Transport policy vs. distance-based road user charging tariff scheme design

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The ARENA project

Transports are vital for social and economic development, but also create various types of negative effects, like, for example, emissions of various kinds, congestion, wear and tear of infrastructure, accidents and noise. These effects can be evaluated economically, and regarded as costs. To allow vehicle owners to fully pay these costs is called internalization of external costs. Today's traffic tax system makes it difficult to achieve competitive neutrality between different modes of transport and between carriers from different countries. Road user charging can be one answer to these problems.

ARENA, a Swedish R&D project, is developing a future-oriented road user charging system for heavy goods vehicles, in response to the challenges of today and also establishes a Test Site to demonstrate practical solutions. This work is also the basis for a research environment in the area of e-transactions.

The ARENA project serves as platform for stakeholders within the area of road user charging. The goal is to gather knowledge and skills in science, industry and public sector for opportunities and constraints of road user charging in a complex, international and competitive telematics environment. ARENA is funded by the Swedish Road Administration, VINNOVA and the European Regional Development Fund. NetPort.Karlshamn is the project coordinator, cooperation partners are Sweco and Blekinge Institute of Technology.

Summary

The purpose of the study reported in this document is to investigate what kind of tariff scheme design, with particular attention to parameters used, that fulfils different defined policy goals. As a step in the study, the ARENA concept has been compared to planned or already introduced systems in Europe. This has been done in order to answer the question of how goal fulfilment and scheme efficiency are affected by different tariff scheme designs.

Currently, Sweden is a member of the Eurovignette collaboration for road usage fees for HGV`s (Heavy Goods Vehicle). Beyond the Eurovignette, road users and vehicle owners also pay fuel tax and vehicle tax. These charges are all reflecting the Swedish transport policy objective that the transport system is to be socio economic efficient and sustainable. A governmental investigation proposed in 2004 that a kilometre tax on all HGV´s with the purpose of influencing a better use of resources within the use of the transport system. The governmental investigation constitutes a framework for investigating and designing a Swedish system together with European Union directives and decisions. The ARENA concept encompasses HGV`s with a weight over 3.5 tonnes and the entire road network. The charge is differentiated with respect to attributes of the vehicle (emission class and weight), location of the road and time (rise during peak hours on city road networks).

Presentations are given of several European countries either planning for an introduction of a distance-based road user tax system or having introduced such charges. Countries included in the study are the Netherlands, France, Finland, Switzerland, Germany and Austria. Focus has been on describing the system characteristics of goal fulfilment and scheme design. The comparison between the European examples and the ARENA concept concludes that several European countries have goal characteristics similar to Sweden but have chosen other tariff scheme designs. Also, countries having goal characteristics that differ from Sweden succeed in achieving effects defined as desired in ARENA.

Based on this conclusion, further studies are proposed. The aim of such studies is to increase the knowledge of other possible tariff scheme designs for the Swedish case and compare these designs with the current ARENA concept.

Sammanfattning

Syftet med studien som presenteras i detta dokumentär är att utreda vilken typ av tariffstruktur, med fokus på de parametrar som utgör tarifferna, som uppfyller olika politiska mål. Genom att jämföra ARENA-konceptet med planerade och introducerade system för vägavgifter i europeiska länder besvaras frågan om hur måluppfyllnad och systemeffektivitet påverkas av olika typer av tariffstrukturer.

I dagsläget är Sverige medlem i Eurovinjettsamarbetet för vägavgifter för tunga fordon. Utöver denna avgift betalar fordonsägare och väganvändare fordonsskatt och bränsleskatt. Dessa avgifter ska motsvara det svenska övergripande transportpolitiska målet om ett hållbart och effektivt transportsystem. År 2004 presenterades en statlig utredning som föreslog ett införande av kilometerskatt för tunga fordon i syfte att förbättra användningen av resurser inom transportsystemet. Den statliga utredningen utgör tillsammans med direktiv och beslut från EU ett ramverk för utformningen av ett svenskt vägavgiftssystem. ARENA-konceptet omfattar tunga fordon över 3.5 ton och hela det svenska vägnätet. Avgiften differentieras med avseende på följande parametrar; fordonets egenskaper (miljöklass och vikt), lokalisering (landbygd, tätort) samt tid (trafikering av hårt belastade vägnät i storstäder medför en högre avgift).

De länder som ingår i studien är Nederländerna, Frankrike, Finland, Schweiz, Tyskland och Österrike. Länderna planerar för en introduktion av system för distansbaserade vägavgifter eller har redan infört sådana system. Beskrivningen av dessa system har fokuserat på systemkarakteristiska såsom måluppfyllnad och struktur. Jämförelsen mellan de europeiska systemen och ARENA-konceptet visar att flera av de europeiska länderna har mål liknande de svenska men har valt en annan typ av tariffstruktur. Länder med mål som skiljer sig från de svenska har visat sig uppnå effekter som eftersträvas i ARENA.

Baserat på jämförelsen föreslås ytterligare studier i syfte att öka kunskapen om andra möjliga tariffstrukturer för Sverige och jämföra dessa med det nuvarande ARENA-konceptet.

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1 Introduction

ARENA, a Swedish R&D project, is developing a future-oriented road user charging system for heavy goods vehicles, in response to the challenges of today and also establishes a Test Site to demonstrate practical solutions. This work is also the basis for a research environment in the area of e-transactions.

Purpose

The purpose of the study reported in this document is to investigate what kind of tariff scheme design, with particular attention to parameters used, that fulfils different defined policy goals.

Question of issue

How is goal fulfilment and scheme efficiency affected by different tariff scheme designs?

Disposition

After this introduction, chapter two gives a presentation of the current Swedish situation concerning internalisation of external transport costs. Policy goals and their connection to a distance-based kilometre tax are presented together with current policy standpoints. The framework for a Swedish kilometre tax issued by policy goals and a governmental investigation (SOU 2004:63) is also described. Finally, a short recap of parts from the Communication for a sustainable future for transport (COM(2009)279/4) and relevant European texts concerning road user charging is given.

The third chapter presents how external costs from goods transport are to be managed and what the expected effects are from different measures. The chapter gives a description of governmental studies and the ARENA-project that describes, more specific, a concept on how a distance based road user charging system can be managed and issues related to the tariff scheme design.

Other European distance-based road user charging systems, both planned and implemented ones, are presented in chapter four. In chapter five, cost drivers in road user charging systems are described.

A comparison between the ARENA concept and the presented European examples reported in chapter four is made in chapter six and the conclusion of the study is presented in chapter seven. Finally, recommendations for further work are presented in chapter eight.

2 The Swedish background

2.1 Current situation

Existing demand management measures in Sweden are:

- Fuel tax - consisting of energy tax and carbon dioxide tax. The fuel tax includes fossil fuels and electricity. The energy tax comprises fuels both for vehicles and heating, and varies depending on the use. The levy of energy tax is based on weight and volume units. Energy tax on gasoline and oil based products used in vehicles is diversified. The carbon dioxide tax is calculated by the quantity of carbon substance. There is also a theoretic sulphur tax but since the existing fuels in regular amounts low contents of sulphur there is no levy in reality[1].

