Anders Betalen voor Mobiliteit

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Market consultation phase 2

Final Report

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Content

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0.901	06th July 2006	Preliminary report
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References

	CESARE III model, as referred to in RCI document RCI_DOC_ConsultationEntitiesRolesAnnexes_V1.0.pdf
	Cost Format phase 2 v1.0.xls
	EU directive 2004/52/EC
	RCI Functional Decomposition, as referred to in RCI document RCI_DOC_ConsultationArchitectureProcessesAnnexes_V1.0.pdf
	Requirement Specification 'Anders Betalen voor Mobiliteit', Version: 0.2 (draft), 27 March 2006
	Review comments Vodafone 28jul06.doc
	Tariffscenariosforphase2assignmentsv1.0.doc

List of toll specific abbreviations

2 G	Second Generation Network – GSM, GPRS
3 G	Third Generation Network - UMTS
BO	Back Office
BOM	Bill of Material
CESARE	Common EFC (Electronic Fee Collection) system for an ASECAP Road Tolling European Service
DSRC	Dedicated Short Range Communication
EETS	European Electronic Toll Service
ERUC	Electronic Road Usage Charging
ES	Enforcement station
GDF	Geographic Data Format
GML	Geographic Marker Language
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HGV	Heavy Good Vehicle
HLR	Home Location Register
HMI	Human Machine Interface
HWN	Hoofdwegennet
LBS	Location-Based Services
LED	Light-Emitting Diode
LRUC	Lorry Road-Usage Charging
MS	Mobile Station
OBE	On-Board Equipment
OBU	On-Board Unit
OWN	Onderliggend Wegennet
RAN	Radio Access Network
RUC	Road-Usage Charging
SIM	Subscriber Identity Module
TCH	Toll Charger
TMSI	Temporary Mobile Subscriber Identification
TSP	Transport Service Provider
UMTS	Universal Mobile Telecommunication System

Table of figures

Reference table "Review comments"

Comments by the Ministry	Reference position
"Communications costs are estimated at 18 Euro per subscriber per year. This is regarded as high, given current price levels and the large amount of subscriptions, no necessity for invoices, no credit risk etc. Please reconsider or give more evidence to this price estimation."	Page 48
"It would be appreciated if the relation between consolidated costs and assumptions / numbers / unit costs is presented in a more explicit way (i.e. underlying formulas in the spreadsheet).	Page 45
"The base scenario is considerably cheaper compared to the big bang scenario. This follows from the tables with costs. It would help the reader to give a little more clarification in the text as to the main drivers for the cost reduction. "	Page 60
"Payment and billing. In the Netherlands, direct debit ('automatische incasso') is a very cheap payment method. Please investigate if this can be used to reduce your processing costs."	Page 28
"There are some questions with the smart-phone solution (what to do if one forgets to switch on the phone, or forget to take it with one when making a trip?). On the other hand: how to enforce when people 'forget' on purpose?"	Page 16
"Is the commercial service of Galileo required/recommended? If so, what costs are assumed?"	Page 43
"If the budget for operational costs would be limited to € 350 million per annum, please indicate how the following aspects would be covered within this given budget:"	Question will be answered in a separate report by 9th of August
- compliance to the functional requirements	
- scope	
- quality of service	

1 Scope of the document

The scope of this document is to provide the Principal's project team "Anders Betalen voor Mobiliteit" with Vodafone's final project results.

The report includes explanations and answers to the comments of the Principal's project team, given on 28th of July 2006 within the document "Review comments phase 2 assignment". The specific text passages covering theses comments are referenced in the table above.

The current version of the document is classified as "public". The Principal may use, review, copy and make public information provided in this report.[1]

Vodafone has already handed over the following deliverables, which are therefore no longer part of this document:

D-1 Work plan for the execution of the required tasks, including work breakdown, time schedule and envisaged effort per activity

D-2 Functional system overview, basic characteristics and focus areas of Vodafone's electronic road usage charging approach for the Netherlands

Therefore this report contains all other deliverables required by the Ministry:

D-3 System concept and high-level design

D-4 Cost estimations

D-5 Migration scenarios

D-6 Risk analysis

D-7 Comments on requirement specifications

[1] For details please refer to the signed service provision contract ARVODI ("Dienstverleningsovereenkomst ARVODI").

2 Summary

Vodafone's system design process for the ABvM followed some essential principles, which were mainly derived from the Ministry's requirements specification.

Starting from that, the stated goal of the system design process was to find the perfect balance between lowest achievable cost, high reliability, quality of service and sufficient user acceptance. The challenging initial and operational cost goals made it especially necessary to consider innovations in technologies and processes.

Technological innovations mainly concern the utilization of mobile network components for localization (additional to GNSS) and enforcement purposes. No additional DSRC communication is used because the GSM terminal and the network can be utilised for short-range communication. Shifting functionalities to the back-office, along with significant economies of scale on the OBU side, will result in lower costs on the data-acquisition and -processing side. The proposed dedicated ERUC devices range from interoperable EETS OBUs to handset-based approaches which no longer require any additional hardware.

Process innovations mainly concern the migration scenario and charging principles. The latter follow a reverse-charging principle with flat fees collected for every kilometre driven and lower tariffs for predefined roads (e.g. for HWN). This will significantly lower the incentive for fraud or for tampering, in turn considerably lowering the investment and operational cost for enforcement measures. During the three-year migration phase, passenger-car users will have the opportunity to choose between the existing taxation methods and registering under the ABvM scheme using a dedicated device. This transition period allows stepwise and efficient learning and a homogenous growth of the system.

The mileage driven is measured by the dedicated ERUC devices and their GNSS capabilities. Additionally various means for plausibility checks, such as tachographs and odometer readings, fuel bills, vehicle-use questionnaires and the enforcement system will be used to counter manipulations. Frauds will be incur mileage estimations by tax authorities, fines and mandatory keeping of a logbook by the driver. The occasional user scheme (i.e. foreigners) employs OBUs for rent with a certain prepayment amount (e.g. € 50), a certain deposit (e.g. € 10) and a certain service fee (e.g. € 5, not refundable). There is no need for declaration machines and internet bookings.

Implementing these technological and procedural innovations will lead to significantly lower initial and operative costs, without affecting the reliability and the quality of the system. The initial investments within the first 5 years, until the full deployment of the system, will add up to **2.1 billion €** including initial expenditure mark-ups and VAT. The operational costs including initial expenditure mark-ups (IEP = 15 %) and VAT (= 19 %) in the full deployment status aggregate to **584 million €** per year.

Including VAT at the cost but not at the revenue side the ratio of enforcement and operational costs to system revenue is **6.3 %**[2] and therefore misses the requirement of 5 % by 1.3 %. However if VAT is equally considered on the cost and revenue side the ratio of enforcement and operational costs to system revenue is **5.2 %** and therefore just over the requirement of 5 %.

[2] Revenue in the first year of full deployment status is estimated at 8,117 Mio € without initial expenditure mark-ups (IEP) and VAT; Revenue in the first year of full deployment status is estimated at 9,335 Mio € with initial expenditure mark-ups (IEP) but no VAT; enforcement and operation costs are estimated at 426 Mio € without initial expenditure mark-ups (IEP) and VAT.

In addition to this base scenario, the specific costs impacts of some alternative scenarios have been computed. The alternative scenarios analysed are (1) “no foreign user” scheme, (2) “no EETS implemented in the future”, (3) “HGVs and vans tollable for ERUC only” and (4) the "big bang” - no migration scenario.

Finally a risk analysis points out specific political, technological and commercial threats to the project.

3 System concept and high level design (D-3)

3.1 System design principles

The system design process for an appropriate ERUC system for the Netherlands was guided by essential principles resulting from requirement specifications produced by and subsequently discussed with the Ministry.[3]

P 1: The system design needs to be as simple as possible and as complex as necessary

P 2: Initial and operational costs goals must be achieved

P 3: The system needs to be accepted by a broad range of users

P 3.1: Privacy of the user must be respected

P 3.2: All users must be treated fairly and equally

P 4: The system needs to be secure

State of the art core technologies for reliable electronic road usage charging schemes are based on GNSS, GPRS and DSRC, as they are deployed in several countries all over Europe.[4] However, none of these ERUC schemes fulfils the requirements of the Dutch scheme. Of these, requirement 18 "annual cost of operation and enforcement shall not exceed 5 % of the system revenue" is particularly hard to meet with existing system designs.[5]

To achieve the challenging cost goals set by the Dutch parliament, potential innovations in technologies and processes need to be considered. The explicit goal of the system design process is to find the perfect balance between lowest possible costs, high reliability and quality of services.

3.2 Overall system description

Vodafone's system design approach does not comply with the requirements specifications given by the Ministry in some details. The modified requirements that are the basis for the following description of the ABvM scheme are listed in chapter 7 "Comments on the requirement specifications (D-7)".

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[3] Vodafone's comments on theses requirements are described in chapter 7 "Comments on requirements specifications (D7)".

[4] DSRC focused scheme are deployed in Austria, Italy, France and Spain, GNSS / GPRS focused scheme is running in Germany.

[5] E.g. in Germany the operational costs average nearly 25 % of the system revenue, in Austria nearly 15 %.

3.2.1 Fundamental principles of the Dutch ERUC scheme

Charging principles

The principles of the ABvM charges (taxes) follow common taxation principles with the addition of technical means of data collection (dedicated vehicle based devices - see below). An operator collects the tax/charge on behalf of the Government (in the following „public-private-partnership (PPP)" principles), while the user is responsible for providing the data and evidence. At the same time, the user is provided with the means (i.e. dedicated devices) for easy and convenient data collection on the one hand with the process being adequately secure and auditable on the other hand.[6]

A road user is charged based on distance driven on road infrastructure, with special tariffs applied to geographical zones (road corridors or urban areas) and/or time of use. The tariffs allow the government to influence traffic through monetary motivation during certain times to make drivers choose certain zones while avoiding others. From an operational standpoint, these special tariffs would need to be lower than the basic fee collected for every kilometre driven. Thus it would be in the best interest of the vehicle operator to reliably collect location and time data (based primarily on GNSS). The incentive for fraud or for tampering with the equipment would thus be minimized. Following this tariff logic would significantly lower the investment and operational cost for enforcement measures and help save cost while simultaneously ensuring better acceptance of the overall system.[7]

A user is only eligible for discounts for certain geographical zones and/or time of use if he/she forwards usage data based on one of the designated vehicle-based devices. In essence, therefore, everybody will use these devices if

- there is a clear monetary benefit (frequent driving and significant discounts), and if
- the devices are easy to obtain and reliable to operate.

Migration scenario

It is anticipated that after a set of migration phases (see chapter "migration scenario"), the use of dedicated devices for data collection will become mandatory for all domestic users with the exception of classic cars, export cars or other special vehicles. During the migration phases the user of a passenger car can choose either to follow the existing taxation or to register under the ABvM scheme using a dedicated device for data collection.

It is likely that occasional users will register at an early stage. This is because by driving only few kilometres per year, they would save money compared to the existing system. Frequent users will register late because they eventually will

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[6] There is a necessity for user contribution to ensure affordability of the system operation (i.e. minimize cost/revenue ratio)

[7] Economically, a basic distance-based flat rate is not so different from the fuel-based taxation principle. However, a distance-based system means everybody (including foreigners who do not fill up inside the country) can be charged. Also, such a system provides the technical means to adjust the charge to location and time. Environmental aspects (e.g. Fuel consumption of a particular vehicle type) can also be taken into account, namely through the ABvM vehicle registration process (e.g. a vehicle with a lower nominal fuel consumption may pay less and vice versa).

pay more. It is anticipated that the total kilometres driven by users follow a structure similar to that shown in the following figure.

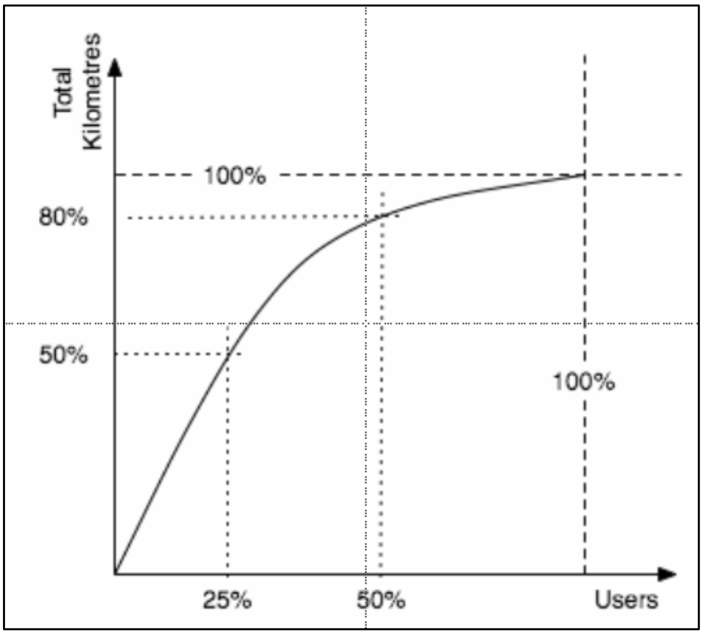

Figure 3-1: Allocation of users and total kilometres driven

For the migration phases this means that relatively many users will register in an early migration phase, producing few total kilometres (with few data for data processing purposes). Frequent road users travelling many kilometres (entailing a large amount of data processing) will register late. In addition, this kind of user is expected to be a friendly one due to benefit he receives.

Data collection

The distance-based fee is a flat rate proportional to the distance travelled on Dutch roads. The user is responsible for declaring the distance travelled within the Netherlands - and possibly outside - based on a dedicated device that calculates the mileage driven using GNSS capabilities. Tachograph or odometer readings are used for plausibility checks of the mileage derived from the unit. The mileage check on the tachograph / odometer will be part of the mandatory annual vehicle check performed by the Technical Inspection Authorities. If there is suspicion that the unit has bee manipulated, the driver may be required to keep a logbook[8]. The driver's logbook may (but need not) be maintained online through a web-based application.[9]

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[8] In case of evidence that the unit was manipulated the mileage will be charged based on an estimation by the taxation authorities.

[9] In essence using either of the dedicated devices will automatically generate a driver's logbook

Audit and enforcement

In case of suspected abuse or fraud, the Dutch Government may make checks similar to or in combination with tax audits. Data from the odometer, tachograph, driver log, fuel bills, vehicle use questionnaires AND the enforcement system or other evidence will be used to verify the distance statements provided by the user.

The enforcement system - based on stationary, nomadic and mobile enforcement units - plays a crucial role as a means to motivate users to adhere to the rules, and to collect evidence for tax/ABvM audits. The principle of the enforcement is NOT to make money but to balance enforcement effort and cost versus reliable charge data and revenue collection.

Dedicated RUC devices

For data collection four dedicated vehicle-based technical means have been designated:

I. EETS OBU
EETS OBU – compliant to the EU directive 2004/52/EC, full interoperability assumed; essentially the EETS OBU needs to support the thin client functionality. Provision of the unit either by the national toll charger or an international EETS provider.

II. Dedicated thin client solution
Thin Client (GNSS/GPRS) with GNSS-based location and time-data collection either fully installed in vehicle or "portable" powered through cigarette lighter; data automatically transferred through GPRS/UMTS controlled by thin-client logic.

III. In-car cradle + use of existing handset
Combination of an in-car cradle and mobile handset, with the cradle providing GNSS data-procession capabilities; GNSS-based location and time-data collection. In addition the cradle allows a fixed/wired connection to the communication device (GPRS/UMTS); GNSS data procession unit connected to communication device (GPRS/UMTS) through a cradle. Use of existing mobile handsets.

IV. GNSS-enabled handset
Mobile handset with integrated GNSS data-procession functionality for GNSS-based location and time-data collection - dedicated application - and automatic data transfer through mobile-data handset functionality controlled by the dedicated application.

Installation, registration and customer care

Each of the abovementioned solutions is available at various facilities either through:

- Telephone, fax or web-based ordering directly from the charge-data collection operator including a registration process, downloading of software (mobile handset - type IV), shipment of device by mail (thin client - type II; or GNSS data procession unit and cradle - type III) or installation by appointment at a service facility (EETS OUB - type I; or thin client - type II), or
- Distribution facilities - points of sales (fuel stations, Vodafone retails outlets, etc.) on-site completion of registration process and distribution of either a thin client - type II; or GNSS data-procession unit and cradle - type III.

The required number and locations of the service and distribution facilities is based on the principle that it should be possible for any user to obtain a vehicle-based device to collect toll data with justifiable effort[10].

All accounts are managed centrally; no monetary value is held within a device! In case of loss or malfunctioning of the device, recorded data is not lost.

Obtaining a thin client - type II - or GNSS data procession unit and cradle - type III - used in combination with a pre-payment requires a minimum prepayment of EUR 50 (toll) + EUR 10 (deposit) + EUR 5 (service fee). The service fee is non refundable.

Thin clients - type II - or GNSS data-procession unit and cradle - type III - may be returned to the operator at service facilities or distribution facilities if

- The user does not need them anymore and opts to collect the deposit and any unused toll charges (pre-payment), or
- The unit is malfunctioning and needs to be exchanged.

Returned units will be tested, refurbished within reason and redistributed by the operator of toll system. Keeping reasonable stock of thin clients at convenient places for users will be the task of the operator's distribution and logistics management system.

In case of loss or non-justified damage, of a device a registered user will need to purchase a replacement.

Payment and billing

As with taxes or utility charges (electricity, gas, water, waste) distance-based fees can be payed for in advance payments (in the case of Dutch citizens) with yearly (or possibly quarterly, monthly) adjustments based on the driver's log (either manual or fully automatically through the dedicated devices). A combination of a monthly down payment (subscriber fee) in combination with user-based charges - similar to telephone pricing - may be possible.[11]

Toll can be paid in:

- Post-payment mode: assumes a valid credit or fuel card with valid bank account, or
- Pre-payment mode: central system account is loaded by paying a certain amount in cash or a valid credit/fuel card.

[10] Justifiable for domestic users would mean that they should have access to a service and distribution facility within their home district at least during normal business hours. Justifiable for foreign users would mean that they should have access to at least a distribution facility on main roads at or close to major border crossings on a 24/7 basis.

[11] Again in order to save cost the point is to balance user convenience versus risk of payment default.

3.2.2 Functional system overview

The functional system overview is based on some technical innovations that will be available for ERUC schemes within the next years with reasonable probability.[12] These innovations mainly concern the utilization of certain mobile network components for localization and enforcement purposes, eliminating the need for DSRC components, neither regarding the OBU nor the roadside equipment (beacon and gantries). An integration of these innovations will lead to significantly lower initial and operative costs, as shown in chapter 4 "Estimation of Costs". Furthermore, implementing these innovations will not affect the reliability and quality of the system.

The following figure shows the functional system overview of a reliable electronic road usage-charging scheme for the Netherlands on basis of utilized mobile network components. The figure will be the reference for processes described later on. [13]

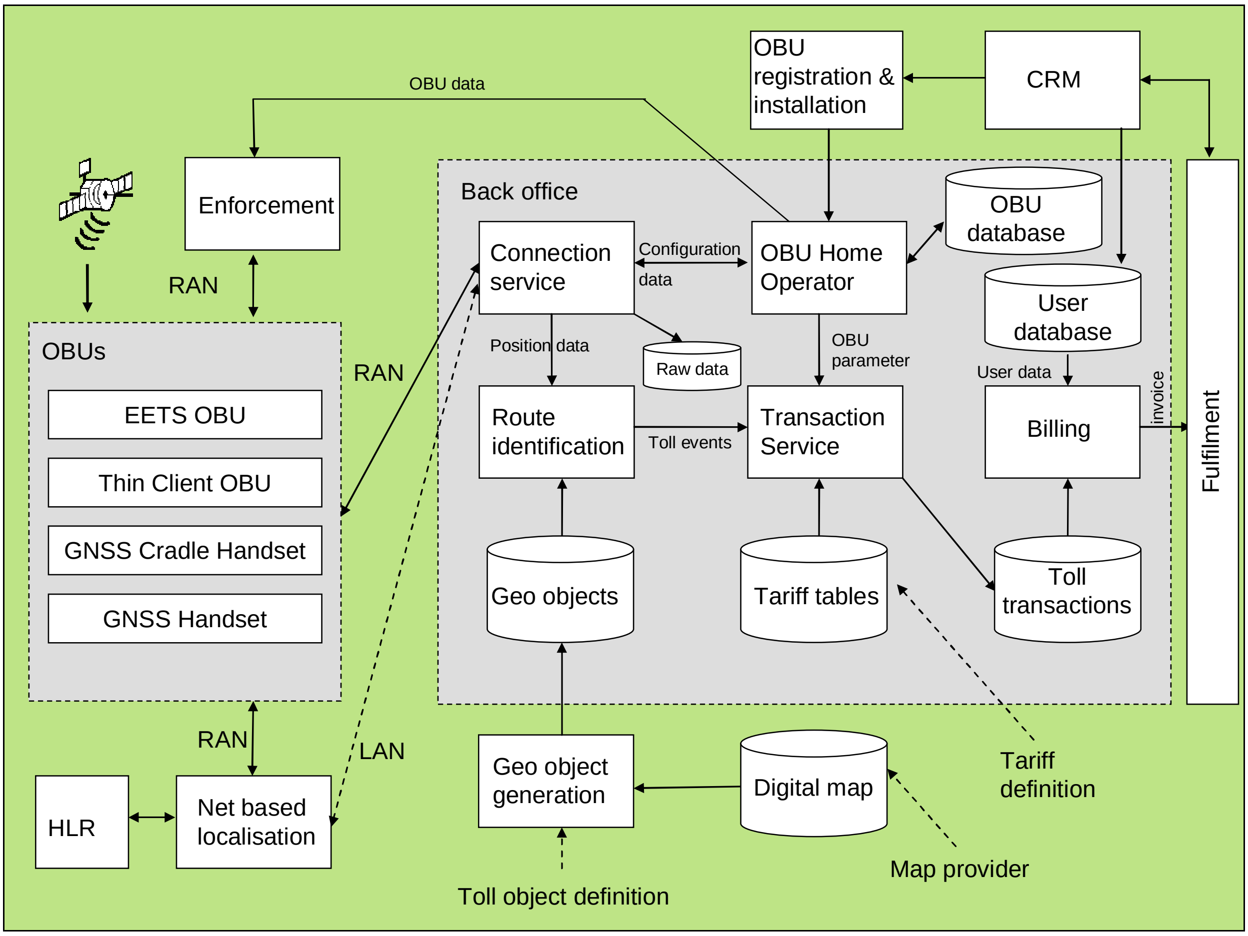

Figure 3-2: Functional system overview of the ABvM ERUC scheme

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[12] The risk of non-availability is assessed in the risk analysis in chapter 6

13 A detailed description of each function and component can be found in the appendix.

3.2.3 Thin-client versus thick-client approach

Choosing a thin- or a thick-client concept is a core decision for an ERUC system.

Pros of the thin-client concept

- No tariff data synchronization issue: All tariff data is stored in the centralized system only and does not need to be sent to the OBUs. New tariff schemes can be introduced without changing the OBU software. This leads to
  - a deterministic behaviour of the charge computation
  - a charge computation that is fair and equal for all users
  - shorter delay times for introducing new or changed tariffs
- No geo-data synchronization issue: All geo data (road network, zone and country definition, toll points definitions) is stored exclusively in the centralized system. No geo data is stored on the OBU. Thus, introducing new geo object types or hierarchy can be done without a software change on the OBU. This leads to:
  - a deterministic behaviour of the road identification. (There are no uncountable numbers of different geo data base versions due to the remote update delay times)
  - a road identification that is fair and equal for all users
  - shorter delay times for changing, adding or removing charged road segments or areas
- No complex OBU software
  - Complex parts of the road identification (route identification and tariff computation) are processed in the back office. This leads to:
    - smaller code size
    - smaller number of potential bug fixes
    - smaller amounts of data for remote software updates (~25%)
- Less effort in changing ERUC scheme
  - only back-office parts need to be updated
  - shorter delay times for activating the changes
  - shorter bug fixing times
  - no restrictions on the type of changes

_ No limitations in memory sizes of

- algorithms: OBUs have only a few Mbytes of RAM, back-office servers allows for up to several Gbytes – if at all required
- geo objects: OBU has limited flash file system space, back office components do not have any real limitations

Cons of the thin client concept

_ No immediate feedback to user about charge or charged objects

- only possible on user's request
- but no user distraction during driving
- DSRC does not offer it, either

_ Higher enforcement effort

- No real-time operation in back office
- Enforcement needs to perform its own route identification with position data from OBU
- more data transfer OBU-> enforcement processing
- but enables a two-stage enforcement:
    - first, check of OBU status
    - only if status check fails, verification of OBU data

_ Data privacy issue

- needs approval of data protection official
- compliance with national data-protection act and related EU directive

3.2.4 Specification of the dedicated devices

Different types of users are covered by the ABvM scheme. A distinction can be made between international and regional drivers, frequent and occasional users, foreign and national drivers. To provide cost- and function-optimised devices, the following groups of devices should be offered or supported by the scheme. The RUC-specific software installed on the different units should be the same version in order minimise maintenance costs.

The devices – an overview

- EETS device
- Dedicated thin-client device
  - Fixed installed version
  - Portable version
- GNSS cradle + mobile handset
- GNSS-enabled mobile handset

All solutions use the same RUC software modules such as positioning, approximation, security, and communication. The board support packages (BSP) are different because so are their hardware components. Except for the EETS unit, all devices do without a DSRC device. The advantage is that a line of sight, as required by DSRC for communication purposes, is no longer necessary. As a result, the unit can be placed anywhere in the vehicle and is not restricted to a position on the dashboard or the windscreen. High-sensitivity GNSS receivers support this free choice of the installation location.

