the greatest chance of causing technological lock-in due to communication due to its closed structure, whereas solution A is more tolerable to other means of communications. There is hardly any communication needed in C and D, and hence, the risk of lock-ins is rather small. The situation is similar with technology lock-in with respect to positioning, except that no substantial difference between A and B can be foreseen. Solution A has requirements on non-tampered messages and secured identity and B the requirement of a certified OBU. We believe the enforcement possibilities and control possibilities are equally large for A (due to a rich availability of position data at central server to control) and B (due to more reliable method to read the state of the OBU-unit). The situation is worse for C due to less rich information to control and unavailability of efficient status checks (e.g., by DSRC). For D, the information availability is even less. The update efforts are significant for B (downloading maps and tariffs and possibly software), but less for A. For C, changing to new tachographs causes update efforts, while for D, no effort is required.

The availability of the system for the user is the highest for D and almost as high for C (due to rather simple equipment). For A and B the availability is lower due to a more complex technology, and A may also suffer from its single-point-of-failure structure. C and in particular D are the solutions that have the highest maintainability due to their simplicity. B has a reduced maintainability due to its more complex OBU. Due to its simplicity, D has the highest user friendliness (although some extra work at border crossings may occur), followed by C. Due to the complexity, including difficulty to install, the user friendliness in A and B is lower. Solution B is probably better than A in this respect due to a potential ability to inform user of current taxes. As indicated, A and B have the highest system complexity, and D represents the least complex solution.

The risk of sabotage, including the magnitude of potential consequences, is the highest for A and B due to their high complexity. The magnitude is even higher for B due to that all OBUs are exactly alike: Once a method is found to compromise one OBU, other OBUs can also be compromised. The risk is lower for C and in particular for D due to their simpler structure. The Fraud resistance is comparably high for the simplest solution (D) and less for the others. The risk of information theft is of course highest for A and B since more sensitive data (e.g., positions) is included in complex systems and less in C and D, where the least sensitive data exists in D. Likewise integrity protection is the highest for D and lowest for A and B due to the different occurrences of essential information (i.e., information crucial for the system). From the individual perspective, the level of privacy protection is similar but somewhat worse for A since position data, which is sensitive from an individual perspective, is sent to a central server. Table 1 provides a summary of the evaluation of the four solutions.

**DISCUSSION**

It seems clear that the simplest candidate system, the fuel tax system (solution D), has obvious advantages in some areas like system cost, operational aspects, and security and privacy. On the other hand, it has some serious problems as well, like low charging accuracy and flexibility. Almost the same applies for the tachograph (solution C) but with some (rather
small) security and privacy problems. Solution A and B have their main merits in the ability to achieve a good charging accuracy and drawbacks in the form of comparably high system cost as well as potential scalability problems and security and privacy problems.

Table 1. Summary of assessment using the relative scale “--", "-“, “0”, “+”, “++", where “- -“ indicates a very low merit of the proposed solution and “++” indicate a very high merit.

<table>
<thead>
<tr>
<th>Criteria type</th>
<th>Criteria</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charging</td>
<td>Distance accuracy</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>accuracy</td>
<td>Vehicle differentiation</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Time differentiation</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Road differentiation</td>
<td>++</td>
<td>++</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Fairness</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Target accuracy</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>System costs and societal</td>
<td>System cost</td>
<td>--</td>
<td>--</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>benefits</td>
<td>New equipment</td>
<td>-</td>
<td>--</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Communication need</td>
<td>--</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>Time to deployment</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>Fostering competition</td>
<td>+</td>
<td>0</td>
<td>+</td>
<td>N.A.</td>
<td></td>
</tr>
<tr>
<td>Support tech. development</td>
<td>++</td>
<td>+</td>
<td>0</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Flexibility and modifiability</td>
<td>Ability to adapt</td>
<td>+</td>
<td>0</td>
<td>-</td>
<td>--</td>
</tr>
<tr>
<td>Scalability</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>Support for additional services</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Integration with services</td>
<td>+</td>
<td>+</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Tech. lock-in: communication</td>
<td>-</td>
<td>--</td>
<td>++</td>
<td>++</td>
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</tr>
<tr>
<td>Tech. lock-in: positioning</td>
<td>-</td>
<td>-</td>
<td>++</td>
<td>++</td>
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</tr>
<tr>
<td>Enforcement possibilities</td>
<td>+</td>
<td>+</td>
<td>0</td>
<td>-</td>
<td></td>
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<tr>
<td>Update effort</td>
<td>+</td>
<td>--</td>
<td>+</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>Operational aspects</td>
<td>Availability</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Maintainability</td>
<td>0</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>User friendliness</td>
<td>--</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>System complexity</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>Security and privacy</td>
<td>Risk of sabotage</td>
<td>-</td>
<td>--</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td>Fraud resistance</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Risk of information theft</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>Integrity protection</td>
<td>-</td>
<td>-</td>
<td>0</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Privacy protection</td>
<td>--</td>
<td>-</td>
<td>0</td>
<td>++</td>
<td></td>
</tr>
</tbody>
</table>