- Vehicle tax depends either on type of vehicle, fuel and carbon dioxide emissions or type of vehicle, fuel and vehicle weight[2].

- The Eurovignette – a collaboration for road usage fees between Sweden, Denmark, Belgium, Luxembourg and the Netherlands. The Eurovignette is based on the directive of the European Union concerning road tolls for using the road network for heavy goods vehicles. Heavy goods vehicles with a weight of 12 tons and more are included. The tax is paid annually and is valid for routes on road networks in the associated countries[3].

2.2 Policy objectives

2.2.1 Transport policy objectives

The overall transport policy objective in Sweden is:

> *The objective of transport policy is to ensure the economically efficient and sustainable provision of transport services for people and businesses throughout the country[4].*

To achieve socio economic efficiency, external costs caused by road transports must be internalised. Road transports cause negative environmental impact, worsen health, increased costs for operation and maintenance of the road infrastructure and gives negative impact on travel time and traffic safety. Economic demand management are considered to contribute to the possibilities of achieving socio economic efficiency. According to the government proposal (2001/02:20)[5], transport related taxes are supposed to correspond to the marginal costs of using the transport system. As the situation is now, the main part of all transports in Sweden does not pay for the full external costs they are causing[6].

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[1] SOU 2004:63, asvnitt 5, s 301
[2]htttp://www.skatteverket.se/skatter/fordon/fordonsskatt/omfordon.4.18e1b10334ebe8bc80003864.html
[3]http://www.skatteverket.se/skatter/fordon/vagavgifter.4.18e1b10334ebe8bc8000899.html
[4] Overall objective of the Swedish transport policy, N9012
[5] Proposition 2001/02:20 Infrastruktur för ett långsiktigt hållbart transportsystem
[6] SIKA 2006:2, s 22

In 2004, the Swedish road tax investigation (SOU 2004:63) was presented and it clearly defines that the purpose of road user charging in Sweden is to influence the users of the transport system to achieve a better use of resources. Revenues from the system are supposed to finance the maintenance of the road rather than get financial funds for new infrastructure[7]. The investigation proposed a kilometre tax levied on all HGVs, both foreign and Swedish. The proposal was adopted in the Swedish parliament in 2006 with a reservation related to the economic impacts. The concern was connected to effects on both regions and industry and was further investigated and concluded in 2007. The conclusion was that if the road user charge is designed as a differentiated tax, then the kilometre tax can be socio economic efficient. The importance of socio economic effects has been stressed in several studies. The revenues must significantly exceed the costs to be socio economically viable.[8]

2.2.2 Traffic safety and environmental objectives

In addition to the transport policy objectives there are more policy objectives to take into consideration when developing a road user charge. According to the government directive the road tax investigation was to take environmental-, traffic safety- and competitive aspects into consideration.

The long term objective concerning traffic safety is that no one shall be killed or seriously injured within the transport system, also called “Vision Zero”. The Swedish trend regarding traffic safety is positive with decreased numbers of injuries and deaths every year but still, the road transport sector is essentially responsible for the number of injuries.

The environmental objectives in Sweden are listed below. Those objectives that can be supported through a kilometre tax are written in *italics*[9].

1. *Reduced Climate Impact*
2. *Clean Air*
3. *Natural Acidification Only*
4. A Non-Toxic Environment
5. A Protective Ozone Layer
6. A Safe Radiation Environment
7. *Zero Eutrophication*
8. *Flourishing Lakes and Streams*
9. Good-Quality Groundwater
10. A Balanced Marine Environment,
11. Flourishing Coastal Areas and Archipelagos
12. Thriving Wetlands
13. Sustainable Forests
14. A Varied Agricultural Landscape
15. A Magnificent Mountain Landscape
16. *A Good Built Environment*
17. A Rich Diversity of Plant and Animal Life

[7] SOU 2004:63, s 381
[8] Förenklad form för svensk kilometerskatt, Per Kågeson, 2007-03-14
[9] SOU 2004:63, s 152

2.3 Current policy situation

The ARENA project is based on the road tax investigation that was concluded in 2004 but since then, there are areas that have received increased focus.

The overall transport policy goal has further been developed. The goal is in line with the arguments for introducing a Swedish road user charge in a transport system that is to be socio economic efficient and sustainable. The current accepted transport policy proposal says that road user charging for HGVs is to be introduced during special circumstances[10]. The proposal was accepted with reservations regarding subsidization for the haulier industry from the then current opposition.

The matter of environment and energy consumption are discussed on a global as well as on a regional and municipal level. The transition against more renewable fuels and an increased use of renewable energy are in focus, and there are goals set up in various levels of the society.

The Minister of Transport and Communications, Åsa Torstensson, has made a statement saying that the Swedish government makes a review of the possibilities of introducing road user charging systems on a regional and/or on municipal level. The Minister has also expressed the need of a fossil fuel independent vehicle fleet[11]. In 2009 the government decided to have only eco friendly vehicles in governmental use[12].

These discussions reflect the increased share of eco vehicles in the road transport system, including the current focus on electrical cars.

Though the Swedish governmental focuses on socio economic efficient and sustainable measures in the transport system, the Minister of Communications has been critical about introducing road user charges. This because the current policy proposal is more focused on the fairness of the transport system - the polluter pays principle, than on a direct environmental measures.

2.4 System requirements set by the policy goals

Directives and governing documents define direct or indirect a number of requirements that is to be taken into consideration when designing a distance based road user charge. The requirements define the encompassed vehicle fleet, the geographical spread and which relevant vehicle characteristics that should be managed.

1. The road user charge shall encompass all heavy goods vehicles with a maximum laden weight of 3.5 tonnes or more.
2. The vehicle owner is responsible for kilometre tax payments.
3. The road user charge shall encompass all public roads.
4. The road user charge shall manage to differentiate the tax rate depending on geographical areas. In this case, one road segment is considered as an area.

[10] Prop. 2005/05:16
[11] Åsa Torstenssons tal vid Centerpartiets kommundagar, Skövde 2 februari 2008.
[12] Transportforum, Linköping 8 januari 2009 av Åsa Torstensson, Infrastrukturminister

5. The road user charge shall manage that a geographical area may overlap another. It shall be possible to manage a regional charge/tax in parallel with a kilometre tax.[13]
6. The road user charge shall manage that different vehicles have different tax rate.
7. The road user charge shall manage different tax rates depending on time (time differentiation)

This means that the resulting kilometre tax for a performed run is a product of vehicles characteristics, driven distance, classification of road segments used and time of day[14].

2.5 European transport policy

In 2009 the European Commission presented a communication, a sustainable future for transport[15] aiming at stimulating further debates towards identifying policy proposals for a sustainable transport system.

Policy objectives, instruments and guidelines for interventions for achieving the objectives, related to road charging, are presented in short below.