In addition, the thin client devices do not include a display. Though this prevents the user from accessing cost information directly, it also helps to reduce costs and driver distraction. To provide the user with cost information, a web-based account or the mobile-phone based account can be used.

There are a number of additional developments that will have an impact on the device design:

- Introduction of new battery technologies, Li-Polymer will be the mass-market battery in handsets from 2008 on (Wh/kg 400 compared to Li-I with Wh/kg 140). Fuel cells (Wh/kg 4000) are expected to be available by 2012 and will solve performance problems)
- Built-in GNSS capabilities
- Availability of Galileo

EETS device

The EETS device is one that fulfils all requirements of a pan-European, fully interoperable unit supporting all existing European RUC schemes. The RCI project led by ERTICO is currently specifying such a unit. The Dutch scheme will only necessitate parts of the functionality offered by the unit.

The EETS device is recommended for drivers travelling extensively throughout Europe and requiring a device that fulfils the requirements of DSRC systems and in addition those of the German ‘LKW Maut System’. Core components of the unit are:

Module	Mandatory	Optional / not requested	BOM relevant	Remark
GNSS receiver	x		x	
Comm module	x		x	
External GNSS / Comm aerial	x		x	
DSRC module	x		x	
Gyro / Motion sensor	x		x	
Memory	x		x	4-16 Mbyte
SAM	x		x	
Display	x		x	
2/3 Buttons	x		x	
LED	x		x	
Buzzer	x		x	
Link to CAN / Most bus	x		x	
Fixed power supply	x		x	

Figure 3-3: Core components of the EETS device

Dedicated thin-client device

The dedicated thin-client device will be available for frequent and occasional (including foreign) users. Both variants are constructed in the same way to increase the number of similar devices, achieve economies of scale and thus reduce the target costs especially for occasional users units that are required in lower numbers. The only difference in design is the power supply. The frequent-user device is linked to the vehicle’s power supply, the occasional user device is a nomadic device that is battery-powered and needs to be re-charged after approximately 400-2800 kilometres.[14]

The dedicated thin-client device is tailored to the Dutch requirements and, in contrast to the EETS device, does not support all European RUC requirements. Its main components are:

[14] The calculations are contained in the appendix number 8.2

Module	Mandatory	Optional / not requested	BOM relevant	Remark
GNSS receiver	x		x	
Comm module	x		X	
External GNSS / Comm aerial		x	X	
DSRC module		x		
Gyro / Motion sensor	x		X	Motion sensor is sufficient
Memory	x		X	1-4 Mbyte
SAM	x		X	
Display		x		
2/3 Buttons		x		
LED	x		X	
Buzzer	x		X	
Link to CAN / Most bus		x		
Fixed power supply	x		X	

Figure 3-4: Core components of the dedicated thin-client device

GNSS in-car cradle + mobile handset

The basic idea of this approach is to incorporate mobile handsets already being used by the clients. The GNSS in-car cradle provides the core RUC functionalities of position, timestamp and memory to store the data derived from the GNSS receiver. The handset acts as a pure communication device which is linked physically or wirelessly to the GNSS cradle.

Whether the handset needs to be on board during every trip depends on the charging policy. To ensure consistent data transfer to the back-office, it would be sufficient to connect the two modules only at defined intervals. In case the user forgot his mobile device, he could still use his car without being in breach of the rules of the scheme. This clearly improves convenience for the user.

Without a communication device, the OBU cannot be triggered by the picocell enforcement unit. This would lead to higher enforcement costs because more enforcement transactions would need to be dealt with manually in the back office. It is therefore recommended to declare the communication module a mandatory part. The RUC software is identical to the software in the dedicated thin-client solution. In case the user did not take the handset with him, the GNSS cradle would still log the position and time information and allow an uninterruptible distance measurement.

Module	Mandatory	Optional / not requested	BOM relevant	Remark
GNSS receiver	x		x	
Comm module	x			Use of existing handsets
External GNSS / Comm aerial		X		
DSRC module		X		
Gyro / Motion sensor	x		x	Motion sensor is sufficient
Memory	x		x	1-4 Mbyte
SAM	x		x	
Display		X		
2/3 Buttons		X		
LED	x		x	
Buzzer	x		x	
Link to CAN / Most bus		X		
Fixed power supply	x		x	For the cradle

Figure 3-5: Core Components of the GNSS cradle and mobile handset

The approach would become even more attractive for the user if it included hands-free car-kit functionalities.

GNSS-enabled mobile handset

With the introduction of Galileo by 2010/11, it is expected that the availability of handsets with integrated GNSS will increase. Under the migration scenario, a deployment would not be required before 2014/15. The aim therefore is to enhance the handsets with the RUC-specific software modules to make them compliant with the system requirements. This means the system operator would be able to use an existing infrastructure, but would need to provide the necessary software. The hardware costs are not included in the business case.

It would be the user's responsibility to have the device with him when using the car and to start the RUC application. Near Field Communication could be a key technology to make this process very convenient. An NFC-enhanced device could become the future 'transportation device', supporting RUC and public transport schemes and providing identification, authorisation and billing capabilities.

In addition, the NFC component could help to link the vehicle (plus account for billing) and the mobile phone, in the case of several users, with different phones, using the same vehicles (e.g. rental cars).

In the case the user does not have the device with him, he will not be able to provide automatic distance measurement. Although the likelihood of the user forgetting his device is low, it would still not be acceptable that not having the device with him meant that he could not use his car. Therefore, convenient alternatives need to be made available for the driver. These should offer the opportunity

- to attend to the occasional user scheme and use of the dedicated device
- to purchase the right to travel for a defined period of time and a maximum of kilometres, via a call centre. The ratio price per kilometre will be on a level that this variant isn't attractive to the user and misuse is avoided. The amount of kilometres linked to a specific period of time should be in the range of the speed limit on motorways and therefore assumes distance travelled under ideal driving conditions – which in reality hardly can be achieved.

In both cases the user would be required to bear the additional cost.

The device's main components are:

Module	**Mandatory**	**Optional / not requested**	**BOM relevant**	**Remark**
GNSS receiver	X			Functionality provided in high-end handsets
Comm module	X			Functionality provided in high-end handsets
External GNSS / Comm aerial		X		
DSRC module		X		
Gyro / Motion sensor	X			Motion sensor is sufficient
Memory	X			1-4 Mbyte required, handsets will offer 100 Mbyte and more
SAM	X			
Display		X		
2/3 Buttons		X		
LED	X			
Buzzer	X			
Link to CAN / Most bus		X		
Fixed power supply	X			

Figure 3-6: Core components of the GNSS-enabled mobile handset

An additional benefit of the GNSS-enabled handset solution is that there would be no installation costs for the user.

Both handset-based approaches include a high-resolution display that can be used for providing RUC-specific information.

3.3 Description of processes

3.3.1 Primary processes

3.3.1.1 Measurement and recording of road usage

The measurement and recording of road usage under the proposed thin-client approach is one of Vodafone's focus areas. Accordingly, it is set out in more detail in the following.

3.3.1.1.1 Description of data processes

The following figure shows an overview of the data flow and processes of recording and measuring of road usage:

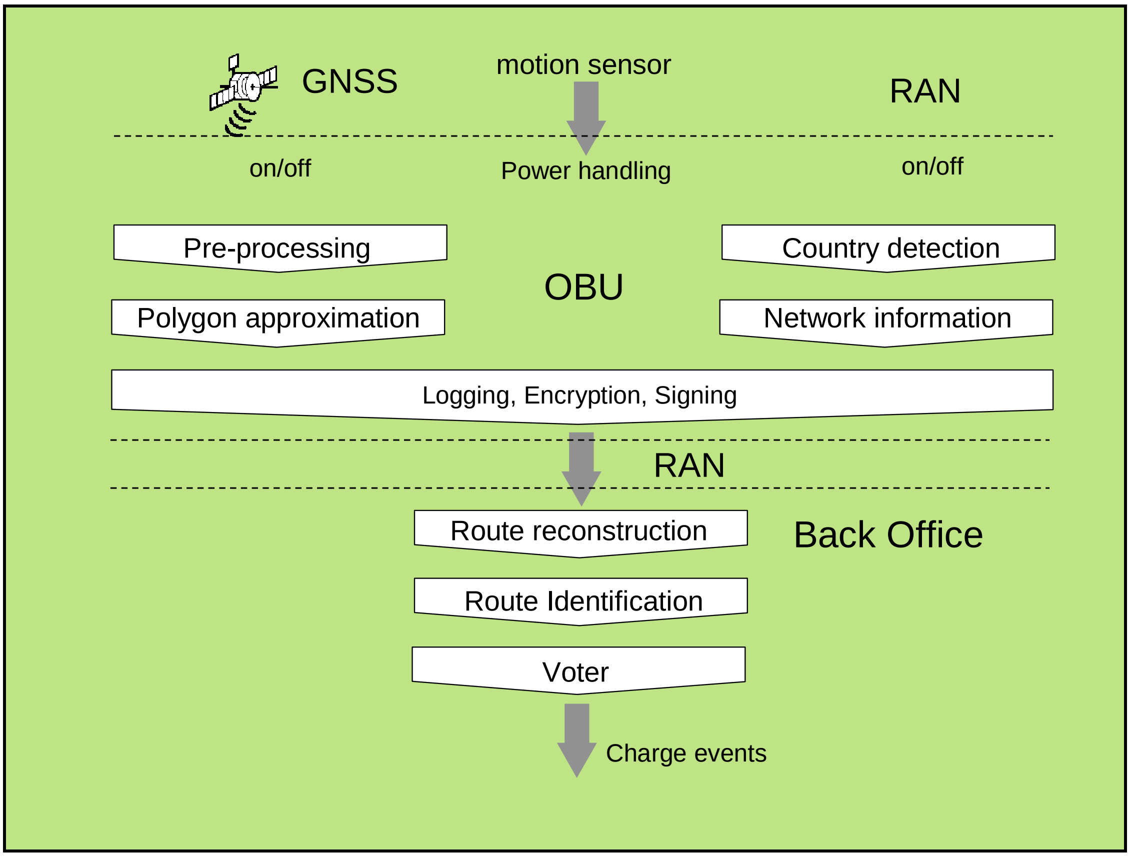


Figure 3-7: Data flow and processes of recording and measuring of road usage

GNSS-pre-processing

The module performs plausibility checks based on speed and quality for every incoming position marked as valid by the GNSS receiver. Outliers and implausible data will be filtered off, thus increasing the confidence level of the GNSS data. The static navigation mode of the GNSS-receiver is overlaid with a virtual static navigation mode realized in software in order to further reduce noise while not moving.

Country detection

A thin-client OBU contains neither a route identification module nor a digital map. Thus, using data from the GNSS receiver, the OBU cannot determine the current country. In order to avoid data exchange over a roaming network and to reduce power consumption outside the Netherlands (increasing battery runtime), the foreign occasional user's GNSS receiver can be switched off. In the case of a Dutch user, the GNSS data will still be used to determine the total distance travelled. The GSM module will be used for rough country detection with the correct identification being performed in the back office using data derived from a digital map. As long as a Dutch network can be seen in the network list, the OBU will assume that it is in or near the Netherlands. As soon as the last Dutch network disappears, the preset action will be taken as discussed. This approach is feasible as the network range is always larger than the country dimension. It will also work if it the device needs to look for several countries.

Polygon approximation

For an efficient route reconstruction using minimal amount of data in the back office, GNSS data is reduced using a polygon approximation. The goal of this approach is to convert position stamps of random-shaped curves into straight lines. The straight lines are either specified by the start and end points or by start point, angle and length (vector). The main part of the algorithm is to detect where to locate the start / end points of the straight lines. A new line starts when the deviation from a regression line exceeds a given threshold. The regression line is constructed from all position stamps belonging to one line. After finding an end point, a new regression line is constructed. The threshold needs to be harmonized with the geo-object generation to provide optimal identification results. In addition there will be a special handling for areas without GPS coverage (ignore or linear connection). The table in Appendix 8.5 shows the influence of the deviation from the regression line on the reduction of GNSS positions for an exemplary route.

Data Logging

In order to allow on-the-spot enforcement without waiting for data-processing in the back office – where batch-mode operation may mean results are produced a couple of hours late - GNSS data will be stored in the local persistent memory of the OBU. During extended enforcement the data will be read from the OBU and projected onto a digital map. The data is structured in a ring buffer in order to always have the most current data available. The size of the ring buffer depends on the amount of data that should be available for the enforcement. (1kByte of data will contain data of at least the last half hour). The data needs to be protected against manipulation either through encryption or signing. The data may be accessed locally or via a remote connection.

Network information

Information from the mobile network, e.g. cell-ID patterns, will also be recorded and stored in the OBU's local persistent memory. This information can be used as required during the extended enforcement process to verify the plausibility of the GNSS data. Thus, manipulations of the GNSS receiver can be discovered. The data's structure mirrors that of the stored GNSS data." The data may be accessed locally or over a remote connection.

Power Handling

The OBU will not be connected to the "ignition on" signal of the vehicle. Therefore a motion sensor will be necessary to detect the movement of the vehicle. If a movement is sensed, the OBU will be switched on and, after a specified time without movement, the OBU will be switched off. It will also be possible to incrementally switch off components before shutting down the OBU (e.g. GPS-receiver after time t1, then GSM-module after time t2, etc...). This will save energy in battery-powered OBUs operated by occasional users.

Communication

The resulting data will be packed into small telegrams and pushed into the communication queue. The communication to the back office will be initiated at fixed intervals or whenever there are a certain number of telegrams in the queue. The data in the queue will only be deleted once the acknowledgement from the back office has been received. The response from the back office may also contain some commands to the OBU (e.g. software update or new configuration set available).

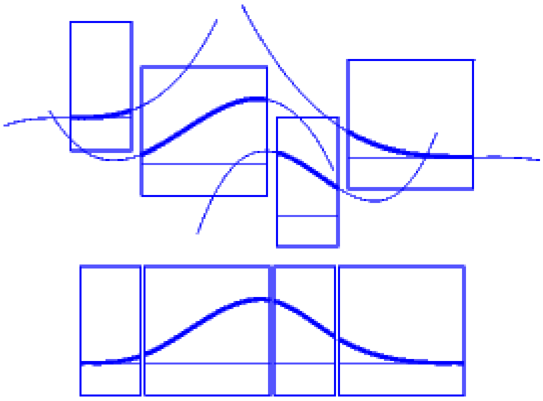
The data is transferred via a cellular network.

All telegrams that contain sensitive data (e.g. positions) will be signed before encryption. This will prevent manipulation of the data. The signatures will be stored locally on the OBU and will only be used on request as part of extended enforcement processes (cp. network information data).

Spline interpolation

A sophisticated way to interpolate between two position stamps is to use splines. A spline is a stepwise-defined polynomial of a given order. Usually a third-order polynomial is used leading to cubic or fourth-order splines. A spline for N position stamps is made from N-1 polynomials (see below). These polynomials start and end on positions stamps (knots), the first derivative for adjacent polynomials at a knot being equal.

Using the spline interpolation approach, the route travelled can be reconstructed. Under certain circumstances, however, a linear interpolation will be applied (e.g. when recovering data from areas without GNSS coverage). Following interpolation, virtual GNSS positions can be generated assuming a velocity harmonized with the geo-object generation. All further processing – route identification – voting – charging – is similar to a thick-client approach using these virtual positions.



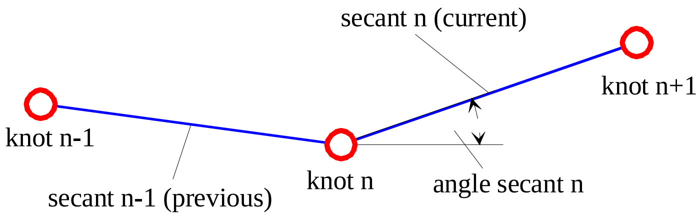


Figure 3-8: Spline interpolation

In order to reach an optimal reconstruction (no overshooting), the given knot angles during spline construction can be one of the following:

- angle provided by the GNSS receiver (route)
- angle of the secant, either current or previous
- length-weighted average angle of the two joining secants at the knot

Route identification

The route identification (RI) module looks for geo objects that are referred to by the given coordinates with each valid position. The algorithm is capable of identifying basic geo objects according to the ISO pre-standard 17575 – zones, corridors and virtual gantries. Geo domains (e.g. countries), corridors (e.g. motorway segments) and zones can be identified in parallel for increased performance and hierarchy-building.

In order to increase performance, the search for geo objects is done on hash-files. The identification process relies on GNSS data only. Thus a certain level of confidence with a certain number of GNSS positions needs to be reached before the geo object found can be identified with certainty.

All road sections in the Netherlands that have a tariff other than the basic will be modelled as corridors. Urban charging areas (see variant IV, e.g. city congestion charging) will be modelled as zones. The Dutch national border will also describe a zone-type geo object that is distance-based. This means that as long as this geo object is the valid one, all distance travelled will be accumulated. Charging points (see variant Ia, e.g. for bridges or tunnels) will be modelled as virtual gantries. Because it supports standard geo objects, the RI-algorithm can accommodate both existing and future RUC systems

The distance travelled can be determined either via the length of the secant between two positions or in a more sophisticated way using the length of the spline. Each valid fix with linear interpolation between two consequent GNSS fixes is used to measure distance. This leads to a systematic speed- and course-dependent error. Assuming the course between two fixes can be approximated by a circular arc, only the chord will be used for distance measurement. The measured distance will always be shorter than the real distance travelled. Since there is no general algebraic solution for determining the length of a cubic spline, a numerical integration algorithm needs to be used. The most efficient numerical integration method for third-order polynomials with respect to accuracy and computational load is the Gauss-Legendre Quadrature. The table in appendix 8.6 shows a summary of distances travelled during a real arbitrary trial with different scenarios.

Voter

The task of the voter module is to check the validity and hierarchical order of geo objects identified by the route identification module. It also prevents double charging on power-on. As a result the voter module will generate an event every time a valid geo object needs to be charged, or for distance-based zones when a certain distance has been travelled. This event will be used by the toll-transaction processing to compute the charge.

The route identification and voter will be processed in batch mode for a better load balancing. However, for enforcement purposes or in the event of an occasional user OBU returning, real-time processing will be necessary. These requests need to be marked and will be prioritized by the load balancing.

As a result of this stage, the direct relationship between position and OBU is lost, only the identified geo objects remain (cp. thick client).

Toll transaction processing

During the toll transaction processing all charge events will be mapped onto the applicable tariffs. This means computing the charges for the single geo objects or as an alternative computing the total charges for the different tariffs. All charging data is referred only to the OBU-ID.

3.3.1.1.2 Calculation of data amount

The following table summarizes the telegrams for a thick- and a thin-client solution. The telegram size comprises only the raw data. However, the total number of bytes includes header (TCP), acknowledgement from the back office and a percentage of lost messages. The table is based on the average numbers for users registered to the ABvM scheme and shows the values for one average user per year.

Type of telegram	size (bytes)	thick client (number / total bytes)	thin client (number / total bytes)
event log	1494	21 / 36912	21 / 36912
Status	235	258 /115291	258 /115291
position data	1496	5 / 8605	589 /1013920
geo data update	404	192 / 120512	0/0
configuration	232	1 / 444	1 / 444
software update	265844 (thick), 88615 (thin)	0.5 / 134358	0.5 / 44857
toll data	229	3194 / 1409689	0/0
Ephemeris	52094	52 / 2722627	52 / 2722627
key	342	258 / 143137	258 / 143137
Signature	346	1 / 560	1 / 560

Figure 3-9: Telegrams for thin- and thick-client solutions

A description of the telegram types can be found in the appendix 8.7.

Considering a number of about 8 million OBU users, a monthly data volume of 148kBytes or 331kBytes can be estimated for a thick-client and a thin-client solution respectively. This amount of data will not cause any capacity issues. For details, see the following summary table and the appendix listing the parameters used.

	thick client	thin client
total transferred data per user per year (bytes)	1825812	4077749
total transferred data per user per year (kbytes)	1783,02	3982,18
total transferred data per user per month (kbytes)	148,58	331,85
total transferred data per year (Gbytes)	14428,06	32223,48
total transferred data per month (Gbytes)	1202,34	2685,29

Figure 3-10: Data volumes of thin- and thick- client solution

3.3.1.1.3 The impact of tariff scenarios on route identification

The following table shows an assessment of the effort necessary in the RI-module to realize the different tariff scenarios described in Tariffscenariosforphase2assignmentsv1.0.doc.

Scenario	**Identification capabilities**	**Computer load**	**Realization effort**	**Maintenance effort**	**Risk**	**Required data**	**Testing effort**
1	Netherlands as distance-based zone	low	Low	very low	very low	no road network digital map	low
1A	Netherlands as distance-based zone + max. 50 virtual gantries	low	low, but with hierarchy	low	low	no road network digital map	low
2	as in scenario 1	low	Low	very low	very low	no road network digital map	low
3	Netherlands as distance-based zone + corridors identification	medium	High	high	high	accurate digital road network map	high
3A	as in 3 + zone identification	high	high, with hierarchy	high	high	accurate digital road network map	high
3B	as in 3 + 3A + virtual gantries	very high	very high, two hierarchy levels	very high	very high	accurate digital road network map	very high
4	as in 1A, but uses zones instead of virtual gantries	low	low, but with hierarchy	low	low	no road network digital map	medium

Figure 3-11: The impact of tariff scenarios on route identification

Note: Risk for scenario 3 will become very high if second-level roads need to be distinguished. In addition the efforts for realization, maintenance and testing will also become very high in this case.

The proposed identification approach based on geo objects specified in the ISO pre-standard can handle all described tariff scenarios with different levels of risk and effort. Higher efforts result in higher costs for software implementation, geo-object generation and field-testing. The maintenance effort increases with the number of required geo objects.

3.3.1.1.4 Privacy concerns

In terms of the thin-client approach, privacy means that it must not be possible to establish a relationship between position traces and customer data at any time.

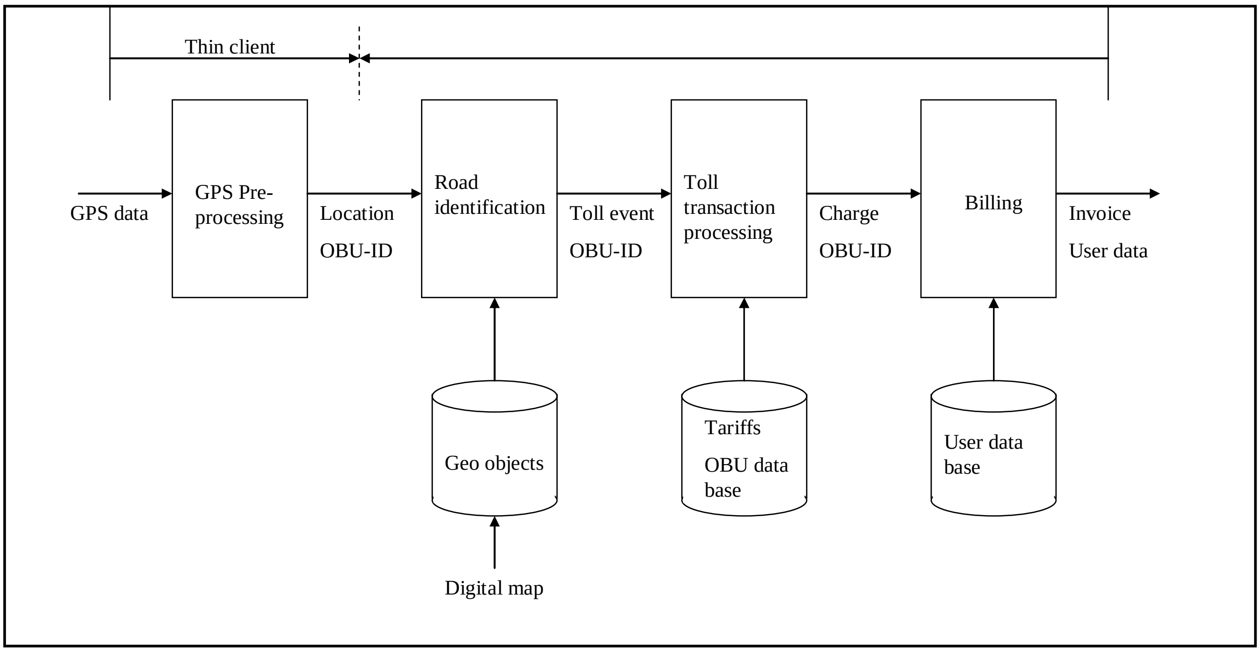


Figure 3-12: Overview of data exchange through entities

The proposed thin-client approach ensures that no entity will have the ability to map position traces to user. The data path is as can be seen in the above figure and is described in the following.

- Thin-client OBU:
  On the OBU, the position traces are obtained from the GNSS receiver. Accumulated data is sent to the back office with reference made only to the OBU-ID. The data is encrypted and a signature available from the OBU. This allow a verifications of the data integrity in cases of suspicion.
- Back office – road identification:
  The road identification done in the back office uses the position traces to derive the parts where toll charges apply and generates toll events based on time, distance and type of road. This data again refers to the OBU-ID only.
- Back office – toll transaction processing:
  The toll transaction processing computes the charge using tariff tables based on the toll events and the vehicle data stored with the OBU-ID in the OBU data base. The charge does not contain any position information and refers to the OBU-ID. The charge is split up by mileage travelled on different road types. This data is then passed to the billing entity.
- Back office – billing entity:
  Using the user database, the OBU-ID is mapped to the customer who is to receive the invoice. The invoice will not contain any detailed position information. In case the customer requests a more detailed invoice, section information

can be added, making it possible to identify the driven route. (This optional feature might be compared to the itemised bill in telephone service).