The result of our evaluation is somewhat different from the results of the evaluation done by Expert Group 9 (1), when comparing the Thin (A) with the Thick client (B). They anticipated the communication need (volume-efficient communication) of the thick client (B) to be much less than in the thin client (A). We argue that there is a difference, but probably rather small, since the update effort is higher in the thick client, which also requires communication. We have an equal potential of integration with services using solution A and B, whereas the Expert Group 9 argued that the solution B was better. Solution A supports integration better due to its more open structure. However, B is more suitable due to its potential of being easily integrated with other toll systems (e.g. the German Toll Collect system). We believe the enforcement possibilities are as high for A as for B; the results of the Expert Group 9, indicate a higher enforcement flexibility for B. We believe that one merit of the thin client is that actual positions are reported, whereas the thick client has potentially better flexibility in
including different schemes for checking the status of the equipment in different ways (e.g. by road-side inspection by DSRC or by communication on mobile networks). This interpretation also affects the fraud resistance, which by the Expert Group 9 is claimed to be better through solution B than by solution A, whereas our suggestion is that they are roughly equally resistant (but on different merits).

There are a number of the criteria which are directly related to the acceptance of the system, which also is a factor to account for when choosing system and system design. In particular security and privacy aspects and user friendliness should be considered from an acceptance perspective. With respect to acceptance it is useful to look at the criteria from different stakeholders’ perspective. One can at least consider four types of stakeholders: public authorities (including politicians), system providers, organisational users (e.g. trucking companies), and individuals (e.g. lorry drivers). This distinction has not been made in the analysis so far, but is probably of more interest if weights are applied to the different criteria. The criteria are not only partly hierarchical, e.g. maintainability affects system cost, but there are also some interdependencies, e.g. time differentiation is rather meaningless without ability to differentiate with respect to road.

We see it as beneficial to proceed with some in depth analyses. Of course it is of most relevance to analyze system costs and societal benefits (primarily connected to road usage effects and tax incomes). Some types of analyses, connected to societal benefits and effects, are in progress for the Swedish situation (e.g. by SIKA, cf. www.sika-institute.se). We find it also of most relevance to analyze the system with respect to sensitive information. An example of sensitive information (in addition to drivers’ behaviour) in our case concerns company-critical information. Examples of critical information include revealed business partners and production capacity, which could be exposed by either actual road position or number of runs. From a company perspective, collected charging information should be strictly kept between the company and the charging authority. Further, information should be protected from criminals with, for instance, the intent of hijacking HGVs.

As several ten thousand HGVs might provide their position data in regular intervals (as in solution A), using the same network resources as mobile users of voice and mobile Internet service, a proper dimensioning of the position system is currently investigated. It has to address the frequency and volume of position data, the HGV density in network cells, the needs of communication protocols, overheads of security solutions, etc. Furthermore, a monitoring system is needed in order to indicate performance problems as quickly as possible.

ACKNOWLEDGEMENTS

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REFERENCES

List of ARENA reports


ARENA REPORT 2008:5. Hamilton, C J. “A market based approach to achieve EFC interoperability in Europe”. Policy Technology


ARENA REPORT 2008:9. Sundberg, J., “PM kring legala frågeställningar”. SWECO VBB


ARENA REPORT 2008:11. Sundberg, J., “PM kring kostnadsberäkning”., SWECO VBB


ARENA REPORT 2008:13
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