- All costs must be reflected in the price to achieve economic efficiency.
- The programme states that economic efficiency can be achieved only if all costs, both internal and external, are reflected in the price. A correct pricing of the transport system, taking both economy and environment into consideration, would help transport operators and citizens to make the right choices by looking for the cheapest option.
- Since public funds are mainly used for financing transport infrastructure, socio-economic benefits (e.g. regional development, public goods) must be assessed by appraisal methods harmonised at EU level.
- External costs are most common paid by all citizens, the polluter pays principle is rarely used and the benefits of price signals are lost.
- In addition to the polluter pays principle, it is predictable that the transport sector has to increase the self financing of investments in relation to infrastructure.

2.6 The European regulatory framework

There are four texts relevant when discussing road user charging: the “Eurovignette” Directive (directive 1999/62/EC, amended by directive 2006/38/EC), directive 2004/52/EC and Council decision of 6 October 2009 on the definition of the European Electronic Toll Service and its technical elements.

[13] Andra vägar att finansiera nya vägar SOU 2006:33
[14] A kilometre tax for heavy goods vehicles in Sweden – A conceptual systems design Part 1: Requirements and preconditions, Version 1.0, 2008-02-12, Jonas Sundberg, Ulrik Janusson, Thomas Sjöström
[15] COM (2009) 279/4

2.6.1 The Eurovignette

- Directive 1999/62/EC, the so-called "Eurovignette directive", on the charging of heavy goods vehicles for the use of certain infrastructures

- Directive 2006/38/EC of 17 May 2006 amends the directive 1999/62/EC with a view to establishing a new Community framework for charging for the use of road infrastructure. This makes it possible to improve the efficiency of the road transport system and ensure the proper functioning of the internal market.

According to the directive the tax can be differentiated in consideration to vehicle class ("EURO" classification), place, time and rank of load and makes it possible to design the tariff scheme on the basis of the "user pays" and "polluter pays" principles. The directive also contains some limitations related to maximum tax per vehicle and year. From 2012 onwards Directive 2006/38/EC will apply to vehicles weighing between 3.5 and 12 tonnes.

The Eurovignette directive 1999/62/EG only allowed levy of tax from heavy goods vehicles on highways and bigger roads at the time when the road tax investigation was concluded. This means that the Swedish proposal was not in agreement with the directive of the European Union[16]. The amended directive[17] implies that member states are allowed to introduce road user charging on the entire national road network. Member states of the European Union have the possibility of introducing a kilometre tax and if a kilometre tax is introduced the levy of tax within the Eurovignette collaboration must stop[18]. Thus, the new Eurovignette directive is in line with the Swedish transport policy for a road user charging system.

2.6.2 The European Electronic Toll Service

- Directive 2004/52/EC concerns the interoperability of toll collection systems within the European Union. In March 2009, there was an agreement on the definition of the European Electronic Toll Service (EETS). Subsequently, the EETS is to be available within three years for vehicles above 3.5 tonnes and/or allowed to carry more than nine passengers (including the driver) and within five years for all types of vehicle.

The Directive 1999/62/EC lists the conditions to be met by Member States wishing to introduce and/or maintain tolls or introduce user charges. Member States that install electronic toll systems are responsible for ensuring that their systems are compatible.

The EETS ensures interoperability between all the electronic road toll systems in the Community, which can use either: dedicated short-range communication (DSRC) and satellite positioning associated with mobile communications.

The Commission intends to carry out a mid-term review 18 months after the entry into force of the decision.

The impacts of the Directive 2004/52/EC and the definition of the EETS on tariff scheme design are limited. However, in order to reach a full EETS definition a template for Toll

[16] SOU 2004:63 s 382
[17] Directive 2006/38/26
[18] SIKA Rapport 2007:2, s 26

Domain Statements has to be developed and agreed upon. This is work that has been commenced but not finished in the work with the Application Guide to the Decision of the EETS. The potential impact of such a template is huge.

3 Internalisation of external costs

3.1 Main Focus

Every transport generates external costs. The main focus of a Swedish kilometre tax is to internalize the external costs that HGVs causes, i.e. the polluter pays principle. In addition to the requirements listed in chapter 2 there are external effects/parameters defined by the marginal costs that the design of the tariff scheme is to be based on.

3.2 Factors and parameters

According to a governmental investigation[19] the kilometre tax must be differentiated, i.e. the owners of transports causing bigger external costs shall pay a higher tax, in order to make the marginal costs internalised. The kilometre tax is calculated by the tariff scheme which is differentiated on the basis of four dynamic factors. These factors are related to the external effects that the marginal costs consist of [20].

Table 1 External effects and differentiated factors

External effects	**Differentiated factors**
Wear and deformation	• Maximum weight of the vehicle
External accidents	• Place • Time
Noise and interference	• Place • Time
Emissions, CO_2 excluded	• Vehicle class, i.e. Euro-class • Place • Time
Congestion	• Place • Time

Thus, the tariff constitutes by the factors place, time, vehicle class and maximum vehicle weight.

3.3 Goal fulfilment and side effects

3.3.1 Socio economic effects – goal fulfilment

Goal fulfilment is achieved if the road user charge supports the policy goals and contributes in achieving them, i.e. the road user charge is to be socio economic efficient. Further on, the one that causes a cost shall also be the one responsible to pay for it in order to make the transport system fair. The costs encompassed by a road user charge should be the marginal costs from the external effects caused by the transport concerned. According to studies, a

[19] SIKA PM 2007:2
[20] Sweco, PM Beskrivning av tariffdatabas för kilometerskatt 2008-11-25

tax differentiated with respect to cost bringing factors i.e. vehicle class ("EURO" classification), place, time and rank of load, increases the possibilities of goal fulfilment[21].

Externalities caused by road transport and the parameters connected to road user charging are presented below:

- Wear and deformation - taking the vehicle weight and number of axles into consideration in the differentiation, the wear and tear on the roads can decrease.

- Noise and interference – differentiation in time and place.

- Emissions – vehicle class, i.e. the environmental or emission class, reflects the externality of emissions, CO_2 excluded. Decrease of emissions will also be enabled by a faster renewal of the vehicle fleet by vehicles with lower emissions levels[22].

- External accidents – differentiation in time and place. A reduction of traffic accidents is in proportional relation to reduced traffic performance.

- Congestion – possible differentiation on time and place. A distance based road user charge for HGVs will not result in any major effects for congestion. If all road vehicles were included in the system, reduced congestion could be expected.

When the tariff scheme design takes marginal costs into consideration and when the design enables the parameters to be differentiated, the kilometre tax can, according to studies, fulfil the policy goals.

3.3.2 Side effects

The positive socio economic effects are achieved when taking a holistic view of the system. In reality though, some regions and industries can experience negative side effects.

The average transport cost increase is estimated to between two to three per cent depending on whether existing or reduced energy tax is included in the calculations. The effects on both industries and regions are expected to be small and the influence from a kilometre tax will not bring significant negative side effects. Though, deviations can be found in individual businesses and smaller regions.

Industries

The side effects on industries can be expected to be small and not only negative according to studies. Industries that have a relatively high component of transport costs and distribution between different modes of transports will be affected by a kilometre tax[23].