In order to ensure privacy, the billing needs to be processed by an entity that is separated from the other back office components. It is also a requirement that there be two separated databases, one for the vehicle parameter referenced by the OBU-ID and another one for the customer-related data, also referenced by the OBU-ID. All data exchanged between different entities needs to be encrypted with changing keys and signed for data integrity purposes. Position traces received from the OBU may only be stored in the raw database referring to the OBU-ID.

Compliance with the EU Directive

Since the thin-client approach involves the processing of personal data – information related to an identified person - , it needs to comply with the EU directive 95/46/EC and the local data protection act. Since no single entity has access to both user information and collected data, there would be no data protection issue to begin with. There is, however, a potential for misuse of data either by higher instances (e.g. government) or by "crackers" illegally gaining access to both sets of data. Thus, ensuring the compliance with the data protection act and the EU directive would increase the acceptance of the system.

Its main provisions are as follows:

_ Only data that is necessary to perform the task may be collected and processed (Article 6.1.b and c)

  - Compliant, since only a minimum set of data will be sent to the back office to reduce data load on the network.

_ Data may only be stored as long as it is required to perform the task, except for statistical and historical use (Article 6.1.e).

  - In order to fully comply with this requirement, it could be necessary to delete the raw position data after processing, thus losing a part of the evidence needed to deal with user complaints (cp. thick client). As an alternative, temporary OBU-IDs (similar to TMSI in mobile network communication, which was introduced so as not to allow generation of customers' movement profiles).

_ Inform the user that personal data will be stored (Article 7)

  - Completed during registration

_ Inform the user about the data and the processing of the data (Article 10)

  - Completed during registration

_ Enable access to the data for the user on request (Article 12)

  - To be realized over a web interface for instance.

_ Ensure the validity (integrity and security) of the collected data (Article 17)

- Compliant since data will be signed and encrypted

_ Approval of the data protection official for the proposed whole data processing (Article 18)

- To be done during development of the system

3.3.1.1.5 Price of digital maps

A thin-/thick-client solution requires having geo objects derived from a digital map or the digital map itself on the OBU. In this case, royalties per OBU need to be considered. These will be in the range of 25 to 50 cents per unit and year.

For the thin-client approach, only one instance of geo objects or of the digital map is required in the back office (as well as some backup databases). In this case, only one licence per database will be necessary. Since geographic data needs to be updated continuously, the royalties or licence fees accrue on a yearly basis. Geo objects will need to be implemented only for those parts of the road network for which the fees differ from the basic one. It is assumed that this will be a minor part of the Dutch road infrastructure. To derive accurate geo objects, it is recommended to gather and up-date the requested data through a specialised service agency. State-of-the-art digital map data provided by the digital map manufacturers might not fulfil the RUC quality requirements and may need to be improved on. Also, in case of infrastructure changes, the modified data needs to be delivered on-line.

An alternative business model could be based on services provided by a governmental land surveying authority. This was an approach developed in the U.K., where Ordnance Survey exists (www.ordnancesurvey.co.uk) – a local map provider half owned by the state. The government pays a yearly lump sum and in return, is granted free access to use digital map data in all state-initiated projects.

3.3.1.2 Determination of costs

The toll events generated by the voter will be mapped onto tariff tables depending on road type, vehicle parameters and time. The data will all be referenced via the OBU-ID to ensure data privacy. The transaction service will use the tariff database to allocate the applicable tariff to the different geo-objects – referenced by their unique IDs.

All proposed variants (I-IV) can be realized leveraging this approach. All tariff changes will be logged in order to validate and recompute the determined charges in case of user complaints. The charged toll events will be stored in a separate database that will be accessed by the billing entity. Due to the centralized tariff data storage, tariffs can be changed at short notice without discrimination. However, the user needs to be informed before entering the changed toll object.

3.3.1.3 Billing and payment

The charging principles for a tolling operator are very similar to mobile operator billing, providing a large number of possible synergies when using the mobile operator billing infrastructure for the ABvM rating and billing process. ABvM requires e.g. prepaid and post-paid billing, variable rating parameters, flexible billing solutions, invoicing, clearing and security, all of which are available as part of mobile operator's billing infrastructure.

Prepaid

The prepaid concept is well-known and widely used within the mobile operator business, including the prerequisites to make prepaid billing work, such as:

- real-time rating
- various methods of account balance top-up using various payment providers (vouchers, credit card, direct debit, electronic banking)
- low-balance notifications
- various methods of balance inquiry

Prepaid as opposed to post-paid is generally used for controlled use and for occasional users or in cases where a post-paid subscription is not allowed because of credit issues,.

Rating

In order to provide the billing entity with monetary values, the toll events data (containing time, road type and distance information) will be combined with the vehicle data and tariff tables, calculating the price for the specific event. The key in this data stream is still the OBU-ID, so no-user specific information is available here. Large similarities can be seen in tolling and mobile operator rating parameters:

- there is a fee per distance (mobile operator: usage amount)
- charge depends on vehicle class (user price plan)
- charge depends on time of use (same)
- charge depends on road type (service used)
- lower tariffs can apply e.g. for roads under maintenance or during certain periods (discounts based on various parameters)

Billing & invoicing

The various rated events for each individual user are collected and presented on a paper or electronic bill. A group of users (e.g. a company) can be combined in one billing account and billed accordingly, even with several billing entities (branch offices).

Besides the usage charges, recurring charges (periodic “subscription” fees) and one-time charges (like registration fee or equipment purchase) can also be billed.

Invoicing can be done on a flexible fixed period (monthly, quarterly, yearly,…) by means of paper or electronic (e-mail, online, CD) invoices.

Reporting

Supplementary reporting possibilities are available based upon (prepaid and post-paid) billing information, using the different parameters as provided by the billing streams.

In addition, reporting tools can be provided to (corporate) users, to create their own usage reports, based upon the (electronic) billing data.

Security

For fraud prevention, existing tools and procedures are used to detect fraudulent (excessive) use or other abnormal behaviour.

Payment

The preferred payment method (for post-paid users) is direct debit, since this is used for the majority of post-paid mobile customers. Other payment methods are available (credit card, electronic banking), but are mainly used for prepaid customers.

Other

In addition to the items mentioned above, payment collection (disputed, refused payments) and billing error handling are also established parts of the mobile operator billing process.

Clearing with TSP

One of the main privileges of a tolling operator is clearing with the TSP. In performing this, all registered and priced transactions are used as a basis for charging. All tolling receipts are transferred to a trust account of the government together with the agreed service charges for the entire operation (including any charges payable to service providers).

The government itself has permanent access to statistical data for monitoring purposes. In addition, regular audits by the government or one of its agents (such as an audit firm) may be allowed access to all data and processes. Even random tracking of charging data all the way to billing with the TSP is ensured through appropriate logs and audit processes which cover both the relevant data and applicable signatures (to ensure authenticity).

Since under normal operation funds are collected only in case of prepayment (if this is not outsourced as well), post-payment streams are collected from very different payment service providers (PSP) or from an EETS service provider. Note: The EETS is itself backed up by different PSPs who assume the payment guarantee.

Clearing is executed on the base of the transmitted priced transaction, which enable the service provider both to bill his registered customers and also to provide for customised and itemised bills. Appropriate commission rates and payment deadlines will be agreed by service provider and tolling operator (and eventually the TSP). Only where transactions are generated by a car which has been blocked by the service provider (grey or black list) at the time of transaction, may the transaction be refused.

3.3.2 Secondary (supporting) processes

3.3.2.1 Registration, installation and customer care

In order for the ABvM scheme to function on a convenient and non-discriminating basis for ALL users, there need to be sufficient options for interaction between users of the ABvM systems and the operator(s) of the system.

The following modes of interaction - or customer service - are anticipated:

- Registration of user, vehicle, mode of payment and on-board equipment data:
  All users, vehicles and on-board equipment need to be registered to the ABvM scheme and to choose between pre- or post-payment in order to be able to legally use the road system.
- Purchase of on-board equipment:
  Different types of on-board equipment are available for all users. The user is free to choose which kind of equipment best suits her/his road usage behaviour. All on-board equipment must be obtained at dedicated locations in order to ensure registration and qualified installation service if required.
- Installation of on-bard equipment:
  On-board equipment such as the frequent user OBU or the GNSS cradle need to installed in the vehicle at dedicated, qualified service centres. As a minimum, installation requires connection of the equipment to the vehicle's power system.
- Re-loading a pre-payment account:
  Users are free to choose between pre- and post-payment to settle charges under the ABvM scheme. If a user decides to use pre-payment or does not qualify for post-payment , he needs to set up a pre-payment account (see point 1 above) during initial registration to the ABvM scheme. Using the road system will result in deduction of charges from the pre-payment account, eventually requiring the road user to reload the pre-payment account balance.
- Obtainment of information about the ABvM scheme:
  Providing information about the ABvM will be necessary to achieve adequate user acceptance of the scheme. Information should be provided about the scheme principles, technology, registration and customer service.
- Inquiries about cost and invoices related to the ABvM scheme:
  The ABvM charge collection will use invoicing processes to inform users about charges due related to the usage of roads. These invoices may be paper-based or electronic versions. In any case, users may have questions regarding these invoices.
- Inquiries about all aspects of on-board equipment or modes of payment:
  On-board equipment may cause difficulties in operation or may fail outright. Questions may also arise relating to pre-

or post-payment. In any case, the user needs to be able to obtain qualified information relating to all issues arising from the use of on-board equipment or form of payment.

- General inquires about the ABvM scheme:
  There may arise general questions concerning the ABvM scheme. These questions need to be addressed to the best degree possible as well.
- Barring:
  For stolen equipment or for credit risk reasons, several options for barring the OBU can be considered. One possibility is to simply bar the SIM included in the OBU, which will make the OBU ineffective. This would be detected through the enforcement procedures as a vehicle without OBU. On the other hand, it would also be possible to flag the OBU-ID with the barring reason in the back office and use this data in the enforcement process, thus providing a possibility to detect stolen OBUs. In that case, measures must be taken to avoid billing of OBUs reported as stolen.

The following locations of interaction are anticipated to the ABvM scheme

Points of sales (PoS)

These are physical installations mostly co-located at e.g. existing petrol stations or mobile phone sales outlets etc. By being located along the road system, existing petrol stations are easy to access and are usually ideally suited (parking, manned store) for all modes of interaction. It is anticipated that the following modes of interaction will be provided:

a. Registration of user, vehicle, choice of mode of payment and on-board equipment data,
b. Purchase of on-board equipment,
c. Re-loading of prepayment accounts,
d. Obtainment of information about the ABvM scheme.

To register users at the PoS, the appropriate registration module of the billing system can be used. The process includes user details registration and user equipment registration (including equipment charging). In addition, for post-paid users, a credit vetting procedure is part of the registration process. As part of registration, user data must be stored in the billing system (with OBU-ID) and the equipment must be registered in the OBU database.

Service Centres

Service Centres will deal will all technical aspects of on-board equipment and its installation into vehicles (see point 3 of modes of interaction). These service centres will be equipped and certified by the ABvM scheme operator, who will also provide training of staff.

Call Centre

The call centre will host service agents able to address all information aspects of the ABvM scheme in several languages (at least the official EU languages). In particular, the call centre agents will be able to address the following modes of interactions:

e. Obtainment of information about the ABvM scheme,
f. Inquiries about cost and invoices under the ABvM scheme,
g. Inquiries about all aspects of on-board equipment or modes of payment,
h. General inquiries about the ABvM scheme.

For billing- and registration-related issues, the customer management module of the billing system can be used as the support tool for CRM agents. For technical problems (as long as they relate to the mobile network), the existing technical support tools can be used. For the other items, the appropriate information must be provided to the knowledge systems.

ABvM Central Service Centre

The ABvM central service centre can deal will all modes of interaction at a central location that is sufficiently convenient for a large number of users. This centre will also provide training facilities for all service agents (PoS, Service Centres, Call Centres) under the ABvM scheme

The following figure shows the relationship between modes and locations of interaction.

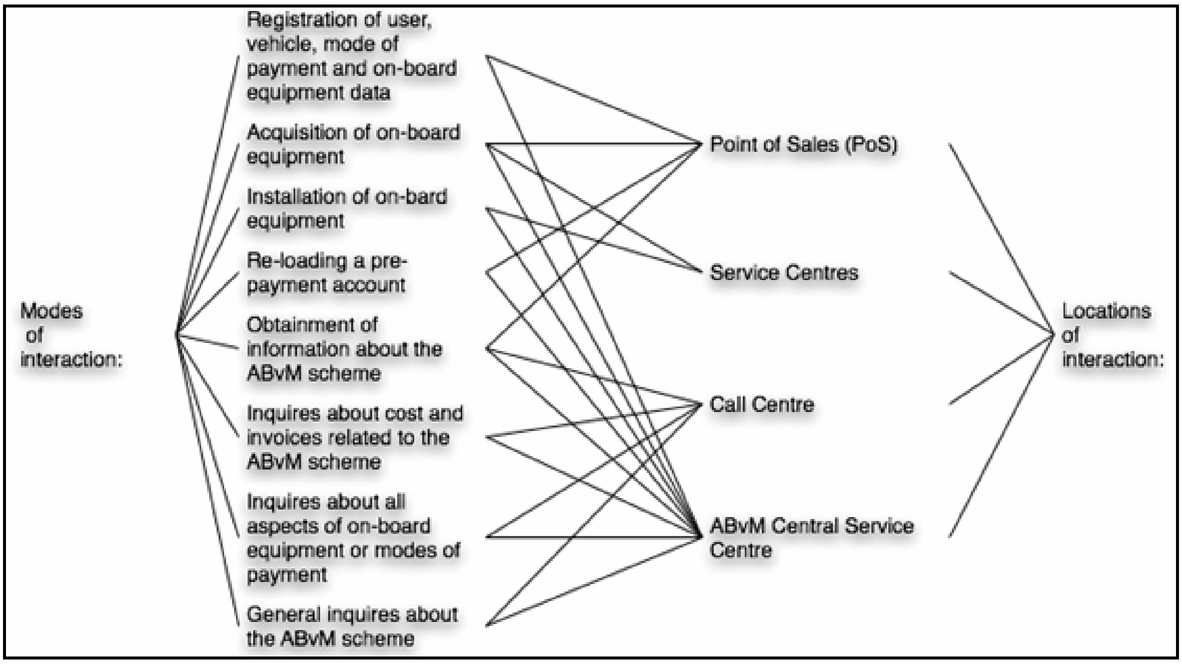


Figure 3-13: Relationship between interaction modes and locations of interaction

As the above figure shows, there are at least two locations for each mode of interaction. Each location provides at least two but usually more modes of interaction.

3.3.2.2 Enforcement

Enforcement plays a crucial role in maintaining a fair and non-discriminatory road-charging scheme. For non-compliant vehicles, occasional users and fraud reasons, a high probability of detection is required. Hence, enforcement units will be set up at strategic locations to verify compliance with the system. Enforcement may also be carried out in conjunction with traditional surveillance work. This section focuses mainly on communications technology enablers rather than enforcement strategy.

Enforcement units are categorised into three types:

- Stationary: units are installed at a fixed location and will operate unmanned. A typical example is an enforcement bridge above motorways, but secondary roads may also be equipped. In general, drivers are aware of the locations, which reduces the effectiveness of these units;
- Nomadic: units are placed at a certain location for a limited period of time. Then, the unit is moved to a different location. These units can operate both manned and unmanned. Since drivers are not aware of the respective location, it is an effective way to govern the risk assessment of non-compliant drivers;
- Mobile: units are installed inside surveillance vehicles and can be used to verify compliance while in motion.

All three categories allow a combination with other automatic enforcement programs such as red light violation and speeding.

The enforcement unit needs to perform two main compliance checks. Both checks can be carried out in parallel, but a failure of one may result in different measures. The first task of an enforcement unit is to register a unique characteristic of both the vehicle and the OBU inside. For the vehicle, this can be achieved by taking a picture of the licence plate and by extracting its licence number. The detection of vehicles for triggering the camera is carried out by a detection loop underneath the pavement or by means of a radar signal. The OBU characteristic can be obtained by requesting the OBU to send its ID. The enforcement unit then acts as a beacon to trigger the OBU it has entered an enforcement zone. The vehicles licence number and the OBU ID are compared with (a copy of) the database entry in the Back Office. The following figure shows the high-level process diagram.

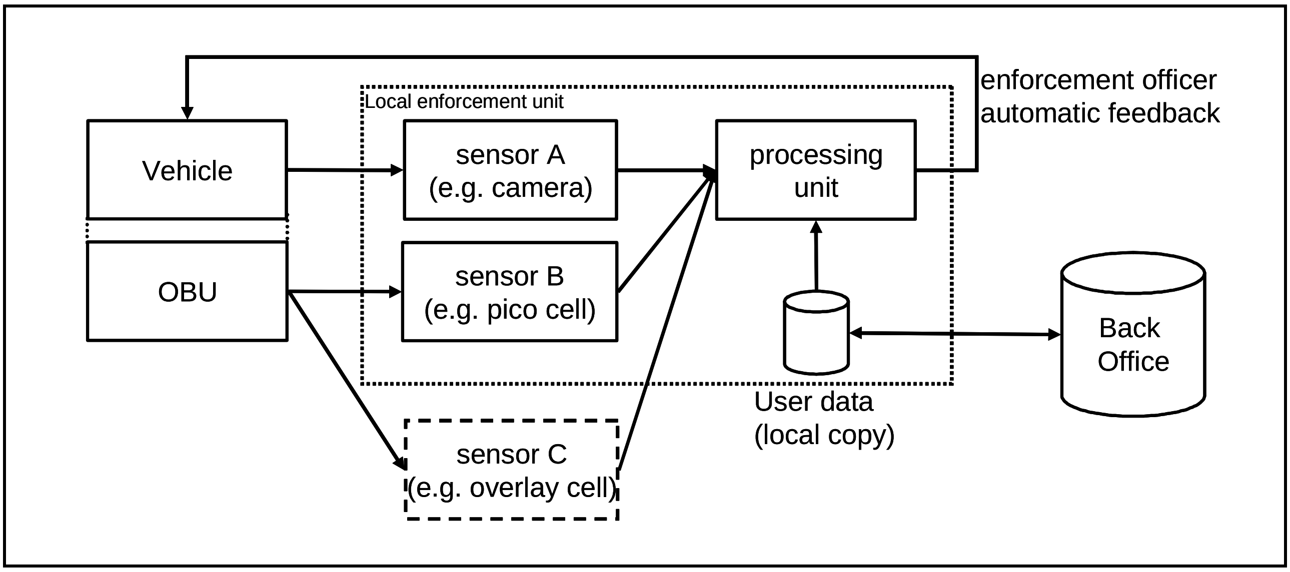


Figure 3-14: High-level enforcement process diagram

The second check validates the data collected and stored by the sensors of the OBU. A vehicle-OBU pair may pass the first check, but this does not imply the OBU sensors are functioning properly. For instance, the distance travelled may have been manipulated by the user jamming the GNSS signal. To verify whether this has been the case, the enforcement unit can make the OBU send the actual GPS coordinates and time stamp. Furthermore, some log data can be transferred for validation purposes.

From general practice, it has been found that it is not feasible to perform a real-time check in the Back Office. The backhaul capacity between enforcement unit and the Back Office is in general not sufficient to transport all data. This is especially true for nomadic and mobile enforcement units (cellular network backhaul). Therefore, the comparison needs to be carried out locally. This is also beneficial for privacy reasons. Data from vehicles found to be compliant are discarded locally and no data is sent to the Back Office. A local copy of the OBU database is required, however. If an entry is missing, the Back Office can be consulted automatically for a final comparison. In case of non-compliance, an enforcement officer can decide to intervene, or further analysis may be carried out in the Back Office.

Communication

Two-way communications is provided for between the enforcement unit and the OBU. The communication from the enforcement unit to the OBU (i.e. downlink communication) is used to notify the OBU it has entered an enforcement area. The resulting communication from the OBU to the enforcement unit (i.e. uplink communication) contains the OBU details necessary to verify road-charging compliance.

EC Directive 2004/52/EC requires the use of communications using the GSM/GPRS protocol and/or 5,8 GHz microwave technology for carrying out electronic toll transactions (both operations and enforcement). However, utilizing a single communication technology reduces costs and increase the MTBF as the OBU contains less components. Hence, a cellular-only solution is proposed. This is also preferred for handset-based solutions.

A cellular communication network such as GSM or UMTS comprises a number of radio cells. A cell is an area covered by one antenna system. For hot-spot areas (i.e. a small area and with a high density of users, for example railway stations or shopping centres), picocells are utilized in addition to macro cells. A picocell covers only a small area but can have a traffic capacity equal to macro cells for larger areas. Since the enforcement unit is comparable with a hot-spot environment, a picocell is incorporated to handle all communications. The following figure reflects schematically an enforcement unit set up along a motorway.

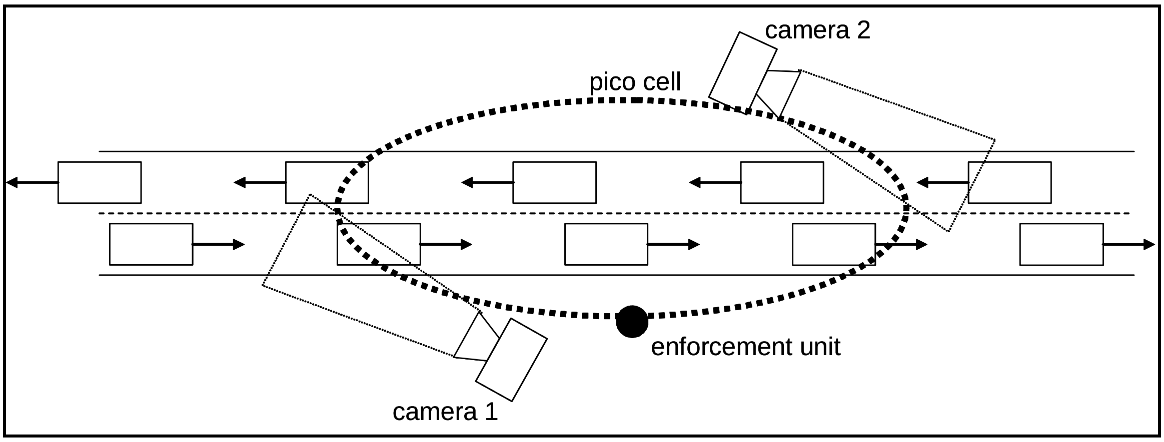


Figure 3-15: Enforcement units set up along a motorway

The enforcement unit connects to the Back Office either via the cellular network for nomadic or mobile units or via a microwave link or leased line for stationary units. As stated before, the capacity of such a backhaul is limited In the case of the cellular network. Hence, data transfer should be minimized.

Downlink

For fixed and nomadic units, it will not be necessary to trigger each individual OBU. A broadcast signal will be sufficient for downlink communication within the enforcement area. By default, a picocell broadcasts a cell ID, which may also be used by the OBU for detection of the enforcement unit. The OBU monitors the presence of a dedicated enforcement picocell at a regular time interval. The length of this interval is dependent of the speed of the vehicle.

On the other hand, it might be necessary for a mobile enforcement unit to address a single OBU. One can think of enforcement officers who intend to verify compliance of a single vehicle while driving on a road. Hence, the set of cell IDs is split into two subsets. The first subset triggers all OBUs within range of the picocell, while the second subset triggers a single OBU only. In order to achieve the latter, the temporary cell ID is based on the license number plate. This allows verification of compliance during surveillance while in motion.

Uplink

Once the OBU receives the picocell (broadcast) signal, it replies by sending the requested data to the enforcement unit. This data message may for instance consist of ID, status, log, actual GPS position and time stamp. If a cellular technology (i.e. the enforcement picocell or the overlay communication network) is utilised for receiving the message, the transfer time can be as high as three seconds. This behaviour will result in a high probability of the message being blocked, in particular in cases where the availability of traffic channels is limited and there is a high number of vehicles.

Since a 4-lane motorway can have a maximum throughput of up to 7500 vehicles per hour, calculations have shown that cellular technology will not be capable of handling all traffic. Therefore, a different solution is presented here. It is proposed to re-use the cellular transmitter of the OBU as a Short Range Device (DSRC device). Instead of deploying the cellular communication channel set-up procedure, the OBU transmits its data to the enforcement unit directly. The cellular protocols are thus bypassed, which saves the extended signalling period.

The Random Access Channel (RACH) is a channel initiated by the mobile device to set up communications. Instead of carrying signalling data, the RACH is filled with the requested OBU data. The enforcement unit is equipped with a dedicated receiver which listens for the RACH only. For 2G technology, the OBU message transfer time is then reduced from 3 seconds to less than 50 milliseconds.

Radio Network Integration

Some operational limitations are inevitable when the picocell is integrated in the cellular network. First, the network needs to know the position of the picocell to begin with. Second, the frequency of the picocell differs according to location and needs to be assigned in accordance with the frequency plan of the hosting cellular operator. Third, regular communication terminals for voice and data need to be diverted from this picocell, which requires additional non-standard measures (some of them involving violations of the communication protocol). Fourth, a multi-operator solution for road charging adds some further complexity to the frequency assignment process.