Three of the industries mostly affected by a kilometre tax related to increased transport costs, are listed below with the most affected industry at the top.

[21] SIKA 2007:5
[22] SIKA 2007:2, s 10-11
[23] SIKA rapport 2007:2, s 61

- Food products
- Round timber
- High-value products

Regions

Regions with a high component of the industries listed above can expect effects by the kilometre tax. Components as profitability and the business sector structure in the regions are also crucial for the effects.

Though, calculations show that effects will be small even at regional level (calculations only apply manufacturing industry). The highest effect concerning employment is calculated in Southern Sweden where the effect is positive and employment increases. In central Norrland the largest negative effect has been calculated at 0, 41 per cent.

In five out of eight regions there will be a decreased production, although at most by 0, 9 per cent. The largest change is positive here too and is found in the Southern part of Sweden. [24]

3.4 ARENA – internalising external costs in Sweden

The Swedish project ARENA is aiming at developing, testing and demonstrating a distance based road user charging scheme, a kilometre tax, for heavy goods vehicles. The project has developed a functional concept that describes how the system could work.

In this chapter, the conceptual design will be briefly presented while the main focus will be on the tariff scheme design.

3.4.1 Conceptual design

Two perspectives have been taken into consideration within the project, the functional and the operator perspective. These perspectives are mainly based on the following requirements developed from both Swedish and European directives:

- The road user charge shall encompass all public roads.
- The road user charge shall manage to differentiate the tax rate depending on geographical areas. In this case, one road segment is considered as an area.
- The road user charge shall manage that different vehicles have different tax rate.
- The kilometre tax shall be interoperable with European Electronic Toll Service (EETS)

ARENA is focused on the system function “Charge tax” which involves measuring, calculating and supplying information in order to determining the correct tax.

[24] SIKA 2007:2, s 100

Measuring data is collected through a compulsory (for the vehicle fleet concerned) On-Board Equipment (OBE) which registers continuously time and position of the vehicle. The OBE is associated with a specific vehicle which ensures that the correct vehicle data i.e. vehicle class and vehicle weight, are used for the tax calculation which can be made either inside the OBE or by a toll service provider, on the basis of the collected information.

The ARENA project defines three actors which constitute the main organisations within the charging system; user, toll charger and toll service provider. Separating the toll charger from the toll service provider makes it possible for the toll charger to be able to manage several toll service providers which will be a result of introducing EETS to create a competitive environment.[25]

3.4.2 Tariff scheme design

Calculation of the tax is based on context data consisting of both map data and tariff data. Map data contains the geometrical depiction of the road network where every Swedish road is represented by a road link. Data is based on the National Road Database (NVDB) which is a digital map with each road link described by attributes such as topology, geometry, length and speed limit.

When data is delivered into the system the attribute location class ID is tied to each link. Location class ID points at a location class in the tariff data where tax differentiation is organised as tariff bands, see figure below. The Locations class ID is the link between map data and tariff data.

	Location Class ID 3 - Highway				
Location Class ID	Time Class ID	Weight ID Min	Max	Vehicle Class ID	Tariff (milli-SEK per kilometre)
3	Low Traffic	≥ 3.5	< 12	Euro 0	528
3	Low Traffic	≥ 3.5	< 12	Euro 1	480
3	Low Traffic	≥ 3.5	< 12	Euro 2	432
3	Low Traffic	≥ 3.5	< 12	Euro 3	384
3	Low Traffic	≥ 3.5	< 12	Euro 4	336
3	Low Traffic	≥ 3.5	< 12	Euro 5	288
3	Low Traffic	≥ 3.5	< 12	EEV	240
3	Low Traffic	≥ 12	< 22	Euro 0	968
3	Low Traffic	≥ 12	< 22	Euro 1	880
3	Low Traffic	≥ 12	< 22	Euro 2	792
3	Low Traffic	≥ 12	< 22	Euro 3	704
3	Low Traffic	≥ 12	< 22	Euro 4	616
3	Low Traffic	≥ 12	< 22	Euro 5	528

Figure 1 Example of a Tariff Band

In the scheme presented in the ARENA project there are four location classes but in a future implemented system there might be more.

- Location class 1, describing tariff structure on country side road links
- Location class 2, describing tariff structure on city road links

[25] Kilometerskatt för lastbilar I Sverige, Ett konceptförslag

- Location class 3, describing tariff structure on highway road links
- Location class 0, for road links free of charge

The tariff for the location class ID are differentiated regarding to time (Time Class ID), weight and Vehicle Class. Hence, there is a unique tariff band for each vehicle combination travelling on a road link belonging to a certain location class on a certain time.

The tariffs are set to reflect the marginal costs for HGVs, concluded by studies mentioned in chapter 3.

Since the traffic density on country side roads does not vary with time as significant as in cities and on highways, there will be no time differentiation on such links. City road links and highway road links have differentiation on time since the external marginal costs vary for transports during rush hour and during lower traffic periods.

As mentioned above, each road link has a unique tariff band for every vehicle combination, i.e. weight and Euro Class. Hence, the tax to be charged is the total sum of driven distance per road category, i.e. tariff band. The tax calculation formula is written as: [26] [27]

- Tax = Σ distance formula accumulated per Tariff Band * Tariff

3.4.3 Technical perspectives

ARENA does not prescribe a specific technical solution although the conceptual design suggested by the project affects the technical solution. The characteristics formed and suggested by the project according to the conceptual design are:[28]

- The extend of the system encompassing the entire road network prescribes position technology by either GNSS (Global Navigation Satellite System) or by GSM (Global System for Mobile Communications).
- The toll charger interface of the system must be designed to be able to manage different OBE´s since requirements set by EETS must be fulfilled.
- The optimal OBE is a so called thin client that only registers time and position of the vehicle, since a thin client does not require as extensive updates as a heavy client.[29]
- A security measure, for example a smart card issued by the toll charger, should be used to secure the thin client OBE and the vehicle.

[26] Price Differentiation for Swedish HGV charging - JELF:s paper till ITS World Congress 2009
[27] Kilometerskatt för lastbilar I Sverige, Ett konceptförslag
[28] Kilometerskatt för lastbilar I Sverige, Ett konceptförslag
[29] A new approach is taken in the ongoing ARENA-project which will lead to new characteristics concerning the OBE. This will be reported in 2010.

3.5 Chapter summary

The characteristics of the ARENA concept with respect to goals and system design are concluded in the table below.

Table 2 Characteristics of the ARENA concept

ARENA	
Goal characteristics	**System characteristics**
Internalisation of external costs - wear and deformation, emissions (CO_2 excluded), noise and interference, traffic safety, congestion	All roads - location - time (rise during peak hours on city road networks) HGVs > 3.5 tonnes

4 European examples

Several European countries plans for an introduction of a distance based road user tax system, and there are already some countries with operational systems with different characteristics. In this chapter, the systems suggested in Finland, the Netherlands and France are given a short presentation.

In Switzerland, Germany and Austria, kilometre tax for heavy goods vehicles has been implemented. In the second part of this chapter, the distance based road user charging systems in these three countries are presented with focus on policy goals, system design, goal fulfilment and side-effects.

After the each description every system is concluded in a summary table.

4.1 Planned systems

4.1.1 The Netherlands

The introduction of road charging in the Netherlands will begin in 2012. The introduction will start with HGVs but all vehicles will be encompassed in 2017. Though, exceptions will be made for some vehicles such as fire engines, ambulances, police cars and non registered vehicles. All Dutch roads will be included and they will be differentiated by time, location and vehicle class. The tax will consist of a basic rate and a potential rise at peak hours on busy roads.

The user pays principle is used and the idea is not to pay when only owning a car but when using it. Present fixed car taxes (motor vehicle tax, provincial surcharges and purchase tax) will be abolished while introducing the kilometre tax.

Satellite navigation will be used and in 2010, a field trial will take place, testing the OBE developed within the framework of the system. The OBE is a small unit with functions such as GSM, GPS and NFC (Near Field Communication)[30].

The expected effects are better accessibility and a cleaner environment. Studies indicate a decreased number of kilometres driven, up to 10-15 percentages in a long-term perspective compared to the situation without kilometre tax. This also implies a reduction in congestion.

The operational costs of the system are political accepted to a maximum of five percentages of the revenues. Revenues will go to the infrastructure fund, financing investments in traffic and transports. [31]

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[30] Ny Teknik, Nederländerna testar superskatt på bilresor
[31] www.verkeerenwaterstaat.nl/english/topics/mobility_and_accessibility/roadpricing/

Table 3 Characteristics of the Dutch system

The Netherlands	
Goal characteristics	System characteristics
Demand management -reduce congestion	All roads All vehicles Time - peak hours at busy roads

4.1.2 France

In 2011, kilometre charging for HGVs will be introduced in France. At present time parts of the motorway network, urban motorways and some inter-urban motorways excluded, are levied with motorway tolls. These tolls are managed by private operators. The current toll is depending on the distance driven and vehicle types, i.e. not only HGVs are obliged to pay the fee. The price also varies by the cost for building the road concerned. [32]

The accepted proposal includes the state road network and local government's roads, roads in some regions are excluded.

Introducing a kilometre tax aims at reducing road freight traffic potentially through modal shift, i.e. road transports towards rail. Additional aims are to reduce CO_2 emissions from goods transports and to finance intermodal transport policy measures.[33]

Every vehicle, both domestic and foreign, with a maximum weight over 3.5 tonnes will be required by law to have an OBE installed. The technology investigated are microwaves (DSRC) installed at pricing points on poles and satellite navigation (GNSS) complemented by mobile communication (GPRS) and microwaves (DSRC) for communication on the ground. (PPT, road pricing in France)

The tariff scheme design is differentiated by truck categories and EURO emission class. Congestion level can be added to the tariff design. The average levy is € 0.12 /km. The total amount of revenues is estimated to € 1 billion. Revenues will mostly be used in building new infrastructure[34].

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[32] http://www.tolltickets.com/country/france/libert.aspx?lang=en-GB
[33] Pay-per-kilometre Eco-tax on Heavy Goods Vehicles
[34] http://www.ARENA-ruc.com/?info=start&aktuellt=227, 2009-09-16

Table 4 Characteristics of the French system

France	
Goal characteristics	System characteristics
Demand management - reduce road freight traffic - reduce CO_2 emissions	Road network not included in the current motorway toll system - some regions excepted Time and place - congestion level possible - some regions excepted HGVs > 3.5 tonnes Vehicle class Emission class

4.1.3 Finland

In Finland there are no existing road tax charging and Finland has not been a member of the Eurovignette cooperation. The Finnish parliament decided to evaluate the possible effects of a congestion charge in the Helsingfors region. Three models have been studied when evaluating the effects of the congestion charge. An investigation for kilometre tax in the southern parts of Finland has been made but in this study, only the Helsingfors study is described.

The Helsingfors study has focused on whether or not it is possible to achieve the transport policy goals (better traffic flow, better competition conditions for public transports, reduced emissions of greenhouse gases, improved traffic safety) and socio economic efficiency. The expected traffic development (increased traffic volumes) will result in increased congestion.

The three models evaluated are presented below. None of the models levied tax during evening, night or during weekends. The tax is differentiated by time also by taking rush hours into consideration.

1. The Circle model:

    - Gantries when passing the region border and the city centre
    - Tax is levied in both directions when passing
    - Microwaves and permanent supervisor cameras as technical solution
    - Charges: € 2/passage during rush hours, € 1/passage between rush hours

2. The line model:

- Gantries when passing the region border and the city centre. The zone between the region border and the city centre are divided into three additional zones by two extra lines.

- Tax is levied in both directions when passing

- Microwaves and permanent supervisor cameras as technical solution

- Charges: € 1/passage during rush hours, € 0,5/passage between rush hours

3. The zone model

- Distance travelled based

- Each kilometre travelled in the zones are levied

  - Satellite navigation together with permanent and mobile supervisor cameras as technical solution

  - Charges within the inner zone : € 0,1/km during rush hours, 0,05 €/km between rush hours

  - Charges within the outer zone: € 0,05/km during rush hours, no charging between rush hours

During rush hours traffic flows were estimated to decrease with 10 -30 percentages. The zone model had the highest impact on decreased traffic flows and decreased travel times.

The congestion charge will also lead to an increased use of public transports. As a result of the above conclusions, traffic safety will be improved and emissions of greenhouse gases from the transport sector will decrease with 11-21 percentages.

Costs related to introducing a congestion charging system with the technical and functional solution varies in the study, from € 40 to € 180 million. Operating costs are estimated to € 10 to € 50 million a year. Socio economic efficiency will be achieved according to the calculations since the revenues are € 140 – 270 million yearly.[35]

[35] Studie om trängselavgifter i Helsingforsregionen - Sammanfattning, Kommunikationsministeriet

Table 5 Characteristics of the Finnish system

Finland	
Goal characteristics	System characteristics
Demand management -reduce congestion Increase traffic safety, reduce emissions etc	Entire road network -all roads inside an area Time - no charging during evenings and weekends - peak hours All vehicles

4.2 Implemented systems

4.2.1 Switzerland

Policy goals

In 1994, Switzerland adopted a new constitutional article with a binding upper limit of 650.000 trans-alpine journeys per year. Protection of the Alps from the increasing transit traffic was the main argument for the decision. The over-all goal is to transfer traffic from road to rail. Economic goals are to internalise the external costs of the freight transports and to help finance large-scale railway projects.

The tax system was introduced in 2001 and encompassed all roads in the country. The system has been amended twice and now all heavy vehicles with a maximum weight over 3.5 tons are included. Buses and mobile homes pay a subsidized tax because of tourism promotion. The tax is levied from these vehicles but it is subsidized.[36]

System design

To be able to internalise the external costs and to use the polluter pays principle the tariff scheme design is differentiated by maximum vehicle weight and the emission class of the vehicle divided into three categories.