In order to overcome these limitations, it is proposed to reserve one dedicated (DCS1800) frequency for the whole road charging area to be covered (i.e. the Netherlands). Since the overlay network does not know this frequency, it does not interfere with regular network operations. Hence, voice and data terminals are not affected. The OBU or handsets incorporated for road charging have knowledge of this frequency prior to operation. It also reduces the time in which an enforcement unit is detected by the OBU.

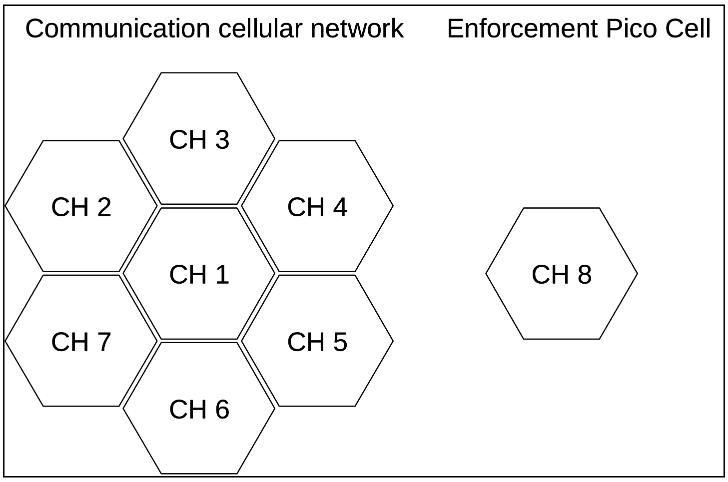


Figure 3-16: Radio network integration of enforcement picocells

Traffic flow direction

The picocell solution does not allow any differentiation between travel directions of the vehicles. This might be necessary from a legal perspective in order to reduce the number of non-compliant vehicles to coincide at the same time passing the enforcement unit.

When two picocells are introduced at the same unit, each picocell can serve a direction of the road. In order to discard propagation effects, the same frequency is used for both cells. This prevents the radio signal being broadcasted in one direction, to be received in the opposite direction (e.g. through reflections caused by other vehicles). Since both picocells operate on the same frequency, the serving cell's signal will be received before that of the neighbouring cell, and with more confidence at that. The small interference zone between the two cells can be neglected and has no influence on the functioning of the system.

3.3.3 Tertiary processes

3.3.3.1 Systems management and maintenance

As described in the systems architecture, the system as a whole is divided into several logical components, the availability levels of which differ substantially depending on the demands and needs they respond to. The entire charging system, customer registration and service are all rated as highly critical and, accordingly, are available around the clock. As far as billing processes are concerned, their availability might conceivably be limited to bank working days under a worst-case scenario, as their processing is eventually dependent on bank processes.

The entire tolling system is designed as a cluster across two computing centres hosted in different locations. Their communications circuits and their energy supply are independent of each other. The locations themselves are connected through a high-speed line (glass fibre) to enable permanent data replication. The cluster system's exact design (minimum availability and/or maximum downtime) is set down in appropriate service-level agreements (SLAs).

The entire IT infrastructure is administered, monitored and supported using professional system management tools. Importantly, this is provided for on a 24/7/365 basis, as possible IT and application problems need to be dealt with through proactive measures to avoid downtime and errors. The integrated ticket system ensures consistent logging of error messages and their processing status.

This supports the asset, change, network, security, capacity and performance management processes. During regular computing centre operation, defined administration routines provide for the entire spectrum of systems management activities, which are executed centrally. Remote monitoring and software distribution ensure availability and reliability across the entire IT system and ascertain the installation of current software versions and virus scanners, and that ownership of licences conforms is up to date.

However, integrated service providers, such as of EETS, need to conform to defined requirements, too, if they use their interoperable OBUs to capture data and transmit the raw data to the system for geographic positioning. In addition, transactions need to be received at defined times for processing, to ensure compliance with payment dates and guaranties.

Security levels with respect to individual systems are defined mainly to ensure security regarding access to the computer centre (both in terms of personnel and data). The tolling system itself is housed in a protected network area. All access systems relating to users and service providers are located in DMZs. Any communication between two systems – including within the computer centre – is based on end-to-end encryption. In doing so, the handbook of the BSI (Bundesamt für Sicherheit in der Informationstechnik, www.bsi.de, Germany's Federal Office of Security in Information Technology) is regarded as a very good guideline.

Besides the standard system maintenance process, which consists in repairing system errors, analysing and removing performance bottlenecks and upgrading the systems environment with new equipment, adaptations will be made and documented mainly to reflect changing requirements. These can arise in manifold ways and guises: For instance, tariff changes need to be entered, tested and pre-installed for service from a certain deadline, following a review process.

But even changes in the traffic infrastructure can be entered out-of-period, independently of the routine quarterly updates. In this connection, the automatic update process for generating all new or altered geo objects should be especially highlighted, which at present takes into account current standard data formats (GDF, GML) from all major geo data suppliers and can, in addition, accommodate GNNS data generated individually. This makes it possible to carry out central updates of infrastructure information very easily and quickly even where all they involve is a detour due to road construction work. Updating OBUs is not necessary, as has been repeatedly mentioned.

In the end, however, standard monitoring of OBUs is also integrated into system management,. This includes permanent read-out of status and error logs, which are broadcast every two weeks or anytime an error occurs. All messages are scrutinised by system management in the back office and reported if necessary. In these cases, remote deactivation is possible at any time.

3.3.3.2 Determining tariffs

Because this concept is based on a thin-client approach, no tariffs are computed in the OBUs themselves. Instead, tariffs are always and exclusively computed centrally in the back office. Compared with a thick-client solution, where tariffs would be computed in the OBU, the following problems can be avoided from the outset:

_ Tariff changes needing to be distributed to all OBUs in a timely manner, causing additional update communications costs.

_ All tariffs computed by the OBUs needing to be recomputed by the back office to prevent fraud attacks and to ensure the OBU in question was using the correct tariff table.

_ Communications between the system operator and the user proving cumbersome in case the OBU shows different tariffs from those applicable,.

Instead, the following advantages can be realised:

_ Road operators can update tariffs quickly to take account of current traffic and weather conditions. All that needs to be done is to inform the user before he enters a toll zone with variable tariffs. [Toll variations must not affect users already inside the zone at the time of the variation].

_ In addition, general tariff updates can be planned and entered into the system to take effect at a pre-determined date and time, ensuring that all users are charged according to the updated tariff.

_ Tariffs can easily be tested in the system before they are applied.

_ Tariff models can be extended or updated without having to update the software in the OBUs. This means an extremely wide range of discount schemes is feasible that could also take into account additional parameters such as refuelling behaviour.

The only drawback would be that the user cannot be sure that he has current information on costs. The only pricing information available on his OBU would be that of the last trip that was actually charged. How current this information is, depends to a very great degree on the layout of the back-office system, that is to say, whether it computes prices in batches or whether it does so in real time. Real-time computing of tariffs, however, should remain limited to certain situations such as border crossings to ensure processing time in the system. On the other hand, it does not seem imperative to provide a driver with up-to-the-minute pricing information, as current DSRC systems do not do so either.

Implications of different Tariff scenarios (III B and other)

As mentioned before all tariff scenarios can comparatively easily be mapped in the back office functionalities. Nevertheless, the complexity of the tariff scenario has a certain impact on the investment and operational costs of the back offices.

Different requirements for digital map resolutions and different requirements regarding types of geo objects have an impact on the development costs and the necessary processing power of the back office system.

3.3.3.3 Supervision

The ABvM scheme should support a supervision process to monitor key performance indicators. Among the key performance indicators are the system availability and reliability, the recognition rate of geo-objects, the accuracy of the mileage estimation, the identification rate of the enforcement system and the service level of the retail scheme.

The degree of fulfilment of the key performance indicators will determine the financial compensation of the operator of the charging scheme. Therefore it is necessary that an independent expert be granted access to the key figures to scrutinize the overall system performance on behalf of the client and the system operator.

3.4 Special topics

3.4.1 Foreign and occasional user scheme

Occasional users are those users who are tollable under the ABvM scheme but only use their vehicles on an infrequent basis (domestic occasional users) or drive comparatively few kilometres on the tolled road system (foreign occasional users).

As a general rule, all users - frequent or occasional - need to be registered under the ABvM scheme. Due to the fact that occasional users will only log few kilometres per year they will be assessed only scant charges. Given the necessity that every user be registered and be generally free to choose his on-board equipment, the actual distribution of on-board equipment may entail significant costs for the ABvM investment and operation.

The cost implication is potentially large for foreign occasional users because many will choose the convenient thin-client solution running on dry batteries (requiring no installation) using pre-payment. Costwise there is the implication for the ABvM operator to provide relative expensive OBUs and the transactions for the frequent reloading of pre-payment accounts. Also, there is the risk that OBUs from occasional users might be stolen or their batteries run out with implications on the replacement, re-registration of new OBUs and additional enforcement cost.

To keep the cost and risks associated with the occasional users low, the ABvM operator should:

- Require every stolen OBU to be reported to the police, with the appropriate documents being shown upon re-issuing of new equipment. Otherwise, the user will need to purchase new on-board equipment at his own expense.
- Require a non-refundable handling charge to be paid for each new/replacement OBU interaction (unless there was a genuine technical malfunction in the OBU),
- Require a minimum pre-payment to be paid by each occasional user at each account reloading transaction,
- Require an OBU deposit (refundable upon returning the unit) to be paid for each non-fixed OBU installation,
- Specify and design on-board equipment so that operation lifetime is maximised while minimising on-board equipment interaction necessities by users. Placement of on-board equipment in the vehicle cabin will be as flexible as technically possible and practical (using a special enforcement technology will dramatically enhance vehicle-cabin-based on-board equipment placement options!)

- Use only dry batteries which have a more predictable lifetime, are cheaper and easier to replace (a special battery recollection will be put in place to mitigate environmental impacts).

In any case treatment of occasional users will need to conform to the non-discrimination regulations of the European Union.

3.4.2 Interoperability and standardisation

In its 1996/62/EC, the EU mandates that all new tolling system have interoperable interfaces. The European Parliament, in its resolution 2004/52/EG demanding the implementation of a Europe-wide tolling system, does the same. Among other things, this means that a user must be able to use all tolling systems in Europe with just one contract, one OBU and one bill.

Besides the EU activities in promoting the requisite standardisation procedures through the EFC Expert Group and projects such as RCI, existing tolling operators and initiatives (such as ASECAP) have been known to drive parallel initiatives to implement the guideline. The most recent example of this is the MEDIA project, which aims for interoperability between several European tolling systems (among them Austria, Italy and France) including a complete integration of an EETS service.

In doing so, the EETS service is to handle the entire contract management, OBU management, billing and fulfilment as an autonomous agent. Importantly, this includes complete assumption of the payment guarantee, meaning the local tolling operator is relieved from non-payment risk.

Vodafone’s concept, as mentioned in the pre-read, accepts the complete EETS functionality, not least because of the ensuing reduction in system costs. But even interoperable OBUs will be accepted as long as they conform to standards regarding the interfaces to the back office. Should an OBU not be able to communicate with the back office, it could start by communicating instead with an OBU proxy of the EETS, as mandated under the standard. The EETS could then initiate the necessary interface conversion towards the backbone and eventually the local tolling operator.

3.4.3 Level playing field

To the EU, future tolling systems should be interoperable firstly and open to the market secondly, as this is the only way to ensure that operating costs for the TSP (transport service provider, i.e. in most cases the government) permanently decrease as soon as components are priced to the market and existing investments (such as interoperable OBUs, EETS systems) become accessible to other system operators.

Whether or not the market is open and to what degree it is so, depends on the TSP (who in most cases will also be the policymaker). The TSP determines the requirements that a tolling system needs to meet. Only a very small number of tasks relating to a tolling system will be considered governmental preserve and will not be farmed out to third parties. This especially includes clearing of tolling charges and their disbursement to the TSP, as well as enforcement.

All other components should be subject to third-party tendering. In making them so, an essential distinction needs to be made: on the one hand are the standardised services that a tolling system's interfaces plug into. This includes mainly communications (GSM/GPRS). On the other hand are the system's own interfaces, which need to be made public from the outset to ensure an open market.

Thus, the thin-client approach, promoted here, can use any communications interface supplied by a mobile operator capable of offering the necessary services (such as GPRS). All other components, especially including OBUs and EETS services, need to be made generally accessible through a clear description of their interfaces. In this connection, existing standard description or their drafts should be referred to when designing the system as this will ensure that existing interoperable tolling systems can play a role in the market.

To limit the issue of responsibility for the correct assessment of tolls, the CESARE approach should serve as a guide. CESARE calls for a so-called interoperability management, which would act as a neutral institution (comparable to Germany's TÜV) on behalf of the TSP, and which would test all new components designed by third parties for compatibility and correctness of operation.

All in all CESARE III recommends the following allocation of roles and tasks within upcoming interoperable European ERUC scenarios (therein called EETS scenarios).

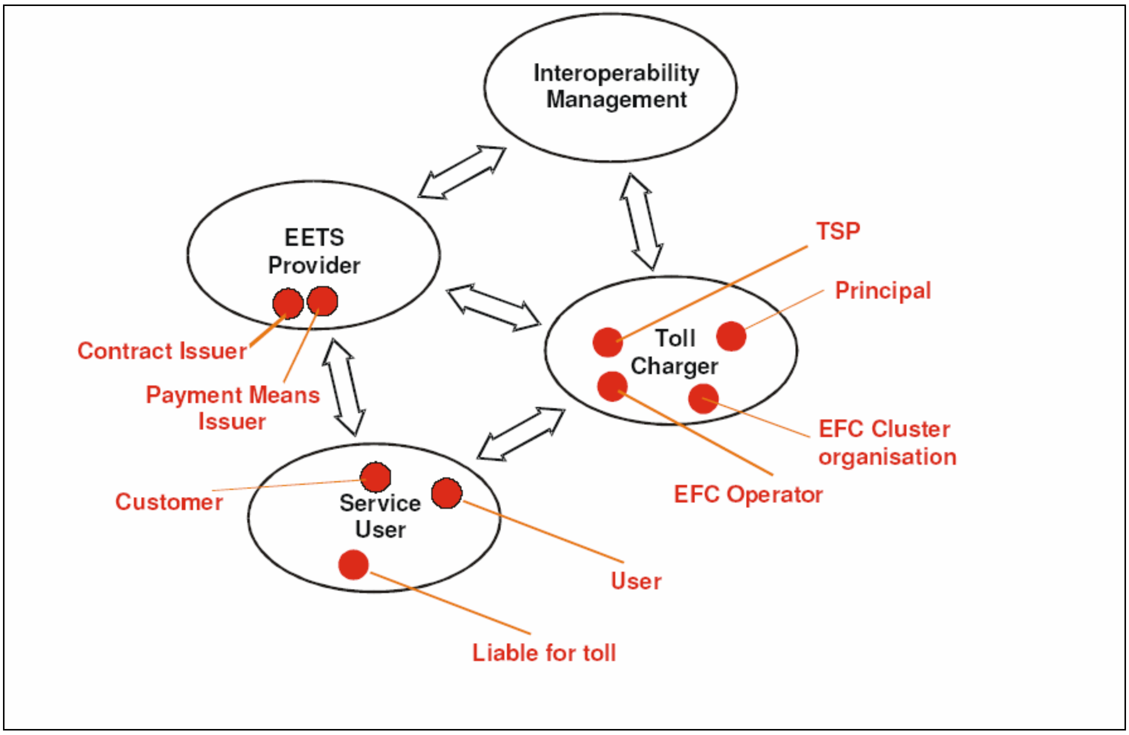


Figure 3-17: CESARE III EETS scenario

According to this the proposed system architecture for the Netherlands can be divided into the following tasks and roles:

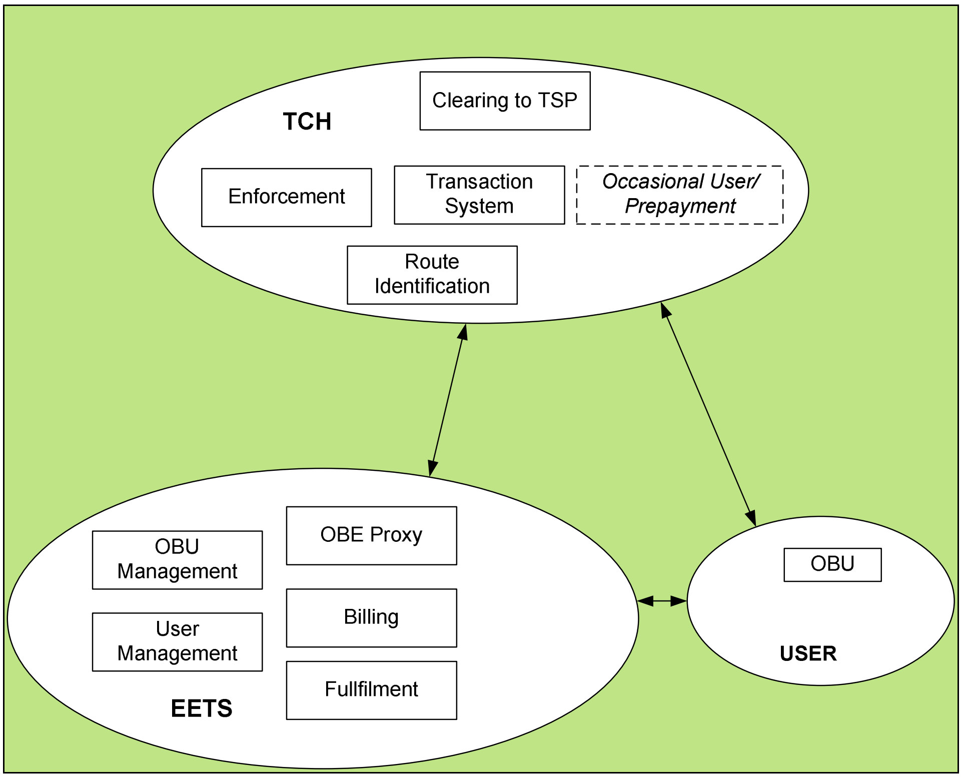


Figure 3-18: Entity roles within the CESARE III model

In this system approach, the local toll charger (TCH) is merely responsible for route identification (incl. tariffs and pricing) and enforcement. Additionally the TCH might be responsible for the occasional user and prepayment user schemes, which will probably not be covered by the EETS providers.

Service level agreements involving the EETS providers guarantee a high availability of some core components of the system. The cost- and risk-intensive parts of customer management (post payment) can be outsourced to specialised services offered by the EETS providers. As there will be most probably two or three EETS providers established within the next years, the Netherlands ERUC scheme can use their flexible and scalable systems. The risks can thus be allocated to different players.

The EETS providers will provide a broad variety of payment means and service offers that will be available for local users. As they are specialised to the European market, the integration of foreign users will not be a problem.

Here is an over view of the advantages of this approach:

- Free choice of an EETS provider (locals and foreigners)
- Users can select between different interoperable OBUs
- Users can use compatible interoperable OBUs which they already own
- OBU logistics are completely covered by established processes of the EETS (except for occasional users)
- Broad variety of payment means and service offers and therefore access to existing processes and payment guarantees (reduction of risk)

_ Simplified system realisation, implementation and start by using different EETS provider (reduction of risk). User registration can start before system realisation / service trials, because EETS provider already use existing networks with a broad variety of contract issuers and payment service providers

_ Local toll charger can use the customer care centre of the EETS providers, which already provide service in different international languages.

_ Using different EETS providers reduces the risk of system implementation for billing and payment / clearing, fulfilment and the timely registration of the users.

The biggest disadvantage of the EETS approach is that it is unsure whether the EETS providers will provide prepayment services. If not, a dedicated system needs to be set up by the local toll charger for this user group. But the system requirements of this system are quite low compared to a system catering to all ERUC users. Additionally the pricing of the interoperable OBUs is an uncertainty factor.

As set out earlier, the thin-client approach selected here is the natural choice when it comes to ensuring the openness of the system. This is so mainly because the interface between OBU and back office will be transmitting raw GPS data exclusively; meaning that the actual charging will only take place inside the certified back office and according to certified charging rules.

The only qualification necessary is that no proprietary compression algorithms must be used if existing interoperable OBUs are to be able to use the interface as well.

3.4.4 Future viability of ABvM core technologies

3.4.4.1 Future of Global Navigation Satellite Systems (GNSS)

The data collection of the proposed technical solution for the ABvM scheme is primarily satellite-based. Today this satellite-based approach relies on location information obtained using the „Global Positioning System (GPS)“. Given that the ABvM scheme is likely to be implemented around 2012 and operated for eventually 10 years, it is very likely that not only the GPS, but also the European GALILEO system will be fully operational and available.

GALILEO is Europe’s initiative for a state-of-the-art global navigation satellite system (GNSS), providing a highly accurate, guaranteed global positioning service under civilian control. While providing autonomous navigation and positioning services, GALILEO will at the same time be interoperable with GPS, the other global satellite navigation systems.

By offering dual frequencies as standard, however, GALILEO will deliver real-time positioning accuracy down to the metre range, which is unprecedented for a publicly available system. It will guarantee availability of the service under all but the most extreme circumstances and will inform users within seconds of a failure of any satellite.

This will make it suitable for applications where safety is crucial, such as running trains, guiding cars and landing aircraft - or providing reliable location information for an ABvM charging for road usage scheme.

The GALILEO infrastructure is currently being implemented and commercial operations is to start from 2010.

The GALILEO infrastructure will provide five positioning services with characteristics as shown in the figure below.

_ A basic level dedicated to consumer applications and general-interest navigation, the Open Service.

_ A service for use where passenger safety is critical, the Safety of Life Service.

_ A restricted-access service level for commercial and professional applications that require superior performance to generate value-added services, the Commercial Service.

_ A restricted service for governmental applications, the Public Regulated Service with high continuity characteristics.

_ A humanitarian "Search and Rescue" service to accurately determine the location of distress messages from anywhere across the globe.

For the purpose of the ABvM scheme, the Open Service and/or the Commercial Service will be suitable and might be used in combination. The use of the commercial service is recommended, but the proposed system would not require it. Therefore no provision was made for Galileo in the estimation of costs (see chapter 4).

Together with GPS (on the basis of GPS/Galileo GNSS receivers implemented in all on-board equipment these service will allow for even more reliable and more accurate positioning on all roads falling under the ABvM.

3.4.4.2 Future of mobile communication networks

The 2G GSM system was developed originally for telephone calls and slow data transmission (max. 38.4 kbit/s). Adding the General Packet Radio Service (GPRS or 2.5G) to the standard, enabled an “always on” high-speed packet data connection with speeds up to 170 kbit/s. Nowadays, GSM has become the most popular wireless communication standard in the world, serving more than 1.5 billion subscribers.

The next milestone was the introduction of the 3G UMTS network. This technology was developed to carry large amounts of data traffic quickly and cost-effectively on an improved radio interface. It is capable of providing higher-bandwidth connections, multimedia services and high-speed internet access to more users simultaneously. In hot-spot areas, data rate of up to 2Mbit/s can be achieved, while a wide area typically enjoys a 384 kbit/s data rate.

As of this writing, UMTS broadband (HSxPA or 3.5G) is being introduced in many markets. This new high-speed data transfer feature has been designed to fully utilize the packet-data transport capabilities of UMTS. 3.5G offers downlink peak data rates of up to 14 Mbit/s at a significant lower roundtrip delay.

In order to enable fixed-mobile convergence and value based charging, the IP Multimedia Subsystem (IMS) was adopted as a new internationally recognized standard. IMS is designed to provide new innovative services independently of the access technology being used.

The next-generation network is currently under researchers’ spotlights. “4G” will be a technology that connects all the existing and future networks seamlessly together. It is estimated to provide a 100 Mbit/s downlink and a 20 Mbit/s uplink. Hence it will offer a first-step solution for the bandwidth gap between the wireless world and the internet. 4G is expected to be commercially available by 2013.

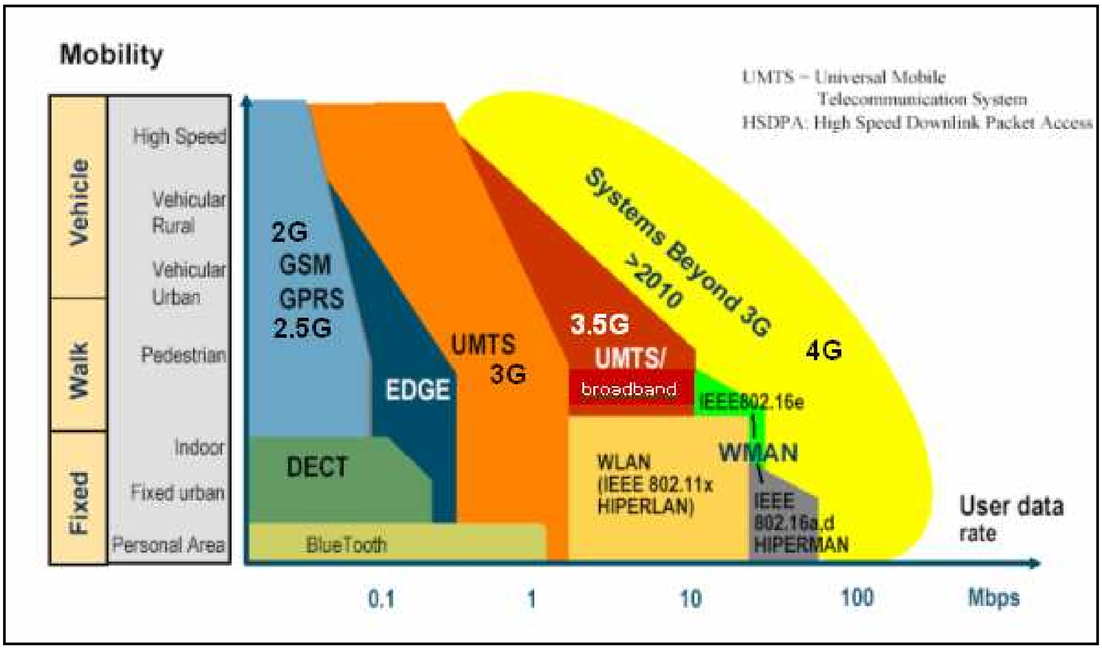


Figure 3-19: Mobile network evolution

Wireless' evolution means connectivity is rapidly becoming available at any time and at any place, thus offering a reliable platform for a dedicated service such as a road charging scheme. Growing demand and continuous competition will stimulate an operator to maintain his network at a high quality level while providing wireless connectivity at minimum costs. The focus on security and privacy aspects are primordial drivers in gaining customer confidence. The seamless migration from 2G towards 3G highlights the future viability of a wireless communication network.