Route-data is collected from an on board equipment installed in the vehicle, communicating with a tachograph recording the kilometres driven. The tachograph is automatically activated by microwaves (DCRS) installed over the way when passing the Swiss border. Information about the vehicle weight and emission class is also stored in the OBE. The operator is responsible for monthly registration of the data collected to the Custom authorized by collecting data on a chip card and sending it to the Custom authorities. Vehicles not fitted with an OBE uses an identification card to record the data. The card is issued when passing the border for the first time and the tax must be paid when leaving the country. The

[36] Fair and efficient – the Distance-related Heavy Vehicle Fee (HVF) in Switzerland

tachograph is complemented by DSRC that register when a vehicle is entering or leaving the Swiss road network. GPS is used as part of the control system.

The tax rate is calculated according to uncovered costs caused by heavy vehicles and the total amount of tonkm driven by heavy vehicles (the weight depends on the admissible weight, not on the laden weight). An assumed average travelled distance of 300 km (assumed transit journey between Basel and Chiasso) is used in the calculation. The maximum tax for a 40-tonne vehicle for this journey was determined by Switzerland and EU of 325 Swiss francs. This results in a maximum rate of 2.75 cents per tonne and kilometre.

The tax is calculated by multiplying the number of kilometres driven with the weight of the vehicle and with a tariff depending of emission class. Three emissions classes are defined, corresponding to the Euro emission classes.

The rate of the tax has been increased several times since the introduction. By January the 1st 2008 the rate was defined to 2.66 Swiss cents per ton and kilometre (Cents/tkm) for vehicles corresponding to the EURO 3 emission class. For vehicles in lower EURO-classes the rate is 3.07 Swiss Cents/tkm and for higher 2.26 Cents/tkm. When the fee was introduced, the rate was defined to 1.68 Swiss cents per ton and kilometre.

Goal fulfilment and side-effects

Revenues are shared between the cantons and the Federation. One third of the revenues goes to the cantons and is used for costs caused by heavy transports, not covered by the kilometre tax design. The Federation uses its share, 2/3, to finance public transport projects and extension of the railway network for goods transport.[37]

The effectiveness in the transport system has increased since the distance based road user charging was introduced. The number of kilometres travelled were reduced at the same time as the goods transported, increased. Differentiation by vehicle class affected the vehicle fleet positive and created a movement towards a renewal of the fleet. Combined with the decreased kilometres driven, emissions from the heavy vehicles have decreased.

Side-effects on the labour market have not been significant. The volume of transports has increased though the numbers of employees have remained stable. It has not been possible to evaluate any significant change in consumer price. The regions in the mountain and peripheral areas have observed a greater impact than other because these areas are not easily accessible by 40 tonne vehicles. Switzerland takes these regions into consideration by compensating them.[38]

[37] http://www.are.admin.ch/themen/verkehr/00250/00461/index.html?lang=en, 2009-09-17
[38] Fair and efficient – the Distance-related Heavy Vehicle Fee (HVF) in Switzerland

Table 6 Characteristics of the Swiss system

Switzerland	
Goal characteristics	System characteristics
Demand management - reduce trans-alpine traffic Internalising external costs	Entire road network No time and place differentiation All heavy vehicles > 3.5 tonnes Emission class

4.2.2 Germany

Policy goals

As a transit country for freight vehicles, Germany has extensive external costs not only caused by domestic vehicles. With this in consideration introducing a distance based charging system including both domestic and foreign vehicles was an attempt to internalise these external costs. By using the external marginal costs and the polluter pays principle the goal was to create a more efficient use of the infrastructure. Reduction of emissions and a more fair division between road- and rail transports were also desirable effects.

Germany applied the Eurovignette up until the introduction of the new distance based tax system. The system was to be introduced by 2003 but due to technical problems the implementation was delayed until 2005.

System design

The only roads that are included in the German Toll Collect system are the motorways and three national highways. Vehicles encompassed by the kilometre tax, are defined as all vehicles over 12 tonnes maximum laden weight. The differentiation is based on the number of axles and emission class. The vehicle is also categorised in one out of four emission classes.

The technical design consists of an OBE which the user gets installed in the vehicle when registering to the system. Through a satellite positioning and map matching system, assisted by microwaves (DSRC), travelled distance data is collected as a sequence of road segments travelled. With data such as the number of axles and emission class of the vehicle, set by the operator, the information are sent to a data central by means of mobile communication (GSM). The DSRC part of the system is also used for control of compliance.

The tax is paid monthly after the use of the road but it is also possible to pay the tax in advance. This can be done through the Internet or special terminals were the tax is manually calculated based on an estimated distance from a manual route description.

The tax (Maut) rate per kilometre is decided by the vehicle class and the number of axles, either up to three axles or more than four axles. The rate varies between € 0.140 and € 0.288 per kilometre[39].

Goal fulfilment and side-effects

In 2007, two years after the system was introduced, the number of fully loaded trips had increased with 2 percentages up to 82 percentages and the number of empty trips was reduced with 15 percentages.

The tariff differentiation depending on emission class has led to the replacement of older vehicles in advantage of newer vehicles. The vehicle weight limit has led to increased sale of lorries with a maximum weight of 10-12 tonnes, i.e. just below the level where the Maut is due.

Secondary roads are used more frequently by operators as a result of the introduction of the kilometre tax on the motorway network. In order to solve this problem, the system was extended to include three national highways and bypasses in 2007.

The operating costs are 18 percentages of the revenues (costs € 620 million, revenues € 3 billion). The high number of employees (1 300) causes a significant share of the operating costs. [40] [41]

Table 7 Characteristics of the German system

Germany	
Goal characteristics	System characteristics
Internalising external costs - wear and deformation Demand management - reduce emissions Fair division between road-and rail transports	Motorway system and some national highways All vehicles > 12 tonnes Number of axles Emission class

4.2.3 Austria

Policy goals

In Austria the distance based road user charging, called GO-Maut, was introduced in 2004. The road network included in the system is motorways and a few express-ways. All vehicles

39 web_einfuhrungstex_sw.pdf, s 20-22
40 SIKA 2007:2, s 39-40
41 A Price worth paying, s 8-10

over 3.5 tonnes maximum laden weight are obliged to pay the tax, regardless of goods transport vehicle or not.

The premier goal when introducing the tax system was to generate revenues for financing infrastructure projects and maintenance of the infrastructure. Internalising the external costs were not the aim as in Germany and Switzerland. However, in January 2010, the tariff scheme design is to be changed and based on emission categories including a traffic safety component[42].

System design

The current tariff is differentiated by the number of axles (indirect involving vehicle weight). There are three vehicle classes according to axles; two, three and four or more axles. Additional tax can be levied depending on whether or not the route passes any of six specific sections (tunnels and motorways)[43].

The upcoming tariff scheme design is as mentioned above, to be based on emission categories i.e. Euro Class. The kilometre tax is levied in addition to the existing charges, for example the Eurovignette, which also deviates from the solution adopted in Germany and Switzerland[44].

The technical solution consists of microwave (DSRC) antennas mounted on gantries placed at each section and in both directions in the road network covered by the tax. When a vehicle passes the gantry the OBE is activated by the antenna and relevant data are stored in the OBE and in road side equipment. The control system consists of intermediate control points along the sections also using DRSC[45].

The tax rate per kilometre from May 1st 2008 is for vehicles with two axles € 0.1580, three axles € 0.2212 and € 0.3318 for four axles or more[46].

Goal fulfilment and side-effects

Costs in relation to revenues are 10-12 percentages[47]. Since the overall policy goal is to finance infrastructure projects the system can be said to fulfil this goal.

Since only motorways and a few express-ways are encompassed by the system there have been problems with sub optimal routes by some hauliers to avoid the tax. Lorry bans have been introduced in some regions trying to avoid this. The effectiveness in the transport system has increased since there are less empty trips. Some smaller companies have disappeared.

A study made on regions and industries was concluded in 2006. The result was that the effects were more significant in industries, in particular the logistic sector, the soil and stone industry, than in regions. These industries are more affected since they have a high

[42] http://www.go-maut.at/go/Article.asp?ID=24515, 2009-09-10
[43] http://www.go-maut.at/go/Article.asp?ID=2644
[44] SIKA 2007:2, s 35
[45] Kilometerskatt för tunga lastfordon i Sverige, kostnadsbedömning, s 17
[46] http://www.go-maut.at/go/Article.asp?ID=23939&Navi=7, 2009-09-17
[47] SIKA 2007:2 s 31

component of transport costs. The effects between regions were expected to be less significant. The northern part of Austria was the region most affected by the distance based road user charge with a 14 percentages increase in transport costs. Consumer price were not expected to be significant effected, explained by decreased gains for the producer to keep the demand of the products[48].

Table 8 Characteristics of the Austrian system

Austria	
Goal characteristics	System characteristics
Internalising external costs - financing infrastructure and maintenance Demand management – reduce emission	Motorways and some national highways All vehicles > 3.5 tonnes Number of axles Emission class (from 2010)

[48] SIKA 2007:2, s 37

5 Cost drivers

Comparing estimated costs in real numbers is related to big uncertainties. Instead, this chapter will present cost driving factors concerning road user charges. The factors are meant to be general, but are based on Swedish studies.

It has been found that enforcement and control systems have a large impact on both investment and operational costs. In the Swedish case, fixed road equipment on the national road network, serving as control points, are complemented by mobile control units, similar to the approach taken in Germany, on the secondary road network.

Another factor with impact on the cost is the OBE in the vehicle which can be expected to cost around € 150[49], installation included. An OBE of some kind must be installed in the vehicle, either integrated within the vehicle computer or retro-fitted. There are three significant factors affecting the price of the OBE; technical requirements, total production volume and possibility of using existing infrastructure. [50] When discussing OBEs in a distance based tax system the European directive (EFC 2004/52) must be considered. The directive prescribes that the road user charge system must manage a European OBE and a European OBE is, according to the directive, based on GNSS [51]. However, when considering the Swedish vehicle fleet, where approximately 100 000 vehicles will be obliged to pay a kilometre tax, the investment cost in OBE´s is not critical in relation to the tax.

Other significant cost factors are information and service including employment costs and systems of enforcement, and the operation and supervision central. In this case, integration with existing systems for billing and customer service will bring considerably lower costs.

According to the above, cost drivers in road user charging systems can be addressed to:

- The geographical coverage – affecting the number of control points
- Vehicles encompassed by the system – affecting the number of OBEs installed and number of vehicles to be controlled
- The infrastructure and staff required for the operation of the system

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49 PM Kilometerskatt för tunga lastfordon i Sverige, Reviderad kostnadsbedömning, november 2007, Jonas Sundberg, Sweco VBB

50 PM Kilometerskatt för tunga lastfordon i Sverige, Reviderad kostnadsbedömning, november 2007, Jonas Sundberg, Sweco VBB

51 PM Sambandet mellan möjligheter till differentiering av skatten och vald teknisk lösning, november 2007, Jonas Sundberg, Sweco VBB

6 System comparison

The European systems described in chapter four are compared with the ARENA concept regards to goals and tariff scheme design characteristics with respect to similarities and differences.

6.1 The Netherlands – ARENA

Table 9 Table comparing the Dutch system and the ARENA concept

	Similarities	**Differences**
Goals	• reduce emissions	• reduce congestion • reduce traffic to decrease noise and incidents and to increase traffic safety.
Tariff scheme design characteristics	• charge by emission class • cover all roads • time and position differentiation	• vehicles – entire vehicle fleet vs HGVs only

ARENA and the Netherlands share the goal to reduce emissions. This is reflected in the system characteristics to charge by emission class which is also present in the ARENA concept. The Netherlands faces a severe congestion problem which clearly necessitates charges which are differentiated with respect to position and time, as well as coverage of all roads and all vehicles. Although ARENA shares these characteristics Sweden faces far lower levels of congestion. Indeed most roads see no congestion at all. ARENA uses coverage of all roads to achieve fairness (polluter pays principle) and to reduce traffic to address the goals of decreasing noise and incidents and to improve traffic safety.

6.2 France – ARENA

Table 10 Table comparing the French system and the ARENA concept

	Similarities	**Differences**
Goals	• reduce emissions	• reduce road traffic • reduce traffic to decrease noise and incidents and to increase traffic safety.
Tariff scheme design characteristics	• charge by emission class • HGVs > 3.5 tonnes • time and position differentiation	• network coverage

Both France and ARENA uses differentiation by emission class of the vehicle as one way of reducing emissions. Though, ARENA has excluded CO_2 emissions (CO_2 emissions are not included in emission classes, i.e. Euro classes), while reducing CO_2, is the main focus in France. Reducing road freight traffic as a goal also contributes to reduce CO_2 emissions if transport is transferred to more environmental friendly transport modes, e.g. rail.

Vehicles encompassed by the kilometre tax are the same in both concepts, i.e. HGVs > 3.5 tonnes, as well as the differentiation with respect to location and time. In France, only the parts of the main road network that are not covered by the current road toll systems will be covered by the distance based road user charge and some regions will be excluded entirely.

6.3 Finland – ARENA

Table 11 Table comparing the Finnish system and the ARENA concept

	Similarities	**Differences**
Goals	• reduce emissions • reduce traffic to decrease noise and incidents and to increase traffic safety.	• reduce congestion • wear and deformation
Tariff scheme design characteristics	• time differentiation • coverage all roads	• vehicles – entire vehicle fleet vs HGVs only • position differentiation • charge by emission class

Finland has studied three models aiming at reducing congestion in the Helsingfors area. The so called zone model is a kilometre based model where the tax levied will be based on every kilometre driven inside the zone. All roads within the area will be covered but no difference will be made where roads are located which are a significant difference compared to the ARENA concept. Both systems uses differentiation factor reflecting time.

Comparing goal characteristics in Finland and Sweden there are similarities such as increased traffic safety, reduced emissions and reduced congestion. However, the Finnish model has as primary goal to reduce congestion since heavy congestion are seen as potential future scenario which differs from the ARENA which has a national perspective having more focus on wear and deformation. The congestion problem in the Helsingfors area is also reflected in the vehicles encompassed by the zone mode, i.e. all vehicles (as in the Netherlands).