4 Estimation of costs (D-4)

In addition to a base scenario the specific cost impacts of four alternative scenarios are elaborated. The analyzed alternative scenarios are (1) "no foreign user" scheme, (2) "no EETS established in the future", (3) "HGVs and vans tollable for ERUC only" and (4) the "'big bang' - no migration" scenario.

All model inputs are based on figures and parameters either derived from the reference cost model (see „Cost Format phase 2 v1.0.xls") or experience gained in other similar road-pricing schemes (i.e. Swiss, German and Austrian HGV charging). Some behavioural assumptions have been made regarding the adoption of different OBU types and customer-service interactions.

In extrapolating growth, all vehicle figures and annual road kilometres travelled have been adjusted for the year 2006 (which is the base year = J 0). A uniform growth of 2% pa is assumed for tollable vehicle numbers; a uniform growth of 1% pa is assumed for annual road kilometres travelled. The road network is assumed as constant (no growth).

The year 2006 is taken as the base year (J 0) (J 1 = 2007, J 10 = 2016). All estimated costs are actual costs as of today.

In the cost format sheet (see „Cost Format phase 2 v1.0.xls") the results from the model scenarios are adjusted according to the assumed IEP (15%) and VAT (19%).

Similarly to costs, revenues are calculated on the basis of annual kilometres travelled with the base year (J 0) being 2006 and assumed toll rates for different vehicle types as outlined in the scenario descriptions below.

4.1 Base scenario

The model simulates investment and operation of a comprehensive road-pricing system for ten fiscal years according to the specification outlined in this report. Data was taken from „Cost Format phase 2 v1.0.xls" for:

- Road Network,
- Vehicle fleet,
- Traffic.

In cases of missing data, appropriate assumptions have been made.

The baseline model includes the proposed migration scenario where road-pricing is initially mandatory for HGVs in year 1, with vans following in year 2 and cars and motorcycles in year 3 to 5. From year 5, all vehicles are subject to mandatory road pricing on all roads. The distribution of tollable vehicles according to the available statistical data and the proposed migration scenario is as follows:

		Year										
		J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
HGV	Domestic	199.757	203.752	207.827	211.984	216.223	220.548	224.959	229.458	234.047	238.728	243.502
	Foreign	49.939	50.938	51.957	52.996	54.056	55.137	56.240	57.364	58.512	59.682	60.876
	Sum of Or Σ	249.696	254.690	259.784	264.979	270.279	275.685	281.198	286.822	292.559	298.410	304.378
Van	Domestic		0	902.027	920.067	938.459	957.238	976.383	995.910	1.015.829	1.036.145	1.056.868
	Foreign		0	130.050	132.651	135.304	138.010	140.770	143.586	146.457	149.387	152.374
	Sum of Or Σ	0	0	1.032.077	1.052.718	1.073.773	1.095.248	1.117.153	1.139.496	1.162.286	1.185.532	1.209.242
Car	Domestic		0	0	3.594.062	5.391.093	7.188.124	7.331.886	7.478.524	7.628.094	7.780.656	7.936.269
	Foreign		0	0	455.175	682.763	910.350	928.557	947.128	966.071	985.392	1.005.100
	Sum of Or Σ	0	0	0	4.049.237	6.073.855	8.098.474	8.260.443	8.425.652	8.594.165	8.766.048	8.941.369
Motorcycle	Domestic		0	0	0	0	537.887	548.645	559.617	570.810	582.226	593.870
	Foreign		0	0	0	0	0	0	0	0	0	0
	Sum of Or Σ	0	0	0	0	0	537.887	548.645	559.617	570.810	582.226	593.870
Other	Domestic		0	0	0	0	0	0	0	0	0	0
	Foreign		0	0	0	0	0	0	0	0	0	0
	Sum of Or Σ	0	0	0	0	0	0	0	0	0	0	0
Sum of Veh Type Σ	Domestic	199.757	203.752	1.109.854	4.726.113	6.545.785	8.903.796	9.081.872	9.263.509	9.448.780	9.637.755	9.830.510
	Foreign	49.939	50.938	182.007	640.822	872.122	1.103.497	1.125.567	1.148.078	1.171.040	1.194.461	1.218.350
	Sum of Or Σ	249.696	254.690	1.291.861	5.366.935	7.417.907	10.007.293	10.207.439	10.411.588	10.619.820	10.832.216	11.048.860

Figure 4-1: Tollable Vehicles (absolute numbers) - migration scenario

Domestic vehicles make up the major portion of the vehicle fleet. They also account for most of the yearly kilometres (Mio yearly km) on the network subject to the ABvM scheme:

		Year										
		J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
HGV	Domestic	8.538	8.623	8.709	8.797	8.885	8.973	9.063	9.154	9.245	9.338	9.431
	Foreign	1.281	1.293	1.306	1.319	1.333	1.346	1.359	1.373	1.387	1.401	1.415
	Sum of Or Σ	9.819	9.917	10.016	10.116	10.217	10.319	10.423	10.527	10.632	10.738	10.846
Van	Domestic		0	27.265	27.537	27.813	28.091	28.372	28.656	28.942	29.232	29.524
	Foreign		0	4.090	4.131	4.172	4.214	4.256	4.298	4.341	4.385	4.429
	Sum of Or Σ	0	0	31.355	31.668	31.985	32.305	32.628	32.954	33.283	33.616	33.952
Car	Domestic		0	0	20.449	40.897	81.794	82.612	83.438	84.273	85.116	85.967
	Foreign		0	0	3.067	6.135	12.269	12.392	12.516	12.641	12.767	12.895
	Sum of Or Σ	0	0	0	23.516	47.032	94.064	95.004	95.954	96.914	97.883	98.862
Motorcycle	Domestic		0	0	0	0	2.929	2.958	2.988	3.018	3.048	3.079
	Foreign		0	0	0	0	439	444	448	453	457	462
	Sum of Or Σ	0	0	0	0	0	3.369	3.402	3.436	3.471	3.505	3.540
Other	Domestic		0	0	0	0	0	0	0	0	0	0
	Foreign		0	0	0	0	0	0	0	0	0	0
	Sum of Or Σ	0	0	0	0	0	0	0	0	0	0	0
Sum of Veh Type Σ	Domestic	8.538	8.623	35.974	56.783	77.595	121.788	123.006	124.236	125.478	126.733	128.000
	Foreign	1.281	1.293	5.396	8.517	11.639	18.268	18.451	18.635	18.822	19.010	19.200
	Sum of Or Σ	9.819	9.917	41.370	65.300	89.234	140.056	141.457	142.871	144.300	145.743	147.200

Figure 4-2: Yearly kilometres on NL road network by vehicle category and origin (in Mio km)

Beside the cost aspects for OBUs, declaration and customer care, payment and billing, enforcement and others, the model also includes the revenue aspects of the ABvM scheme.

Revenues are calculated on the basis of tollable vehicles over time and assumed cost/kilometre driven (on a flat rate basis - no tariff differentiation with rates according to similar tolling already in operation in Europe). As a possible total revenue / year, the figure from „Tariff scenarios for phase 2 assignments v1.0.doc“ was taken as an indication.

For the annual revenue calculation, the following flat tariff per km and vehicle type in EUR was assumed.

	Year										
	J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
HGV	0,0	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13	0,13
Van	0,0	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
Car	0,0	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04
Motorcycle	0,0	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Other	0,0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Figure 4-3: Assumed toll rates per km in € (flat rate) for the tollable vehicle categories

Revenues generated matter for the EETS OBU. It is generally anticipated that service fees accruing to the EETS operator most likely will be based on percentage of the total revenue generated in a specific road-pricing network (in this case the Netherlands). For modelling purpose a 5% of the EETS OBU revenue generated under the ABvM scheme, was assumed as a service fee. This service fee includes the provision of the OBU and all billing and payment aspects.

Beside the EETS OBU, also the thin client, the GNSS cradle and the GNSS-enabled handset have also been modelled. For the baseline scenario, the following distribution of OBU type (as a portion of total OBUs issued) over time is assumed:

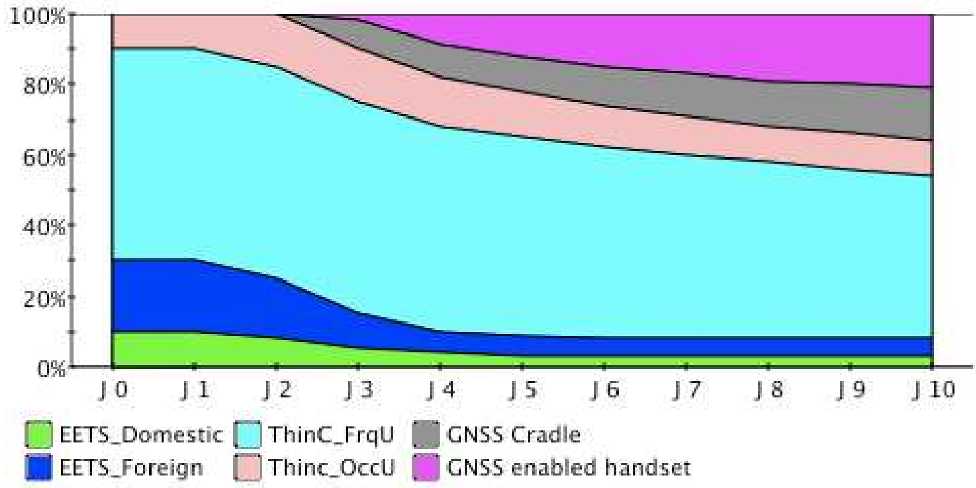


Figure 4-4: Distribution of OBU types as % of total OBUs used

It is anticipated that the GNSS cradle and the GNSS-enabled handset will a significant portion of OBUs used in the future (i.e. Year 2017 and after of the ABvM scheme is to be introduced by 2012).

Based on experience, component pricing in 2006 and taking into account significant economy of scales, system prices (OBU ready for installation including antennas plus installation kits and batteries, if necessary) for the different OBU types are estimated.

The economies of scale play an especially important role. In current road pricing schemes OBUs are usually in the range of 50.000 to 250.000 units. Under the ABvM scheme, and because different version of the thin client are essentially the same type, OBU production is estimated to be in the range of 2.500.000 to 5.000.000 over a period of several years. This factor of 10 in production scales and the relatively easy design of the thin client have a significant effect on OBU cost. Over time, a further reduction in OBU system prices of 2% pa is anticipated.

		Year										
		J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
EETS	EETS_Domestic	150	147	144	141	138	136	133	130	128	125	123
	EETS_Foreign	0	0	0	0	0	0	0	0	0	0	0
Thin Client	ThinC_FrqU	80	78	77	75	74	72	71	69	68	67	65
	Thinc_OccU	100	98	96	94	92	90	89	87	85	83	82
GNSS Cradle		50	49	48	47	46	45	44	43	43	42	41
GNSS enabled handset		20	20	19	19	18	18	18	17	17	17	16
Sum of Type	Σ		0	0	0	0	0	0	0	0	0	0

Figure 4-5: OBU types and system prices over time

For interoperability reasons, the most complex and therefore most expensive OBU is the EETS OBU. The occasional user version of the thin client is slightly more expensive because of battery power constraints.

Over time, a significant number of OBUs (in the range of 15% pa) will need to be exchanged due to malfunctioning, change of vehicle (possibly change of ownership) or other reasons. A significant portion of the exchanged OBUs will be refurbished (new housing, checked for correct functioning) and returned to operation.

	Year										
	J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
Sum of Vehicles	249.696	254.590	1.291.861	5.366.935	7.417.907	10.007.293	10.207.439	10.411.588	10.619.820	10.832.216	11.048.860
Installed OBUs	0	254.590	1.291.861	5.366.935	7.417.907	10.007.293	10.207.439	10.411.588	10.619.820	10.832.216	11.048.860
New OBU	0	254.590	1.037.171	4.075.074	2.050.972	2.589.386	200.146	204.149	208.232	212.396	216.644
New Swap OBU	0	303.081	1.222.553	4.867.770	3.437.379	4.403.708	1.993.593	1.516.009	1.501.726	1.516.595	1.531.459

Figure 4-6: Total tollable vehicles, new OBUs, new and swapped OBUs

To ensure convenient and non-discriminatory service to all users, a reasonable number of points of sales and service points need to be provided. The number of tollable users according to the migration scenario determines the number of facilities over time. After year 5, the number of points of sales decreases because, although the number of OBUs (Stock OBUs) increases, the demand for services at points of sales decreases in favour of web- or call-centre-based services.

		Year										
		J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
Border Crossings		350	350	350	350	350	350	350	350	350	350	350
PoS	Stock	2004	2556	3308	3960	3960	3960	3699	3438	3308	3047	3047
	Change	2004	552	652	652	0	0	-261	-261	-130	-261	0
Service Points	Stock	76	76	388	1.610	2.225	3.002	3.062	3.123	3.186	3.250	3.315
	Change	76	0	311	1.223	615	777	60	61	62	64	65

Figure 4-7: Border Crossings, Point of Sales and Service Points

Stationary and nomadic/mobile enforcement is modelled. On average 43 nomadic/mobile enforcement units and 88 stationary enforcement stations will operate on a 24x7 basis throughout the ABvM network.

The communication costs are estimated at 18 Euro per subscriber per year. These costs include the SIM card. Whether this specific estimation is realistic for 2012 and beyond is, along with other cost estimations, subject for further in-depth analysis. On the one hand, one can assume that an increase in wireless capacity will subsequently decrease the communication costs. On the other hand, the subscriber load above the data traffic load is the dominant cost driver here. Investments in the core network (e.g. HLR capacity, signalling expansion) are inevitable if the system is to host an additional 8 million subscribers. Furthermore, the introduction of new network technologies may be delayed for compatibility reasons since the OBU churn is far lower compared to the communication handsets. Hence, the forecast communication costs will provide a sufficient level of confidence to withstand the outcome of future market developments.

The investment and operation of central IT comprises basic development and geo data, OBU mileage reports (i.e. processing of data transferred from different OBU types), billing, invoicing and finally payment collection costs.

A significant part of the central IT system cost is variable cost depending on the number of OBU actively used in the system. Therefore, overall investment will increase proportionally with the number of additional OBUs.

An overall overhead mark-up of 10% has been factored in for investment and operational costs.

Finally, interest (8%) for financing is factored in It is assumed that the operator will need to finance the investment and operation while receiving an operator's fee as an income. The operator will receive a constant flat operator's fee in each of the 10 years the system is in operation (J 1 - J 10). Operator fee and interests are modelled so that financing and interest are paid back by the year 10 out of the operator's fee . No operator profit is considered. Depending on the investment necessities significant interests have to be taken into account in the initial years. Interest is calculated and is shown in overall Result sheet (see Appendix).

Project costs mark-up and marketing & communications (initial) are considered separately (i.e. as done in the KMP sheet).

Results

As expected, the investment in OBUs (75%) and operationally declaration & customer care (67%) make up the largest blocks of the ABvM scheme by far. This is due to the large number of OBUs in the field and the necessary data transfer and processing taking place in the back office.

	Initial Cost (Invest J 0 to J 5)		Operational cost ex depreciation (Operation J 5)	
	absolute	relative	absolute	relative
On-Board Unit				
Sum of On-Board Unit Σ	**1.158,714**	**75%**	**26,490**	**6%**
Declaration & Customer Care				
Sum of Declaration & Customer Care Σ	**92,981**	**6%**	**284,344**	**67%**
Payment and Billing				
Sum of Payment and Billing Σ	**28,785**	**2%**	**40,939**	**10%**
Enforcement				
Sum of Enforcement Σ	**53,916**	**3%**	**38,310**	**9%**
Miscellaneous				
Sum of Miscellaneous Σ	**211,822**	**14%**	**36,394**	**9%**
Sum of Cost Domains Σ	**1.546,218**	**100%**	**426,477**	**100%**

Figure 4-8: Results - Cost Ratios

Payment and billing makes up 2% of the investment and 10% of operational cost.

Miscellaneous includes investment (project costs, etc.) and operational overhead (administrative staff, offices and equipment, etc.).

The following figures show investment and operation cost over time. The migration scenario has a clear effect on investment and operation costs.

Investment over time

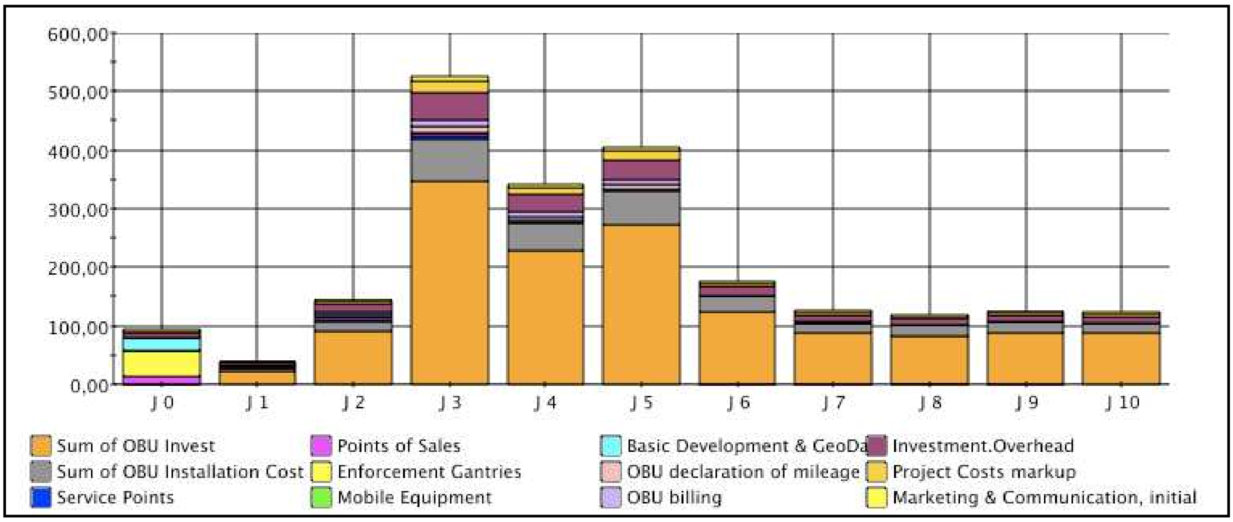


Figure 4-9: Investment over time (in Mio. €)

The OBU investment and installation costs dominate. According to the migration scenario cars become tollable under the ABvM in year 3 to 5. It is during these years that the major part of OBU investment accrues. After year 6, total investment - largely replacement of OBUs - stabilises around € 100 Mio pa.

Operation over time

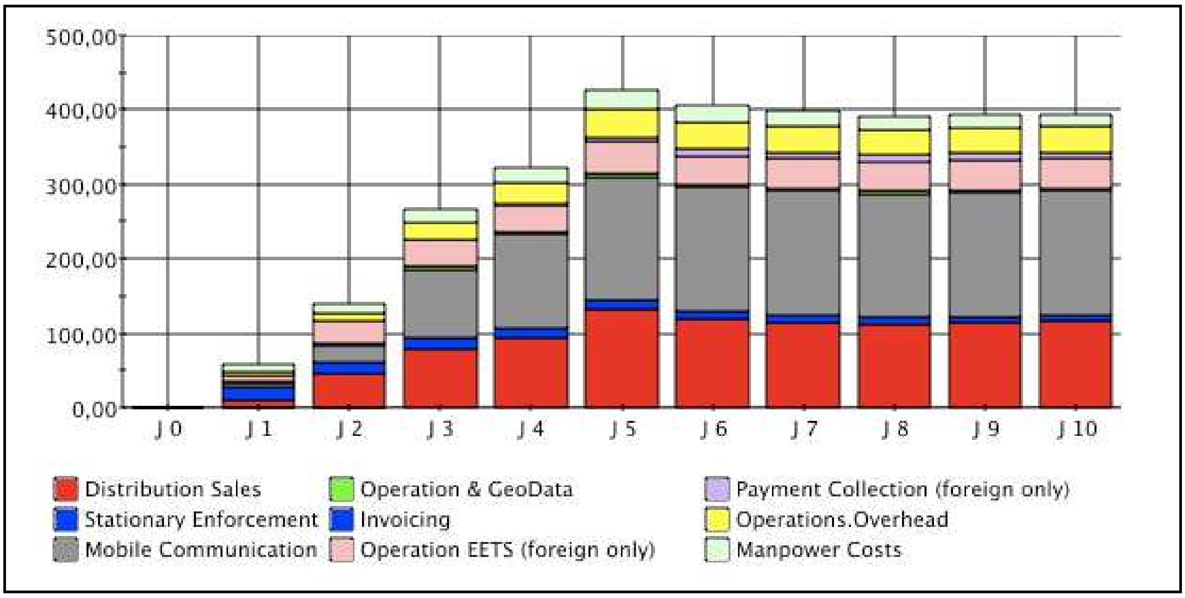


Figure 4-10: Operational cost over time (in Mio €)

Operational cost over time largely depends on the number of OBUs in use. In year 5, all vehicles will be subject to the ABvM scheme, and the total operational cost will stabilise around € 400 million p.a.

„Distribution sales", mobile communication and „EETS operations " make up the major operation cost parts.

Based on the total kilometres p.a. and taking into account the proposed migration scenario, the assumed flat tariff and a residual violator rate of 3%, the revenues (in Mio. €) can be estimated as follows.

		Year										
		J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
HGV	Domestic	0	1.087	1.098	1.109	1.120	1.132	1.143	1.154	1.166	1.177	1.189
	Foreign	0	163	165	166	168	170	171	173	175	177	178
	Sum of Origin Σ	0	1.251	1.263	1.276	1.288	1.301	1.314	1.327	1.341	1.354	1.368
Van	Domestic	0	0	2.645	2.671	2.698	2.725	2.752	2.780	2.807	2.835	2.864
	Foreign	0	0	397	401	405	409	413	417	421	425	430
	Sum of Origin Σ	0	0	3.041	3.072	3.103	3.134	3.165	3.197	3.228	3.261	3.293
Car	Domestic	0	0	0	793	1.587	3.174	3.205	3.237	3.270	3.302	3.336
	Foreign	0	0	0	119	238	476	481	486	490	495	500
	Sum of Origin Σ	0	0	0	912	1.825	3.650	3.686	3.723	3.760	3.798	3.836
Motorcycle	Domestic	0	0	0	0	0	28	29	29	29	30	30
	Foreign	0	0	0	0	0	4	4	4	4	4	4
	Sum of Origin Σ	0	0	0	0	0	33	33	33	34	34	34
Other	Domestic	0	0	0	0	0	0	0	0	0	0	0
	Foreign	0	0	0	0	0	0	0	0	0	0	0
	Sum of Origin Σ	0	0	0	0	0	0	0	0	0	0	0
Sum of Veh Type Σ	Domestic	0	1.087	3.743	4.574	5.405	7.058	7.129	7.200	7.272	7.345	7.418
	Foreign	0	163	561	686	811	1.059	1.069	1.080	1.091	1.102	1.113
	Sum of Origin Σ	0	1.251	4.304	5.260	6.216	8.117	8.198	8.280	8.363	8.447	8.531

Figure 4-11: Estimated revenues over time by vehicle type and origin

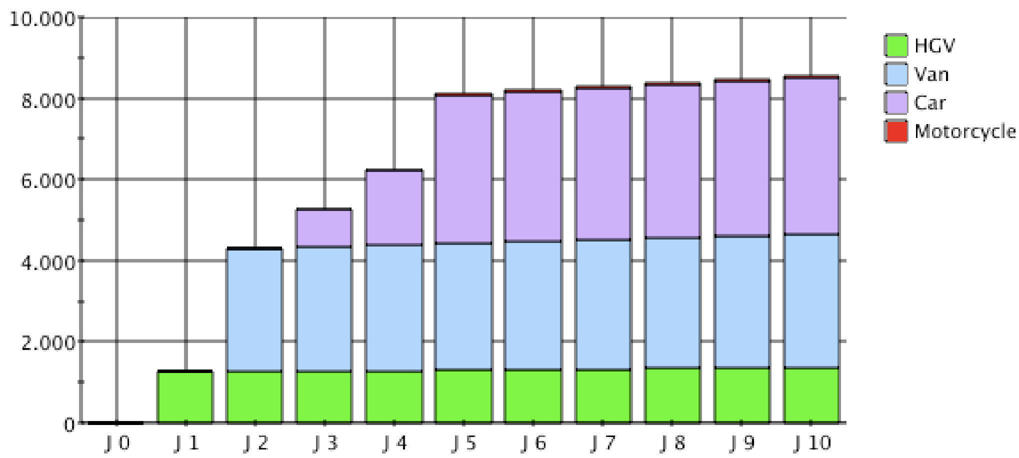


Figure 4-12: Estimated revenues over time by vehicle type

Based on the investment, operation and revenues, the following ratios can be calculated:

Sum Investment J0 to J5	**1.546,218**
Sum Operations + Mobile Enforcement in J5	**426,477**
Ratio Investment / Revenue in J0 to J5	6,1%
Ratio Operation + Mobile Enforcement / Revenue in J5	**5,2%**

Figure 4-13: Investment and Operation Ratios

The total result sheet and the KMP sheet - based on „Cost Format phase 2 v1.0.xls" is generated and provides complete picture of investment and operational cost over time.

Anders Betalen voor Mobiliteit	Project costs markup	3%	Depr term project costs & comm m
VARIANT 5: KMP	Communication markup, initial	1%	
Vodafone	Comm markup, annually	0%	
	IEP	15%	
Base Scenario	VAT	19%	

	Total	**Per annum**	**Per annum**
OBU	*Initial costs*	*Operational costs ex depreciation*	*Depreciation*
On-Board Unit development & production	€ 962	€ -	€ 135
On-Board Unit distribution & registration	€ -	€ 26	€ -
On-Board Unit installation in vehicle	€ 196	€ -	€ 27
Other	€ -	€ -	€ -
Sub total	€ 1.159	€ 26	€ 162
IEP	€ 174	€ 4	€ 24
Total ex VAT	€ 1.333	€ 30	€ 187
VAT	€ 253	€ 6	€ 35
Total incl VAT	€ 1.586	€ 36	€ 222
Total as percentage of Grand Total	74,9%	6,2%	79,9%
Declaration and Customer Care	*Initial costs*	*Operational costs ex depreciation*	*Depreciation*
OBU declaration / communication	€ 50	€ 166	€ 10
Occasional User System	€ 9	€ 26	€ 2
Customer Care	€ 34	€ 79	€ 7
Other	€ -	€ 12	€ -
Sub total	€ 93	€ 284	€ 19
IEP	€ 14	€ 43	€ 3
Total ex VAT	€ 107	€ 327	€ 21
VAT	€ 20	€ 62	€ 4
Total incl VAT	€ 127	€ 389	€ 25
Total as percentage of Grand Total	6,0%	66,6%	9,2%
Payment and Billing	*Initial costs*	*Operational costs ex depreciation*	*Depreciation*
Processing and billing costs	€ 29	€ 4	€ 7
Payment collection costs	€ -	€ 8	€ -
Follow-up costs	€ -	€ -	€ -
Other	€ -	€ 29	€ -
Sub total	€ 29	€ 41	€ 7
IEP	€ 4	€ 6	€ 1
Total ex VAT	€ 33	€ 47	€ 8
VAT	€ 6	€ 9	€ 2
Total incl VAT	€ 39	€ 56	€ 10
Total as percentage of Grand Total	1,9%	9,6%	3,5%

Enforcement		*Initial costs*		*Operational costs ex depreciation*		*Depreciation*
Fixed enforcement stations & labour	€	44	€	10	€	4
Transportable enforcement stations & labour	€	-	€	-	€	-
Mobile enforcement equipment & labour	€	2	€	26	€	1
Enforcement backoffice costs	€	8	€	2	€	2
Other	€	-	€	-	€	-
Sub total	€	54	€	38	€	8
IEP	€	8	€	6	€	1
Total ex VAT	€	62	€	44	€	9
VAT	€	12	€	8	€	2
Total incl VAT	€	74	€	52	€	10
Total as percentage of Grand Total		3,5%		9,0%		3,8%

Miscellaneous		*Initial costs*		*Operational costs ex depreciation*		*Depreciation*
Project costs	€	59	€	-	€	3
Marketing & communication	€	20	€	1	€	1
Generic office and facilities costs	€	20	€	5	€	2
Infrastructure/equipment related costs not covered e	€	13	€	4	€	1
Operational costs not covered elsewhere	€	-	€	-	€	-
Labour costs not covered elsewhere	€	80	€	22	€	-
Other	€	20	€	5	€	-
Sub total	€	212	€	37	€	7
IEP	€	32	€	6	€	1
Total ex VAT	€	244	€	43	€	8
VAT	€	46	€	8	€	2
Total incl VAT	€	290	€	51	€	10
Total as percentage of Grand Total		13,7%		8,7%		3,6%

OVERVIEW		*Initial costs* Totals		*Annual operational costs* Totals		*Annual depreciation* Totals
OBU	€	1.586	€	36	€	222
		74,9%		6,2%		79,9%
Declaration and Customer Care	€	127	€	389	€	25
		6,0%		66,6%		9,2%
Billing and Payment	€	39	€	56	€	10
		1,9%		9,6%		3,5%
Enforcement	€	74	€	52	€	10
		3,5%		9,0%		3,8%
Miscellaneous	€	290	€	51	€	10
		13,7%		8,7%		3,6%
Grand Total		**2.116**		**584**		**278**

Figure 4-14: Cost estimations for the base scenario

4.2 "No foreign users" scenario

For this scenario, it is assumed that foreign users do not fall under the ABvM scheme. They would be exempt from distance-based tolling.

Although foreign users may become liable to purchase a vignette (7-day, 1 month, 1 year) the cost of the vignette or running the vignette system is not considered in the model.

Generally the cost of running a vignette system beside the ABvM scheme can be seen as relatively low, especially if the declaration and customer care, payment and billing, enforcement can be shared between the ABvM and the vignette system.

Not including foreign users in the ABvM scheme has the following consequences:

- Fewer tollable vehicles using fewer OBUs with significant savings in investment and operational cost
- Less transactions
- No revenues from foreign users

The exemption of foreign users may cause problems. Although it is likely that, in the future, a vignette scheme will be instituted in addition to the ABvM scheme, there will still be a problem concerning the non-discriminatory constraint for EU citizens: having domestic users pay under the ABvM scheme and exempting or pricing foreign road usage with a vignette might be seen as discriminatory.

Not considering foreign users under ABvM reduces the total cost of running the system by more than the reduction in total revenues.

Sum Investment J0 to J5	**1.385,887**
Sum Operations + Mobile Enforcement in J5	**334,774**
Ratio Investment / Revenue in J0 to J5	6,3%
Ratio Operation + Mobile Enforcement / Revenue in J5	**4,7%**

Figure 4-15: Investment and operation ratios – "no foreign users" scenario

Anders Betalen voor Mobiliteit	Project costs markup	3%	Depr term project costs & comm m
VARIANT 5: KMP	Communication markup, initial	1%	
Vodafone	Comm markup, annually	0%	
	IEP	15%	
No foreign users scenario	VAT	19%	

		Total		Per annum		Per annum
OBU		*Initial costs*		*Operational costs ex depreciation*		*Depreciation*
On-Board Unit development & production	€	854	€	-	€	120
On-Board Unit distribution & registration	€	-	€	23	€	-
On-Board Unit installation in vehicle	€	174	€	-	€	24
Other	€	-	€	-	€	-
Sub total	€	1.028	€	23	€	144
IEP	€	154	€	3	€	22
Total ex VAT	€	1.182	€	27	€	166
VAT	€	225	€	5	€	31
Total incl VAT	€	1.407	€	32	€	197
Total as percentage of Grand Total		74,2%		6,9%		79,0%
Declaration and Customer Care		*Initial costs*		*Operational costs ex depreciation*		*Depreciation*
OBU declaration / communication	€	47	€	148	€	9
Occasional User System	€	8	€	23	€	2
Customer Care	€	33	€	69	€	7
Other	€	-	€	-	€	-
Sub total	€	88	€	240	€	18
IEP	€	13	€	36	€	3
Total ex VAT	€	102	€	276	€	20
VAT	€	19	€	53	€	4
Total incl VAT	€	121	€	329	€	24
Total as percentage of Grand Total		6,4%		71,7%		9,7%
Payment and Billing		*Initial costs*		*Operational costs ex depreciation*		*Depreciation*
Processing and billing costs	€	26	€	4	€	6
Payment collection costs	€	-	€	1	€	-
Follow-up costs	€	-	€	-	€	-
Other	€	-	€	-	€	-
Sub total	€	26	€	5	€	6
IEP	€	4	€	1	€	1
Total ex VAT	€	29	€	6	€	7
VAT	€	6	€	1	€	1
Total incl VAT	€	35	€	7	€	9
Total as percentage of Grand Total		1,8%		1,5%		3,5%

Enforcement		Initial costs		Operational costs ex depreciation		Depreciation
Fixed enforcement stations & labour	€	44	€	10	€	4
Transportable enforcement stations & labour	€	-	€	-	€	-
Mobile enforcement equipment & labour	€	2	€	26	€	1
Enforcement backoffice costs	€	8	€	2	€	2
Other	€	-	€	-	€	-
Sub total	€	54	€	38	€	8
IEP	€	8	€	6	€	1
Total ex VAT	€	62	€	44	€	9
VAT	€	12	€	8	€	2
Total incl VAT	€	74	€	52	€	10
Total as percentage of Grand Total		3,9%		11,4%		4,2%

Miscellaneous		Initial costs		Operational costs ex depreciation		Depreciation
Project costs	€	53	€	-	€	3
Marketing & communication	€	18	€	0	€	1
Generic office and facilities costs	€	18	€	4	€	2
Infrastructure/equipment related costs not covered e	€	12	€	3	€	1
Operational costs not covered elsewhere	€	-	€	-	€	-
Labour costs not covered elsewhere	€	72	€	17	€	-
Other	€	18	€	4	€	-
Sub total	€	190	€	29	€	7
IEP	€	28	€	4	€	1
Total ex VAT	€	218	€	33	€	7
VAT	€	41	€	6	€	1
Total incl VAT	€	260	€	39	€	9
Total as percentage of Grand Total		13,7%		8,5%		3,6%

OVERVIEW		Initial costs Totals		Annual operational costs Totals		Annual depreciation Totals
OBU	€	1.407	€	32	€	197
		74,2%		6,9%		79,0%
Declaration and Customer Care	€	121	€	329	€	24
		6,4%		71,7%		9,7%
Billing and Payment	€	35	€	7	€	9
		1,8%		1,5%		3,5%
Enforcement	€	74	€	52	€	10
		3,9%		11,4%		4,2%
Miscellaneous	€	260	€	39	€	9
		13,7%		8,5%		3,6%
Grand Total		**1.897**		**459**		**249**

Figure 4-16: Cost estimations for the "no foreign users" scenario

4.3 *"No EETS provider" scenario*

It is assumed that there is no European EETS provider and as a consequence, no EETS OBUs are available.

Under the ABvM scheme, EETS OBUs will be substituted by thin clients but also GNSS cradles or GNSS-enabled handsets. Frequent foreign users will more likely adopt a thin-client solution requiring installation. Occasional foreign users may prefer a GNSS-enabled handset requiring no installation.

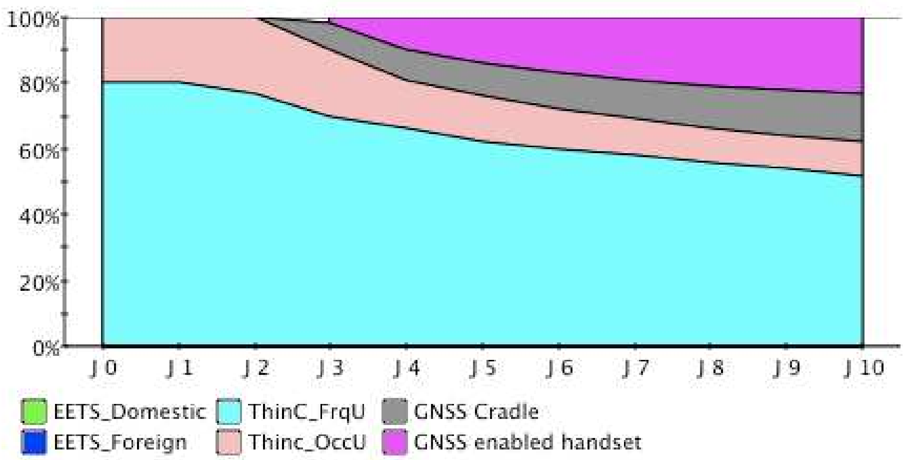


Figure 4-17: Distribution of OBU types as % of total OBUs used - No EETS scenario

All other assumptions remain similar to the base scenario.

Sum Investment J0 to J5	**1.610,368**
Sum Operations + Mobile Enforcement in J5	**431,496**
Ratio Investment / Revenue in J0 to J5	6,4%
Ratio Operation + Mobile Enforcement / Revenue in J5	**5,3%**

Figure 4-18: Investment and operation ratios – "No EETS" scenario

Anders Betalen voor Mobiliteit	Project costs markup	3%	Depr term project costs & comm m
VARIANT 5: KMP	Communication markup, initial	1%	
Vodafone	Comm markup, annually	0%	
	IEP	15%	
No EETS scenario	VAT	19%	

	Total	Per annum	Per annum
OBU	*Initial costs*	*Operational costs ex depreciation*	*Depreciation*
On-Board Unit development & production	€ 1.012	€ -	€ 142
On-Board Unit distribution & registration	€ -	€ 29	€ -
On-Board Unit installation in vehicle	€ 199	€ -	€ 28
Other	€ -	€ -	€ -
Sub total	€ 1.210	€ 29	€ 169
IEP	€ 182	€ 4	€ 25
Total ex VAT	€ 1.392	€ 33	€ 195
VAT	€ 264	€ 6	€ 37
Total incl VAT	€ 1.657	€ 39	€ 232
Total as percentage of Grand Total	75,2%	6,6%	80,2%
Declaration and Customer Care	*Initial costs*	*Operational costs ex depreciation*	*Depreciation*
OBU declaration / communication	€ 52	€ 166	€ 10
Occasional User System	€ 9	€ 29	€ 2
Customer Care	€ 34	€ 86	€ 7
Other	€ -	€ 7	€ -
Sub total	€ 95	€ 288	€ 19
IEP	€ 14	€ 43	€ 3
Total ex VAT	€ 109	€ 331	€ 22
VAT	€ 21	€ 63	€ 4
Total incl VAT	€ 130	€ 394	€ 26
Total as percentage of Grand Total	5,9%	66,7%	9,0%
Payment and Billing	*Initial costs*	*Operational costs ex depreciation*	*Depreciation*
Processing and billing costs	€ 31	€ 4	€ 8
Payment collection costs	€ -	€ 18	€ -
Follow-up costs	€ -	€ -	€ -
Other	€ -	€ 17	€ -
Sub total	€ 31	€ 39	€ 8
IEP	€ 5	€ 6	€ 1
Total ex VAT	€ 35	€ 45	€ 9
VAT	€ 7	€ 9	€ 2
Total incl VAT	€ 42	€ 54	€ 10
Total as percentage of Grand Total	1,9%	9,1%	3,6%

Enforcement		Initial costs		Operational costs ex depreciation		Depreciation
Fixed enforcement stations & labour	€	44	€	10	€	4
Transportable enforcement stations & labour	€	-	€	-	€	-
Mobile enforcement equipment & labour	€	2	€	26	€	1
Enforcement backoffice costs	€	8	€	2	€	2
Other	€	-	€	-	€	-
Sub total	€	54	€	38	€	8
IEP	€	8	€	6	€	1
Total ex VAT	€	62	€	44	€	9
VAT	€	12	€	8	€	2
Total incl VAT	€	74	€	52	€	10
Total as percentage of Grand Total		3,3%		8,9%		3,6%

Miscellaneous		Initial costs		Operational costs ex depreciation		Depreciation
Project costs	€	61	€	-	€	3
Marketing & communication	€	20	€	1	€	1
Generic office and facilities costs	€	21	€	6	€	2
Infrastructure/equipment related costs not covered e	€	14	€	4	€	1
Operational costs not covered elsewhere	€	-	€	-	€	-
Labour costs not covered elsewhere	€	83	€	22	€	-
Other	€	21	€	6	€	-
Sub total	€	221	€	37	€	8
IEP	€	33	€	6	€	1
Total ex VAT	€	254	€	43	€	9
VAT	€	48	€	8	€	2
Total incl VAT	€	302	€	51	€	10
Total as percentage of Grand Total		13,7%		8,7%		3,6%

OVERVIEW		Initial costs Totals		Annual operational costs Totals		Annual depreciation Totals
OBU	€	1.657	€	39	€	232
		75,2%		6,6%		80,2%
Declaration and Customer Care	€	130	€	394	€	26
		5,9%		66,7%		9,0%
Billing and Payment	€	42	€	54	€	10
		1,9%		9,1%		3,6%
Enforcement	€	74	€	52	€	10
		3,3%		8,9%		3,6%
Miscellaneous	€	302	€	51	€	10
		13,7%		8,7%		3,6%
Grand Total		**2.204**		**591**		**289**

Figure 4-19: Cost estimations for the “no EETS provider” scenario

4.4 *"Big bang - no migration" scenario*

This scenario envisages that all vehicles become tollable as early as from year 1. Full operation thus commences from year 1.

Rolling out such a large-scale operation in just about two years has many adverse consequences:

- All initial investments are made in year 0 and year 1, resulting in significantly more interest for financing
- More OBUs will be swapped in the year 1 to 5 compared to the baseline scenario, resulting in higher reinvestment
- More and earlier investment in PoS, service points and enforcement.

Significant demand problems with the „big bang" scenario are foreseen:

- All production and distribution activities need to be fulfilled within a few months, resulting in higher cost. Therefore a huge demand will have to be met in the few months predating the „go live". Existing resources such as fuel stations, to be used as „points of sales", may not be able to cope with the demand.

Demand problems may be mitigated by extending the development and preparation phase (e.g. 2-3 years rather than 1 year). However, this would result in higher project costs with no direct revenues collected from the ABvM scheme. Conceivably, revenues from the existing vehicles taxation scheme may need to be allocated to the operator during an extended development and preparation phase.

All other assumptions remain the same as in the base scenario.

Sum Investment J0 to J5	**2.308,703**
Sum Operations + Mobile Enforcement in J5	**441,452**
Ratio Investment / Revenue in J0 to J5	5,6%
Ratio Operation + Mobile Enforcement / Revenue in J5	**5,3%**

Figure 4-20: Investment and Operation Ratios - „big bang"

Anders Betalen voor Mobiliteit	Project costs markup	3% Depr term project costs & comm m
VARIANT 5: KMP	Communication markup, initial	1%
Vodafone	Comm markup, annually	0%
	IEP	15%
Big Bang - no migration scenario	VAT	19%

	Total	Per annum	Per annum
OBU	*Initial costs*	*Operational costs ex depreciation*	*Depreciation*
On-Board Unit development & production	€ 1.500	€ -	€ 210
On-Board Unit distribution & registration	€ -	€ 26	€ -
On-Board Unit installation in vehicle	€ 300	€ -	€ 42
Other	€ -	€ -	€ -
Sub total	€ 1.801	€ 26	€ 252
IEP	€ 270	€ 4	€ 38
Total ex VAT	€ 2.071	€ 30	€ 290
VAT	€ 393	€ 6	€ 55
Total incl VAT	€ 2.464	€ 36	€ 345
Total as percentage of Grand Total	78,0%	5,9%	84,1%
Declaration and Customer Care	*Initial costs*	*Operational costs ex depreciation*	*Depreciation*
OBU declaration / communication	€ 53	€ 182	€ 11
Occasional User System	€ 11	€ 26	€ 2
Customer Care	€ 43	€ 78	€ 9
Other	€ -	€ 13	€ -
Sub total	€ 106	€ 299	€ 21
IEP	€ 16	€ 45	€ 3
Total ex VAT	€ 122	€ 344	€ 24
VAT	€ 23	€ 65	€ 5
Total incl VAT	€ 145	€ 409	€ 29
Total as percentage of Grand Total	4,6%	67,6%	7,1%
Payment and Billing	*Initial costs*	*Operational costs ex depreciation*	*Depreciation*
Processing and billing costs	€ 31	€ 4	€ 8
Payment collection costs	€ -	€ 7	€ -
Follow-up costs	€ -	€ -	€ -
Other	€ -	€ 29	€ -
Sub total	€ 31	€ 40	€ 8
IEP	€ 5	€ 6	€ 1
Total ex VAT	€ 36	€ 47	€ 9
VAT	€ 7	€ 9	€ 2
Total incl VAT	€ 43	€ 55	€ 11
Total as percentage of Grand Total	1,4%	9,1%	2,6%

Enforcement		Initial costs		Operational costs ex depreciation		Depreciation
Fixed enforcement stations & labour	€	44	€	10	€	4
Transportable enforcement stations & labour	€	-	€	-	€	-
Mobile enforcement equipment & labour	€	2	€	26	€	1
Enforcement backoffice costs	€	8	€	2	€	2
Other	€	-	€	-	€	-
Sub total	€	54	€	38	€	8
IEP	€	8	€	6	€	1
Total ex VAT	€	62	€	44	€	9
VAT	€	12	€	8	€	2
Total incl VAT	€	74	€	52	€	10
Total as percentage of Grand Total		2,3%		8,7%		2,6%

Miscellaneous		Initial costs		Operational costs ex depreciation		Depreciation
Project costs	€	88	€	-	€	4
Marketing & communication	€	29	€	1	€	1
Generic office and facilities costs	€	30	€	6	€	3
Infrastructure/equipment related costs not covered e	€	20	€	4	€	2
Operational costs not covered elsewhere	€	-	€	-	€	-
Labour costs not covered elsewhere	€	120	€	23	€	-
Other	€	30	€	6	€	-
Sub total	€	316	€	38	€	11
IEP	€	47	€	6	€	2
Total ex VAT	€	364	€	44	€	12
VAT	€	69	€	8	€	2
Total incl VAT	€	433	€	52	€	15
Total as percentage of Grand Total		13,7%		8,7%		3,6%

OVERVIEW		Initial costs Totals		Annual operational costs Totals		Annual depreciation Totals
OBU	€	2.464	€	36	€	345
		78,0%		5,9%		84,1%
Declaration and Customer Care	€	145	€	409	€	29
		4,6%		67,6%		7,1%
Billing and Payment	€	43	€	55	€	11
		1,4%		9,1%		2,6%
Enforcement	€	74	€	52	€	10
		2,3%		8,7%		2,6%
Miscellaneous	€	433	€	52	€	15
		13,7%		8,7%		3,6%
Grand Total		**3.159**		**605**		**410**

Figure 4-21: Cost estimations for the "Big bang" scenario

4.5 "HGVs and vans only" scenario

This scenario envisages that only HGVs and vans become tollable under ABvM in year 1 and 2 respectively.

For modelling purposes the following consequences were taken into account:

- Given the commercial use of HGV and vans, more post payment is likely
- Proportionally to the lower number of tollable vehicles, less distribution, installation and customer service facilities will be required. However, to ensure non-discriminatory convenience for the user, a significant number of facilities will still need to be provided.

All other assumptions remain the same as in the base scenario.

Sum Investment J0 to J5	**362,095**
Sum Operations + Mobile Enforcement in J5	**141,102**
Ratio Investment / Revenue in J0 to J5	1,9%
Ratio Operation + Mobile Enforcement / Revenue in J5	**3,2%**

Figure 4-22: Investment and operation ratios – "HGVs and vans only" scenario

Anders Betalen voor Mobiliteit	Project costs markup	3%	Depr term project costs & comm m
VARIANT 5: KMP	Communication markup, initial	1%	
Vodafone	Comm markup, annually	0%	
	IEP	15%	
Only HGV and Vans Scenario	VAT	19%	

		Total		Per annum		Per annum
OBU		*Initial costs*		*Operational costs ex depreciation*		*Depreciation*
On-Board Unit development & production	€	169	€	-	€	24
On-Board Unit distribution & registration	€	-	€	7	€	-
On-Board Unit installation in vehicle	€	34	€	-	€	5
Other	€	-	€	-	€	-
Sub total	€	203	€	7	€	28
IEP	€	30	€	1	€	4
Total ex VAT	€	234	€	8	€	33
VAT	€	44	€	2	€	6
Total incl VAT	€	278	€	10	€	39
Total as percentage of Grand Total		56,1%		5,2%		57,9%
Declaration and Customer Care		*Initial costs*		*Operational costs ex depreciation*		*Depreciation*
OBU declaration / communication	€	26	€	23	€	5
Occasional User System	€	5	€	7	€	1
Customer Care	€	20	€	22	€	4
Other	€	-	€	9	€	-
Sub total	€	52	€	61	€	10
IEP	€	8	€	9	€	2
Total ex VAT	€	59	€	70	€	12
VAT	€	11	€	13	€	2
Total incl VAT	€	70	€	84	€	14
Total as percentage of Grand Total		14,2%		43,3%		21,0%
Payment and Billing		*Initial costs*		*Operational costs ex depreciation*		*Depreciation*
Processing and billing costs	€	4	€	4	€	1
Payment collection costs	€	-	€	1-	€	-
Follow-up costs	€	-	€	-	€	-
Other	€	-	€	21	€	-
Sub total	€	4	€	24	€	1
IEP	€	1	€	4	€	0
Total ex VAT	€	5	€	27	€	1
VAT	€	1	€	5	€	0
Total incl VAT	€	5	€	33	€	1
Total as percentage of Grand Total		1,1%		16,9%		2,0%

Enforcement		*Initial costs*		*Operational costs ex depreciation*		*Depreciation*
Fixed enforcement stations & labour	€	44	€	10	€	4
Transportable enforcement stations & labour	€	-	€	-	€	-
Mobile enforcement equipment & labour	€	2	€	26	€	1
Enforcement backoffice costs	€	8	€	2	€	2
Other	€	-	€	-	€	-
Sub total	€	54	€	38	€	8
IEP	€	8	€	6	€	1
Total ex VAT	€	62	€	44	€	9
VAT	€	12	€	8	€	2
Total incl VAT	€	74	€	52	€	10
Total as percentage of Grand Total		14,9%		27,1%		15,6%

Miscellaneous		*Initial costs*		*Operational costs ex depreciation*		*Depreciation*
Project costs	€	14	€	-	€	1
Marketing & communication	€	5	€	0	€	0
Generic office and facilities costs	€	5	€	2	€	0
Infrastructure/equipment related costs not covered e	€	3	€	1	€	0
Operational costs not covered elsewhere	€	-	€	-	€	-
Labour costs not covered elsewhere	€	19	€	6	€	-
Other	€	5	€	2	€	-
Sub total	€	50	€	11	€	2
IEP	€	7	€	2	€	0
Total ex VAT	€	57	€	12	€	2
VAT	€	11	€	2	€	0
Total incl VAT	€	68	€	15	€	2
Total as percentage of Grand Total		13,7%		7,5%		3,5%

OVERVIEW		*Initial costs* Totals		*Annual operational costs* Totals		*Annual depreciation* Totals
OBU	€	278	€	10	€	39
		56,1%		5,2%		57,9%
Declaration and Customer Care	€	70	€	84	€	14
		14,2%		43,3%		21,0%
Billing and Payment	€	5	€	33	€	1
		1,1%		16,9%		2,0%
Enforcement	€	74	€	52	€	10
		14,9%		27,1%		15,6%
Miscellaneous	€	68	€	15	€	2
		13,7%		7,5%		3,5%
Grand Total		**496**		**193**		**67**

Figure 4-23: Cost estimations for the “HGVs and vans only” scenario

4.6 Scenario Summary

The following table provides a summary of results derived from the different scenarios.