6.4 Switzerland - ARENA

Table 12 Table comparing the Swiss system and the ARENA concept

	Similarities	Differences
Goals	• reduce emissions • reduce road traffic • Internalisation of external costs	• wear and deformation, noise and incidents, traffic safety, congestion
Tariff scheme design characteristics	• charge by emission class • HGVs > 3.5 tonnes • network coverage	• time and position differentiation

Switzerland is the only European country that has implemented a distance based road user charge covering the entire road network, similar to the ARENA concept. However, the Swiss system does not take the characteristics location and time into consideration resulting in a significant difference between the Swiss and the ARENA concept.

Switzerland is experiencing great impact from transit traffic which is reflected in the goal characteristics of the system. Reducing traffic in Switzerland aims to protect the Alps and reducing traffic in Sweden aims to have positive effects on noise and interference and traffic safety.

Vehicles encompassed by both systems are HGVs > 3.5 tonnes and both systems also share the component of emission class.

Regions in Switzerland with a higher impact by the road user charging receive compensation from the Federation.

6.5 Germany – ARENA

Table 13 Table comparing the German system and the ARENA concept

	Similarities	Differences
Goals	• wear and deformation • reduce emissions • reduce road traffic • noise and incidents, traffic safety, congestion	
Tariff scheme design characteristics	• charge by emission class • HGVs > 3.5 tonnes • network coverage	• road network coverage • time and position differentiation • weight limit • vehicle weight vs number of axles

Similar to Switzerland, Germany experiences a great impact of transit traffic which is reflected in the goal characteristic by internalisation of the external costs, mainly wear and deformation. In contrast to ARENA, the German system covers only the motorway system and the national highways and characteristics as location or time within the road network are not identified in the system. Reducing emissions are a desirable effect and Germany is reflecting this goal by differentiation by emission class, just as the ARENA concept.

In both systems the HGVs are levied to pay the tax, but in Germany the weight limit is higher than in Sweden; 12 tonnes compared to 3.5 tonnes. Also the differentiation factor reflecting vehicle size is different, in Germany it is the vehicles number of axles instead of vehicle weight as in ARENA.

6.6 Austria – ARENA

Table 14 Table comparing the Austrian system and the ARENA concept

	Similarities	Differences
Goals	• wear and deformation/ financing new infrastructure • reduce emissions	• reduce road traffic • noise and incidents, traffic safety, congestion
Tariff scheme design characteristics	• charge by emission class • HGVs > 3.5 tonnes	• road network coverage • time and position differentiation • vehicle weight vs number of axles

In Austria, financing of maintenance and infrastructure are the main goal characteristics which is partly similar to ARENA having wear and deformation as an important parameter in the concept. Austria will develop the concept further in 2010 by differentiate the tax also by emission class, to reduce emissions, similar to ARENA. Though, traffic safety, noise and interference and congestion are missing in the Austrian concept when comparing with ARENA.

The road network coverage in Austria is, as in Germany, limited to the motorways and some national highways, i.e. different from the entire road network coverage in ARENA. Furthermore Austria does not take either location or time into consideration when determining the tax.

Vehicle size is reflected as number of axles in the Austrian system and vehicle weight in the ARENA concept, but vehicles encompassed by the system are defined as HGVs over 3.5 tonnes in both countries.

7 Conclusion

The systems in Germany, the Netherlands and Austria have internalisation of external costs as primary goal when designing their tariff scheme road user charge. Sweden currently also belongs to this group, but the design differs between these systems and the ARENA concept.

The road networks encompassed by the system are in both Germany and Austria restricted to motorways and some expressways, compared to the entire road network in the ARENA and also in the Netherlands and in Switzerland. The restricted geographical design in Germany and Austria results in fewer kilometres of roads being charged and therefore the demand of control and enforcement decreases.

Since the Swedish concept encompassed all roads, the demand of control in Sweden is extensive. Also, as the road network in the ARENA tariff scheme design is represented by one road link for each road, the map data becomes complex.

Systems that have demand management as a clear objective are the ones in Switzerland (reduced trans-alps traffic), the Netherlands (reduced congestion), Finland (reduced congestion) and France (reduced road side traffic and reduced CO_2 emissions). Evaluations of these systems have shown, as presented in chapter 4, that the effects of the system, in several cases, are the desired effects sought by Sweden.

Based on the comparison made in chapter 6 and on the discussion above, it is concluded that several European countries have goal characteristics similar to Sweden but have chosen other tariff scheme designs. Also, countries having goal characteristics that differ from Sweden succeed in achieving effects defined as desired in ARENA.

As a conclusion, it is here proposed that further studies are needed to increase the knowledge of other possible tariff scheme designs for the Swedish case and compare these designs with the current ARENA concept.

8 Further Work

For further work some possible tariff scheme designs have been identified and are presented below.

- Geographical coverage restricted to the main road network and parts of the secondary road network.
  Experiences from Germany and Austria shows that a distance based road user charging tariff scheme based on a restricted geographical coverage can fulfil policy goals similar to Swedish ones. The number of control points is also reflected by the geographical coverage and has significant affects on the system costs.

- Pricing points – virtual or real.
  Pricing points as the basis for road user charging are in this case not considering the exact number of kilometres driven although a good approximation can be made in closed networks with entry and exit registration. Examples of this tariff scheme design are passing specific road links as in France, Italy and Austria, and also in Sweden - the bridge over Svinesund and the Öresund Bridge.

- Fuel and vehicle tax.
  Shifting from taxation of fuel and vehicles to taxation of vehicle and infrastructure use is an ongoing development for instance in the Netherlands as the use of fuel as a tax base is gradually losing its strength. A taxation shift of this kind or a partly shift combined with some kind of road user charging can probably be rather successful. A tariff scheme design combining fuel and vehicle tax and road user charge should be further studied.

- Road user charging for all vehicles.
  Letting the road user charge include not only heavy goods vehicles but also private cars will have effects on both costs and benefits. Including all vehicles in a road user charging system will result in more OBEs installed and more vehicles to be controlled, but the infrastructure investments will be fairly equal. Also, an increased number of vehicles will create a huge market and lower the price of the OBE, and at the same time effects from the entire vehicle fleet will positively affect the fulfilment of the policy goals.

List of ARENA reports

ARENA REPORT 2008:1 “Road User Charging of Heavy Goods Vehicles in Sweden”. Final report ARENA 1., NetPort.Karlshamn, SWECO, BMT Transport Solutions GmbH.

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

ARENA REPORT 2008:3 “A kilometre tax for heavy goods vehicles in Sweden – A conceptual systems design. Part 2: Proposals for systems design”., Sundberg, J., Janusson, U., and Sjöström, T., SWECO Infrastructure.

ARENA REPORT 2008:4 “A New Approach to Control in the ARENA concept for HGV kilometre tax in Sweden”., Sundberg, J., SWECO Infrastructure.

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