	Baseline	No foreign users	No EETS	Big bang	HGVs and vans only
investment (J0 to J5) in Mio €	1.546.218	1.385.887	1.610.368	2.308.703	362.095
operation + mobile enforcement in Mio €	426.477	334.774	431.496	441.452	141.102
investment / revenue ratio	6,1%	6,3%	6,4%	5,6%	1,9%
operation + mobile enforcement / revenue ratio in J5	5,2%	4,7%	5,3%	5,3%	3,2%

Figure 4-24: Result summary of the 5 different scenarios

As expected, the „big bang“ scenario is the most expensive one on the investment and operational side. However, the investment / revenue and operation / revenue ratios are comparable to those of the baseline and „no EETS“ scenarios. This is due to the earlier revenue generation.

The baseline, „no foreign user“ and „no EETS“ scenarios all have similar investment / revenue and operation / revenue ratios in the range of just over 6% and around 5% respectively.

The „no EETS“ scenario has a slightly higher investment than the baseline scenario. The main reason for this is that EETS OBUs will need to be substituted by thin-client OBUs. EETS OBUs from foreign EETS providers are paid through operational expenses (5% of revenue generated by foreign EETS units under ABvM). Because on average the ABvM operator expenses are slightly higher than the EETS fee (just over 5%), the total investment is slightly higher in the „no EETS“ scenario than under the baseline scenario.

The „ HGVs and vans only“ scenario clearly stands out. It has by far the best investment / revenue and operation / revenue ratios with 1,9% and 3,2% respectively. Especially the operation / revenue ratio (not yet considering IEP and VAT) is well below the 5% benchmark. The reasons for these favourable ratios are:

- HGVs and vans account for disproportionably more yearly kilometres on all roads subject to ABvM
- HGVs and vans pay higher tolls per kilometre because their environmental impact (wear and tear on the road, noise, pollution) is larger than those of cars or motorcycles
- Including all HGVs AND vans results in significantly large numbers of dedicated thin client OBUs, leading to better OBU pricing (economies of scale)

The summary table suggests that the most economic solution - considering the investment / revenue and operation / revenue ratios - would be to introduce road charging on all roads for all HGVs and vans only.

However, if road charging under ABvM scheme is to be introduced for all vehicles, the baseline scenario proves to be the optimum solution because:

- All users are treated in an equal way i.e. no one is discriminated in violation of EU regulations (this would potentially be the case under the „no foreign user" scenario)
- Compared to the other two „all vehicles included" scenario, it is the least expensive solution
- it is a balanced risk / cost / revenue solution thanks to the stepwise integration of different vehicles types over 5 years.

5 Migration scenarios (D-5)

Introducing the KMP for all vehicles on all roads with tariffs depending on time and location implies large technical, financial and political risks. On the other hand, less ambitious forms of road user charging – e.g. limited to freight, selected areas or road types – will encounter stronger political opposition and show reduced results in terms of environment, congestion and fair allocation of costs.

The Principal requested the contractors to compose optimum scenarios for stepwise introduction of the KMP – in view of the proposed KMP solution as a final step. Criteria for optimum migration scenarios are:

- Potential to mitigate technical and financial risks
- Potential to show immediate results in terms of objectives (fairness, congestion, environment)
- Minimum effort and complexity for the users
- Minimum cost
- Transparency of the implementation strategy (simple message to the citizen)
- Re-usability of investments for subsequent steps in the implementation
- Possibility to integrate toll roads in the overall architecture

In order to address these criteria, Vodafone proposes the following migration scenario, which is structured into three main roll-out phases, where “t” is the estimated start year of the KMP (2012):

Phase	Time	Vehicle classes	Type	Est. # of vehicles
1	t	HGVs (NL + foreigners)	Mandatory	240.000
2	t+1	Vans (NL + foreigners)	Mandatory	992.000
3 4	t+2	All passenger cars (NL + OUS)	Voluntary	1.000.000
4	t+3	All passenger cars (NL + OUS)	Voluntary	2.800.000
5	t+4	All passenger cars (NL + OUS + foreigners + MC)	Mandatory	4.500.000

Figure 5-1: Migration scenario for the ABvM KMP scheme

In the first roll out phase (t) road usage charging will be mandatory for all Dutch and foreign HGVs from a certain reference date on all public and private roads (any mileage driven) in the Netherlands. This user group is relatively small and will in all probability already be predominantly equipped with German LKW OBUs or interoperable EETS OBUs. In addition, this user group will already be used to different charging schemes within Europe and will have gained substantial experience regarding their special needs and behaviour. As HGVs are obliged to operate tachographs, these might be used for additional enforcement purposes and plausibility checks in case of uncertainties.

In roll-out phase two (t+1 year), road-usage charging will become mandatory on all public and private roads (any mileage driven) in the Netherlands for all Dutch and foreign vans from a certain reference date. System load will increase by a factor of 5 as about 1.000.000 vans expected. As most vans probably will not be pre-equipped with OBUs, the OBU supply facilities and registration processes[15] will need to be enhanced accordingly, but not yet to full expansion stage. Valuable experience can thus be gained ahead of the main expansion stages one year later.

In rollout phase three and four (t+2 and 3 years), road usage charging will become available on all public and private roads (any mileage driven) in the Netherlands for all Dutch passenger cars from a certain reference date on a voluntary basis. Contrary to the implementation of the ERUC schemes for heavy good vehicles and vans (mandatory for all vehicles at the time of implementation), passenger car owners will have the choice to declare their taxes traditionally (MRB) or use an OBU instead.

This transition period permits a continuous and homogenous growth of the system. It can be assumed that in a first step mainly those car owners will use the OBU opportunity that travel below average by vehicle and therefore have a financial benefit from the system. They can be classified as “friendly users”. In contrast to those friendly users, the so-called “unfriendly users” will travel above average, cause the highest network load and tend to cheat the system. Before this user group is integrated into the ERUC scheme, valuable experience can be gained, especially in the enforcement processes and supporting plausibility check processes.

In roll-out phase five (t+4 years) road usage charging will become mandatory on all public and private roads (any mileage driven) in the Netherlands for all Dutch and foreign passenger cars from a certain reference date. The special challenges of this phase are the abovementioned “unfriendly users” and the occasional-user scheme (including OBUs in return for payment of rent). Until that stage, the OUS facilities have to support a small number of foreign HGVs and vans only. An assumed fraction of more than 95 % of all OUS (foreign passenger cars) will needs to be catered for the first time at this stage.

[15] Telephone, fax or web-based ordering, software downloading, snail mail, installation at a service facility, distribution and registration facilities at points of sales (fuel stations, Vodafone outlets, etc.)

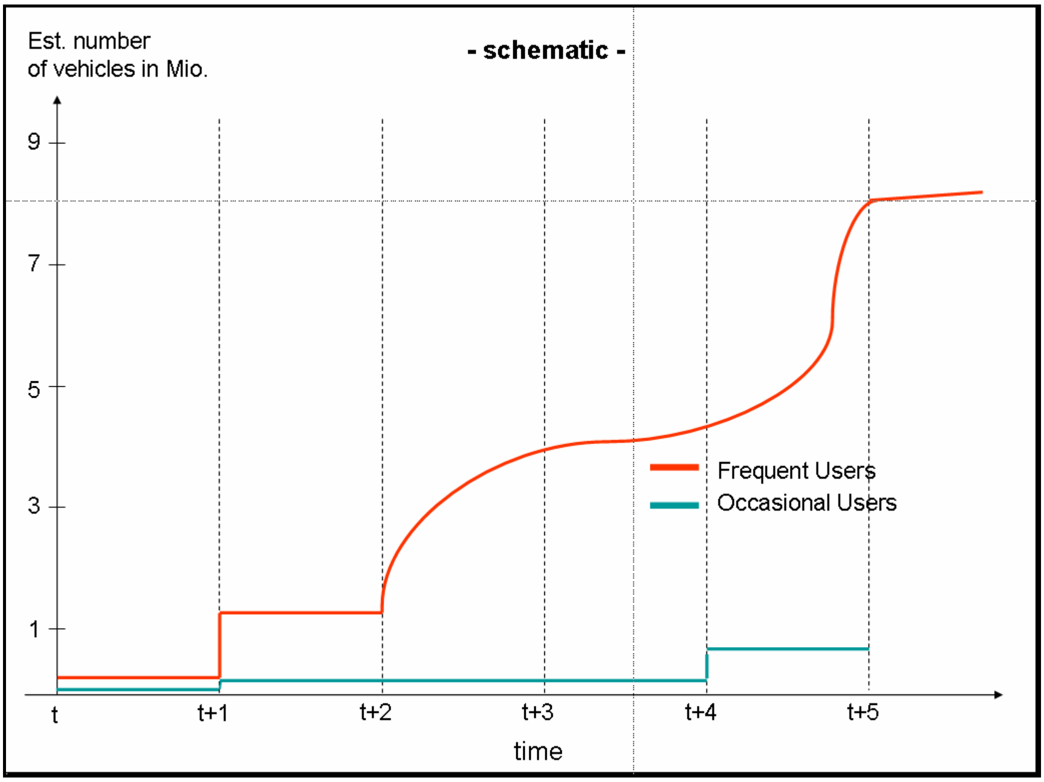


Figure 5-2: Schematic allocation of frequent and occasional users during migration period

The migration scenario described above ensures some important advantages:

_ Reduction of technical, financial and political risks thanks to incremental and continuous learning and improvement

_ Reduction of costs caused by system failures, thanks to incremental and continuous learning and improvement

_ Increase in the overall acceptances thanks to a fair procedure (transition from HGVs to passenger cars, voluntary transition period with financial advantages) and convenience (simple message to the citizen)

_ Maximum utilisation of existing and easy-to-gain ERUC experience (friendly-user concept)

_ Full re-usability of investments for the subsequent steps in the implementation

_ Full integration of otherwise-tolled roads in the overall architecture, as any road (mileage) is charged from the very beginning

6 Risk analysis (D-6)

The objective of the ABvM project is a balanced and stable introduction of a Kilometre Pricing System in 2012 that complies with the functional requirement specification.

There are several risks that may prevent the objective of the project being met, each associable with specific consequences (time, cost, loss of functionality, other) and a specific probability of occurrence. A severity index multiplies the assessments for the consequence and probability of occurrence of a special risk, indicating the priority of the risk.[16] The following table shows the top ten risks and their assessment:

Risk Event	RS	C	RP	SI	PP	Mitigation Measure	Risk Owner
Political support for the project proves not sufficient – ABvM KMP to be skipped	Pol	4	3	12	DE	Continuously inform politicians and society about the benefits	Ministry
Fraud rate turns out higher than expected incl. significant revenue losses	Soc	4	3	12	OP	A) Increase mobile enforcement dramatically B) Start information campaigns	EFC Operator Ministry
No European-wide ERUC solution, therefore no interoperable OBUs, no EETS provider	Pol	3	3	9	DE	Support political processes by proactive lobbying	EC, Ministry
Full commercial start of Galileo postponed by more than 1 year	Tech Mar	3	3	9	IM	European companies to provide commercial support by	European companies
Data privacy and security concept rejected by the data protection authority	Pol	3	3	9	DE	Involvement of data protection authority from early on in the project	Ministry
Technology of network-enabled enforcement turns out to unviable	Tech	4	2	8	DE	A) Conduct intensive research and development B) Start comprehensive field tests in NL C) Plan a DSRC scenario as an alternative solution	Vodafone Ministry Ministry
GNSS-enabled handsets not available in 2014 or low market penetration	Mar	3	2	6	OP	Use of surrogate products: dedicated thin client or GNSS-enabled cradle	EFC Operator
Users prove unable to operate handset solutions, causing acceptance to decrease	Mar	3	2	6	OP	Communication and training programmes	EFC Operator
No dedicated cellular network spectrum available for enforcement purposes	Mar	4	1	4	DE	Address the business case of MNOs	EFC Operator

[16] The classification and assessment scheme for the different risks are based on the guidelines of the Ministry, as set out in the "Risk Inventory Assesment.doc" document

Average prices of OBUs / cradles / handsets not decreasing as expected	Mar	4	1	4	OP	Ensure a legal environment for lively competition	Ministry
Handset-based approach turns out not to be feasible due to legal restrictions (in-car use without external aerial)	Pol	2	2	4	DE	Provide external aerial	EFC Operator
GNSS accuracy for chosen tariff scenario proves insufficient (corridor identification on secondary roads)	Tech	2	2	4	DE	Implement additional localization means (beacon)	EFC Operator
Back-office capacity turns out to be insufficient	Tech	4	1	4	OP	Investments in back office enhancements	EFC / EETS operator
State-of-the-art digital map data provided by the digital map manufactures does not fulfil RUC quality requirements	Tech	2	2	4	DE	Digital maps have to be improved by individual measurements	EFC / EETS operator
Mobile network capacities proves insufficient	Tech	3	1	3	OP	Investments in network enhancement	Mobile network operator

Figure 6-1: ABvM risk analysis

Legend

C	Consequence
DE	Development phase
EC	European Commission
IM	Implementation phase
Mar	Market developments risks
OP	Operation phase
Pol	Politics and policy risks
PP	Project phase
RP	Risk probability
RS	Risk source
SI	Severity index
Soc	Societal acceptance risks
Tech	Technology risks

7 Comments on the requirement specifications (D-7)

The Ministry has asked the contractors of the second round of the market consultation to comment in detail on the current requirement specifications (Version 0.2).

The following table contains an overview of the requirement specifications and the related comments by Vodafone. The proposed changes in the requirement specifications are contained in Vodafone's ABvM system design, as it is described in the main chapters 3 to 5.

System functionality		**Comments by Vodafone**
Requirement [1]	Road user charging shall be based upon the **distance travelled** with a vehicle in the Netherlands.	Agreed. For clarification: "**any** distance travelled".
Requirement [2]	Road user charging shall be differentiated on the basis of **time.**	Agreed. Time granularity should be at least one second in order to have a fair differentiation of tariffs.
Requirement [3]	Road user charging shall be differentiated on the basis of the **location** of the vehicle**.**	Agreed.
Requirement [4]	Road user charging shall be differentiated on the basis of **vehicle characteristics.**	Agreed. Characteristics need to be enforceable.
Requirement [5]	Road user charging shall be introduced on **all roads** in the Netherlands.	Any distance travelled on **and off road** with a vehicle in the Netherlands should be charged. Requirement [5] should be skipped.
Requirement [6]	The road pricing system shall have adequate **flexibility in its design** to allow changes in the parameters for road user charging as mentioned in requirements [1] to [5].	Agreed. Need to be restricted for requirements 1 to 4. All parameter changes need to be activated for all dedicated ERUC devices at the same time to guarantee a deterministic behaviour.
Requirement [7]	The road pricing system shall be **'free-flow'**.	Agreed
Users		**Comments by Vodafone**
Requirement [8]	**All road users** shall be charged for road use.	No. All **vehicle users** shall be charged for any distance travelled.
Requirement [9]	The road pricing system shall include possibilities/facilities to charge **occasional road users.**	ERUC should be mandatory for Dutch vehicle users as any distance travelled will be charged. OUS schemes for foreign OUS users only.
Requirement [10]	The road pricing system shall include possibilities/facilities to charge road users with **foreign number plates**.	Covered by requirement 9.
Technological requirements		**Comments by Vodafone**
Requirement [11]	The road pricing system shall comply with the **European directive** on the interoperability of electronic road toll systems (EU-directive 2004/52/EC)	Agreed, but future technologies such as UMTS and network-enabled enforcement need to remain possible as well. Directive refers to GSM/GPRS only.

Requirement [12]	The road pricing system shall be sufficiently **reliable** to ensure correct and adequate road user charging. In particular: Road users shall be adequately protected against over-charging	No over-charging should be tolerated. In case of under-charging, system unreliability should be equal to all users.
Requirement [13]	The road pricing system shall be sufficiently **reliable** to ensure correct and adequate road user charging. In particular the road pricing service organisation shall be adequately protected against loss of income due to system failure	Risk of income losses should be covered by the government. This would eliminate the need to make a monetary provision for such losses, resulting in significant cost reductions.
Requirement [14]	The road pricing system shall adequately protect its users against **discomfort.**	Level of acceptable "discomfort" needs to be defined in more detail.
Requirement [15]	The actual costs for driving (road charge) shall be **visible in the vehicle**.	This requirement needs to be skipped due to cost implications and safety reasons.
Requirement [16]	The road pricing system shall be sufficiently **safe and easy to use** (human machine interaction) to avoid dangerous behaviour and social exclusion.	Agreed, non-visibility of actual costs is important for safety.
Costs		**Comments by Vodafone**
Requirement [17]	The **costs for development and initial implementation** of the road pricing system shall not exceed € 2,200 million	Agreed
Requirement [18]	The annual **costs for operation and enforcement** of the road pricing system shall not exceed **5%** of the system revenue.	Requirement should be changed to a more realistic target ratio.
Comments on Implementation		**Comments by Vodafone**
Requirement [19]	System developments for **acceleration scenarios** shall be able to migrate into the general road pricing system.	Agreed
Requirement [20]	The road pricing system shall be designed, developed and built in such way that **different implementation scenarios** can be supported.	Agreed. EETS provider should be considered within the implementation scenarios.
Requirement [21]	The road pricing system shall be designed, developed and built in such way that **future developments** can be incorporated.	Agreed. Implementation should be based on existing standards and pre-standards.
Requirement [22]	The road pricing system shall have adequate capacity to charge the road use of **8,159,000** vehicles	Agreed. For clarification: "distance travelling" instead of "road use".
Security and privacy		**Comments by Vodafone**

Requirement [23]	The road pricing system shall have adequate **security measures** to: • Prevent fraudulent use of the system • Detect fraudulent use of the system • Recover from fraudulent use of the system	Agreed
Requirement [24]	The road pricing system shall comply with national and international **privacy** regulations (Wet Bescherming Persoonsgegevens (WBP) and EU-directive 95/46/EC)	Agreed

Figure 7-1: Comments on the requirement specifications

8 Appendix

8.1 Functional system overview legend

The following figure comprises the functional system overview of a reliable electronic road-usage charging scheme for the Netherlands on basis of utilized mobile network components.

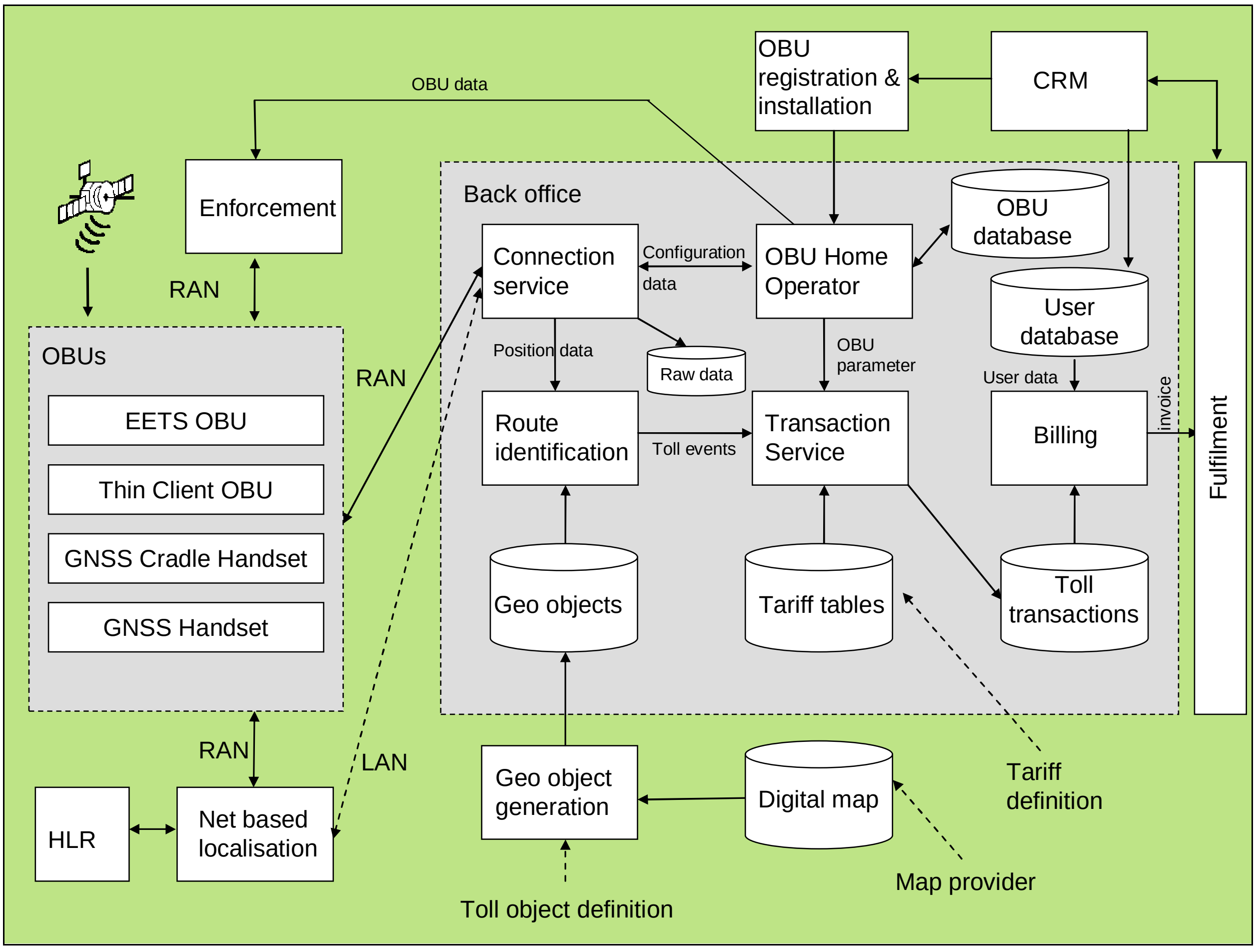


Figure 8-1: Functional system overview of the ABvM ERUC scheme

All OBU and handset variants are based on a number of common principles:[17]

- GPS pre-processing, comprising filtering and plausibility check
- Polygon approximation: data compression dependent on vehicle movements
- Communication module, including telegram queues and handling

[17] OBU functionality is discussed in more detail in chapter 3.5.1 "Thin-client and mobile-phone-based approaches"

_ OBU status control, error-handling logging, configuration management
_ Remote software update
_ Security components, comprising encryption and signature

Enforcement

_ OBU or handset set triggered via cellular network (stationary, or mobile units) to send status to the enforcement entity
_ OBU status is checked for plausibility and completeness
_ Data from OBU enforcement equipment (e.g. camera, size measurement) is verified against OBU data from OBU database
_ Data from enforcement and from OBU is synchronized with a time base (e.g. GSM time signal)

Connection service (OBE-proxy)

_ Routes incoming and outgoing telegrams
_ Encrypts and decrypts telegrams
_ Stores raw data for logging functionality

OBU home operator (OBU management)

_ Front end to OBU data base
_ Handles all accesses to OBU data base
_ Interface to connection service, configuration data including software and keys
_ Interface to transaction service for OBU-specific data e.g. vehicle or emission class
_ Interface to enforcement for OBU-specific data and OBU-ID number plate-mapping
_ Interface to OBU registration for entering or changing OBU/customer data

OBU database

_ Stores all OBU-specific data e.g. OBU-ID, number plate, vehicle data, …

User database

_ Stores all customer-specific data e.g. OBU-ID, customer information, means of payment
_ Interface to billing in order to map OBU-ID to customer

Raw data

_ Database for logging all incoming raw data (e.g. position, error log, …) to be used as proof in case of customer complaints

Route identification

_ Interpolation of compressed position data
_ Distance measurement
_ Geo-object identification (e.g. corridors, zones, virtual gantries)
_ Hierarchical handling of geo objects and geo-object types

Transaction service

_ Assessing toll events with tariffs according to time- and vehicle-specific data

Toll transactions

_ Toll events with computed charge

Billing

_ Generating invoices from toll transactions
_ Utilizing the billing capabilities of the mobile network providers

Geo objects

GNSS / GPRS based ERUC allows the definition and adoption of various geo objects, as specified in ISO pre-standard 17575:

_ corridors
_ zones
_ geo domains
_ virtual gantries
_ grids

Tariff tables

_ Tariff structures depending on time and vehicle data

Geo-object generation

_ Importing and filtering digital maps (incremental update)
_ Extracting external specified toll objects
_ Analysis of geo objects for robustness
_ Generation of geo objects suitable for route identification

Digital map

_ Standard format digital map (e.g. GDF or GML)

Net-based localisation

_ Uses the mobile network infrastructure to localize a mobile device in order to support GPS localization, e.g. in areas where GPS is not available (tunnels) or where the GPS accuracy is not sufficient to distinguish several roads

HLR

_ Home-location register of mobile network provider
_ Resolves temporary identification numbers

OBU registration/installation

_ All new registration, de-registration and registration changes are requested to this entity

CRM

_ All information of new charge payers and vehicles (e.g. number plate, country of registration, maximum permitted weight, number of axles on trailer unit, contract data , payment means, exemptions) need to be entered into the CRM system

Fulfilment

_ Invoices to be issued to customers e.g. on a monthly or variable cycle.
_ Fulfilment department to print and issue all invoices to customers

8.2 Thin-client battery-based range calculation

$$range\,[km] = \frac{effectice\ capacity\,[Wh]}{consumption\,[{}^{Ws}/_{km}]};$$

- Exemplary parameter values:
  - _Battery capacity: 2000mAh @ 12V
  - _Relative effective capacity for GNSS receiver: estimated 10%
  - _Consumption per km: 3-20 Ws/km based on trials

→Range [km] = ~2800km (motorways)

→Range [km] = ~ 400km (urban)

8.3 Flow-chart of polygon approximation in general

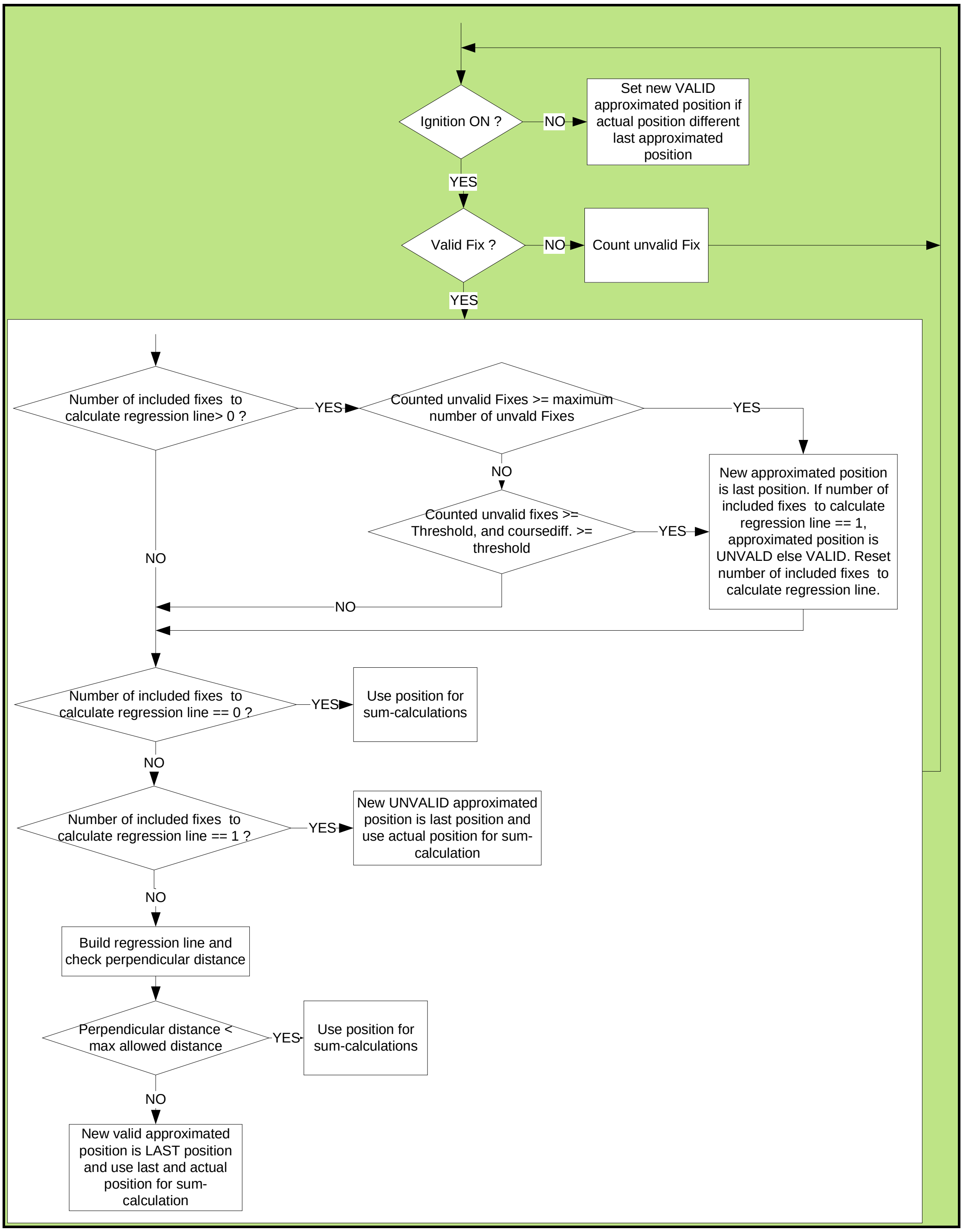


Figure 8-2: Flow-chart of polygon approximation in general

8.4 Parameters for data volume calculations

Parameter		
number of users	8485000	
avg km travelled per user per year	16271	
number of passenger cars	7776000	
usage of passenger cars per year (days)	300	
distance travelled per day passenger cars (km)	55	
km travelled per year passenger cars	16550	
time of operation per day passenger cars (h)	1,1	
average velocity passenger cars (km/h)	50,2	
number of motorcycles	517000	
distance travelled per day motorcycles (km)	80	
usage of motorcycles per year (days)	50	
km travelled per year motorcycles	4000	
time of operation per day motorcycles (h)	2	
average velocity motorcycles (km/h)	40	
usage of HGV per year (days)	200	
number of HGV	192000	
km travelled per day HGV (km)	190	
km travelled per year HGV	38000	
time of operation per day HGV (h)	7	
average velocity HGV (km/h)	27,1	
%km travelled on motorways per user per year	50	
number of toll sections (corridors)	1283	
time of operation per day (h)	1,29	
time of operation per user per year (h), (d)	332	258
average velocity (km/h)	49,0	
length of toll network (km)	3268	

Colouring scheme:

Data yet to be provided by ministry (light green)

VF assumptions based on experience or design (dark green)

Figure 8-3: Parameters for data volume calculation

8.5 Influence of deviation on the reduction of GNSS positions

Tolerance in m	number of fixes	percentage
original	835	100,00%
1	303	36,29%
2	191	22,87%
3	133	15,93%
4	103	12,34%
5	88	10,54%
6	76	9,10%
7	67	8,02%
8	66	7,90%
9	59	7,07%

Figure 8-4: Influence of deviation from the regression line on reduction of GNSS positions

8.6 Accuracy of the spline interpolation

Scenario	Odometer [km]	Spline 5m tolerance[km]	Error absolute[km]	Error %
Motorway	410,4	404,376	6,024	1,47%
motorway tunnel	9,7	10,002	-0,302	-3,11%
Slip road	4,6	4,536	0,064	1,39%
Urban	93,1	90,388	2,712	2,91%
urban narrow roads				
urban tunnel	1	0,744	0,256	25,60%
urban high buildings	14,2	14,486	-0,286	-2,01%
urban alleys				
Mountains	11,5	11,622	-0,122	-1,06%
Valleys	21,2	21,187	0,013	0,06%
Serpentines	5,8	6,116	-0,316	-5,45%
Rural	184	186,968	-2,968	-1,61%
Villages	2,5	2,595	-0,095	-3,80%
rural alleys	5,5	5,696	-0,196	-3,56%
Interurban	175,7	172,757	2,943	1,68%
country roads	88,4	87,946	0,454	0,51%
under bridges	1,2	1,49	-0,29	-24,17%
round about	5,9	6,275	-0,375	-6,36%
traffic jam	10,4	10,43	-0,03	-0,29%

Figure 8-5: Accuracy of the spline interpolation

8.7 Description of telegram types

The telegram types are described in the following:

Event log

The event-log telegram contains status and error logs from the OBU. It is assumed that on average an event log will be sent to the back office every two weeks. The trigger for sending this telegram is either that the internal buffer fills up or that a critical error occurs in the OBU.

Status

The status telegram contains status information from the OBU such as software version, last error, and state of the OBU. This information will be sent to the back office once a day during operation.

Position data

All relevant data from the GNSS receiver will be transferred using this type of telegram. In the case of the thick-client solution, it will only be necessary during an extended enforcement or in response to a customer complaint. Therefore only 5 are assumed. The preferred thin-client solution uses this telegram to transfer all position data to the back office for further processing. Considering the average mileage driven and the average velocity, it can be estimated that 589 telegrams will need to be accommodated.

Geo-data update

This telegram updates all changes in the charge objects and applies only to a thick-client solution. It will cover construction sites (5% of existing) and newly-built roads (10% of existing) but also amendments to the charging scheme.

Configuration

The data in these telegrams enables a remote reconfiguration of the OBU. It is assumed that this will happen only once a year.

Software update

A software update is assumed to occur every two years. Due to the complexity of a thick-client solution, a bigger size of the software is assumed. The data is based on current implementations.

Toll data

This telegram contains the charged objects and applies only to thick clients. It is assumed that each toll passage will trigger a telegram of this kind. The necessary data is estimated from the length of the road network, the number of motorway sections and the percentage of motorway usage.

Ephemeris

This telegram contains the ephemeris for the GNSS receiver in order to increase accuracy at start and to decrease time to first position. The ephemeris is valid for approximately a week.

Key

This telegram allows the exchange of a session key, which is required once per operation day in order to guarantee a secured connection to the back office

Signature

This telegram retrieves the signatures for the last position telegrams. It will only be necessary to verify the integrity of the data as part of an extended enforcement.

8.8 *Cost and revenue model result sheets in mill. €*

8.8.1 Baseline scenario

	Year										
	J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
Expenditures											
Investment											
Direct											
OBU nvest											
EETS	0,000	4,118	12,262	25,946	6,799	3,324	3,646	3 645	3,643	3,642	3,640
Thin Client	0,000	17,871	77,526	296,792	194,881	235,883	99,151	66 762	61,721	68,244	65,912
GNSS Cradle	0,000	0,000	0,000	23,034	17,454	24,554	15,851	13 086	13,802	14,517	15,232
GNSS enabled handset	0,000	0,000	0,000	2,021	10,336	9,641	5,851	4 147	4,216	2,479	2,514
Sum of OBU Invest Σ	0,000	21,989	89,787	347,793	229,469	273,401	124,499	87 640	83,383	88,883	87,298
OBU nstallation Cost											
EETS	0,000	1,261	3,830	8,270	2,211	1,103	1,235	1 259	1,285	1,310	1,337
Thin Client	0,000	3,668	14,616	57,917	39,715	49,571	21,309	13 199	12,785	12,350	11,891
GNSS Cradle	0,000	0,000	0,000	4,895	3,785	5,433	3,579	3 015	3,245	3,482	3,728
GNSS enabled handset	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0 000	0,000	0,000	0,000
Sum of OBU Installation Cost Σ	0,000	4,928	18,447	71,082	45,710	56,107	26,123	17 474	17,315	17,142	16,956
Customer Care											
Service Points	0,382	0,000	1,556	6,113	3,076	3,884	0,300	0 306	0,312	0,319	0,325
Points of Sales	14,028	4,564	4,564	4,564	0,000	0,000	0,000	0 000	0,000	0,000	0,000
Sum of Customer Care Σ	14,410	4,564	6,120	10,677	3,076	3,884	0,300	0 306	0,312	0,319	0,325
Enforcement											
Enforcement Gantries	44,000	0,000	0,000	0,000	0,000	0,000	0,000	0 000	0,000	0,000	0,000
Mobile Equipment	0,115	1,151	0,000	0,575	0,000	0,575	0,000	0 000	0,000	0,000	0,000
Sum of Enforcement Σ	44,115	1,151	0,000	0,575	0,000	0,575	0,000	0 000	0,000	0,000	0,000
Central IT System											
Basic Development & GeoData	22,000	0,000	5,000	0,000	3,000	0,000	0,000	2 000	0,000	0,000	0,000
OBU declaration of mileage	0,000	0,601	2,562	11,086	6,321	7,180	0,856	0 572	0,584	0,595	0,607
OBU billing	0,000	0,623	2,658	11,499	6,556	7,448	0,888	0 593	0,605	0,617	0,630
Sum of Central IT System Σ	22,000	1,225	10,220	22,586	15,877	14,628	1,744	3 166	1,189	1,213	1,237
Sum of Direct Investment Σ	80,525	33,857	124,573	452,713	294,133	348,596	152,666	108 586	102,199	107,556	105,816
Overhead	8,052	3,386	12,457	45,271	29,413	34,860	15,267	10 859	10,220	10,756	10,582
Project Costs markup	3,548	1,492	5,488	19,944	12,958	15,357	6,726	4 784	4,502	4,738	4,662
Marketing & Communication, initial	1,183	0,497	1,829	6,648	4,319	5,119	2,242	1 595	1,501	1,579	1,554
Sum Investment	93,307	39,231	144,348	524,576	340,823	403,933	176,900	125 823	118,422	124,630	122,613
discounted	93,307	36,093	122,176	408,481	244,163	266,224	107,264	70 190	60,776	58,845	53,262
Present Value	1.520,783										
Operations											
Direct											
Distribution Sales	0.000	10.523	44.448	78.184	93.387	132.448	119.308	115 206	112.187	114.562	116.974
Stationary Enforcement	0,000	17,908	16,219	14,712	13,367	12,167	11,095	10 139	9,286	8,524	7,844
Mobile Communication	0,000	4,584	22,788	92,779	125,670	166,147	166,081	166 014	165,948	165,882	165,815
Central IT System											
Operation & GeoData	0,000	2,351	2,877	4,079	3,916	4,109	3,573	3 548	3,549	3,550	3,551
Invoicing	0,000	0,090	0,374	1,588	0,887	0,988	0,115	0 076	0,076	0,076	0,076
Sum of Central IT System Σ	0,000	2,441	3,252	5,668	4,803	5,096	3,688	3 624	3,625	3,626	3,627
Operation EETS (foreign only)	0,000	8,408	28,940	33,961	34,117	40,796	38,479	38 864	39,253	39,645	40,042
Payment Collection (foreign only)	0,000	-0,151	-0,521	0,205	3,852	7,285	8,993	9 083	9,174	9,265	9,358
Sum of Direct Operation Σ	0,000	43,712	115,127	225,510	275,196	363,939	347,644	342 930	339,472	341,504	343,660
Overhead	0,000	4,371	11,513	22,551	27,520	36,394	34,764	34 293	33,947	34,150	34,366
Interests	0,000	7,465	-24,180	-46,195	-31,599	-24,996	-4,479	-0,275	0,100	-0,361	-0,220
Sum Operations	0,000	55,548	102,460	201,866	271,117	375,337	377,930	376 948	373,519	375,294	377,806
discounted	0,000	51,104	86,722	157,191	194,226	247,378	229,160	210 279	191,697	177,199	164,114
Present Value	1.709,070										
Sum	93,307	94,779	246,807	726,442	611,940	779,269	554,830	502 771	491,941	499,924	500,419
Sum discounted	93,307	87,197	208,898	565,672	438,389	513,602	336,424	280 469	252,474	236,045	217,376
Present Value	3.229,853										

Figure 8-6: Expenditures under the baseline scenario

	Year										
	J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
Revenues											
Toll Revenues	0,000	1.250,502	4 304,396	5.259,857	6.215,748	8.117,166	8.198,337	8.280,321	8.363,124	8.446,755	8.531,223
OBU service fee	0,000	1,273	5,186	20,375	10,255	12,947	1,001	1 021	1,041	1,062	1,083
Sum	0,000	1.251,776	4 309,582	5.280,232	6.226,003	8.130,112	8.199,338	8.281,341	8.364,165	8.447,817	8.532,306
Sum discounted	0,000	1.151,634	3 647,630	4.111,654	4.460,265	5.358,407	4.971,710	4.619,718	4.292,647	3.988,733	3.706,335
Present Value	40.308,732										
Toll Collection Ratio	8,0%										
Dropped Tax											
Revenues	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0 000	0,000	0,000	0,000
Revenues discounted	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0 000	0,000	0,000	0,000
Present Value	0,000										
Toll Collection Ratio including dropped Vignette Revenues	8,0%										
Mobile Enforcement											
Manpower Costs	1,075	10,754	11,292	17,785	18,674	26,144	23,333	20 825	18,586	16,588	14,805
Costs discounted	1,075	9,894	9,558	13,849	13,378	17,231	14,148	11 617	9,539	7,832	6,431
Present Value	114,552										
Toll Collection Ratio including Mobile Enforcement	8,3%										
Minimal Toll Opertor's Fee	0,000	497,805	497,805	497,805	497,805	497,805	497,805	497 805	497,805	497,805	497,805
Yearly Toll Collection Ratio including Mobile Enforcement based on Operators Fees		40,6%	11,8%	9,8%	8,3%	6,4%	6,4%	5,3%	6,2%	6,1%	6,0%
Sum Investment J0 to J5	**1.546,218**										
Sum Operations + Mobile Enforcement in J5	**426,477**										
Ratio Investment / Revenue in J0 to J5	6,1%										
Ratio Operation + Mobile Enforcement / Revenue in J5	**5,2%**										

Figure 8-7: Revenues, mobile enforcement and ratios under the baseline scenario

8.8.2 „No foreign user“ scenario

	Year										
	J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
Expenditures											
Investment											
Direct											
OBU Invest											
EETS	0,000	3,295	10,751	23,162	5,067	3,251	3,244	3,243	3,241	3,240	3,239
Thin Client	0,000	14,297	67,442	263,001	172,540	212,829	88,217	59,400	54,915	60,719	58,644
CNSS Cradle	0,000	0,000	0,000	20,284	15,438	22,066	14,103	11,643	12,280	12,917	13,552
CNSS enabled handset	0,000	0,000	0,000	1,779	9,124	8,666	5,206	3,690	3,751	2,206	2,236
Sum of OBU Invest	0,000	17,592	78,193	308,225	203,169	246,812	110,770	77,976	74,188	79,082	77,671
OBU Installation Cost											
EETS	0,000	1,009	3,358	7,383	1,973	1,079	1,099	1,121	1,143	1,166	1,189
Thin Client	0,000	2,934	12,738	51,335	35,163	44,733	18,959	11,744	11,376	10,988	10,580
CNSS Cradle	0,000	0,000	0,000	4,310	3,347	4,882	3,184	2,682	2,887	3,098	3,317
CNSS enabled handset	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Sum of OBU Installation Cost	0,000	3,943	16,096	63,028	40,484	50,695	23,242	15,547	15,405	15,252	15,086
Customer Care											
Service Points	0,306	0,000	1,359	5,424	2,730	3,537	0,267	0,272	0,278	0,283	0,289
Points of Sales	14,028	4,564	4,564	4,564	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Sum of Customer Care	14,333	4,564	5,923	9,988	2,730	3,537	0,267	0,272	0,278	0,283	0,289
Enforcement											
Enforcement Gantries	44,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Mobile Equipment	0,115	1,151	0,000	0,575	0,000	0,575	0,000	0,000	0,000	0,000	0,000
Sum of Enforcement	44,115	1,151	0,000	0,575	0,000	0,575	0,000	0,000	0,000	0,000	0,000
Central IT System											
Basic Development & GeoData	22,000	0,000	5,000	0,000	3,000	0,000	0,000	2,000	0,000	0,000	0,000
OBU declaration of mileage	0,000	0,431	2,237	9,830	5,604	6,539	0,762	0,509	0,519	0,530	0,540
OBU Billing	0,000	0,499	2,320	10,197	5,813	6,783	0,790	0,528	0,539	0,549	0,560
Sum of Central IT System	22,000	0,930	9,557	20,027	14,416	13,321	1,552	3,037	1,058	1,079	1,101
Sum of Direct Investment	80,448	28,228	109,769	401,844	260,799	314,941	135,832	96,833	90,929	95,696	94,147
Overhead	8,045	2,823	10,977	40,184	26,080	31,494	13,583	9,683	9,093	9,570	9,415
Project Costs markup	3,544	1,244	4,836	17,703	11,490	13,875	5,984	4,266	4,006	4,216	4,148
Marketing & Communication, initial	1,181	0,415	1,612	5,901	3,830	4,625	1,995	1,422	1,335	1,405	1,383
Sum Investment	93,219	32,709	127,193	465,633	302,199	364,934	157,393	112,204	105,364	110,887	109,092
discounted	93,219	30,093	107,657	362,583	215,493	240,522	95,436	62,593	54,075	52,357	47,388
Present Value	1.362,414										
Operations											
Direct											
Distribution Sales	0,000	9,108	38,644	68,198	81,394	115,626	103,998	100,414	97,791	99,860	101,962
Stationary Enforcement	0,000	17,908	16,219	14,712	13,367	12,167	11,095	10,139	9,286	8,524	7,844
Mobile Communication	0,000	3,668	19,578	81,701	110,895	147,826	147,767	147,708	147,649	147,590	147,531
Central IT System											
Operation & GeoData	0,000	2,341	2,850	3,973	3,855	4,054	3,565	3,543	3,544	3,545	3,546
Invoicing	0,000	0,072	0,327	1,408	0,787	0,900	0,103	0,067	0,067	0,067	0,067
Sum of Central IT System	0,000	2,412	3,176	5,381	4,642	4,954	3,667	3,610	3,611	3,612	3,613
Operation EETS (foreign only)	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Payment Collection (foreign only)	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Sum of Direct Operation	0,000	33,096	77,618	169,993	210,297	280,573	266,527	261,872	258,337	259,586	260,950
Overhead	0,000	3,310	7,762	16,999	21,030	28,057	26,653	26,187	25,834	25,959	26,095
Interests	0,000	7,458	-18,657	-37,474	-24,097	-18,107	0,043	3,259	2,964	1,764	0,924
Sum Operations	0,000	43,863	66,722	149,519	207,230	290,523	293,224	291,318	287,135	287,309	287,968
discounted	0,000	40,354	56,474	116,428	148,453	191,478	177,798	162,511	147,363	135,656	125,090
Present Value	1.301,611										
Sum	93,219	76,573	193,916	615,151	509,429	655,457	450,617	403,522	392,498	398,196	397,061
Sum discounted	93,219	70,447	164,130	479,011	364,951	432,000	273,234	225,103	201,438	188,013	172,479
Present Value	2.664,024										

Figure 8-8: Expenditures under the „No foreign users“ scenario

	Year										
	J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
Revenues											
Toll Revenues	0,000	1.087,393	3.742,953	4.573,789	5.404,998	7.058,405	7.128,939	7.200,279	7.272,282	7.345,004	7.418,454
OBU service fee	0,000	1,019	4,531	18,081	9,098	11,790	0,890	0,908	0,920	0,945	0,964
Sum	0,000	1.088,412	3.747,484	4.591,870	5.414,097	7.070,195	7.129,879	7.201,187	7.273,208	7.345,949	7.419,418
Sum discounted	0,000	1.001,339	3.171,870	3.575,634	3.878,621	4.659,835	4.323,238	4.017,158	3.732,748	3.468,473	3.222,910
Present Value	35.051,825										
Toll Collection Ratio	7,6%										
Dropped Tax											
Revenues	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Revenues discounted	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Present Value	0,000										
Toll Collection Ratio including dropped Vignette Revenues	7,6%										
Mobile Enforcement											
Manpower Costs	1,075	10,754	11,292	17,785	18,674	26,144	23,333	20,825	18,586	16,588	14,805
Costs discounted	1,075	9,894	9,558	13,849	13,378	17,231	14,148	11,617	9,539	7,832	6,431
Present Value	114,552										
Toll Collection Ratio including Mobile Enforcement	7,9%										
Minimal Toll Opertor's Fee	0,000	410,465	410,465	410,465	410,465	410,465	410,465	410,465	410,465	410,465	410,465
Yearly Toll Collection Ratio including Mobile Enforcement based on Operators Fees		38,7%	11,3%	9,3%	7,9%	6,2%	6,1%	6,0%	5,9%	5,8%	5,7%
Sum Investment J0 to J5	1.385,887										
Sum Operations + Mobile Enforcement in J5	334,774										
Ratio Investment / Revenue in J0 to J5	6,3%										
Ratio Operation + Mobile Enforcement / Revenue in J5	4,7%										

Figure 8-9: Revenues, mobile enforcement and ratios under the „No foreign users“ scenario

8.8.3 „No EETS“ scenario

	Year										
	J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
Expenditures											
Investment											
Direct											
OBU Invest											
EETS	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Thin Client	0,000	26,158	103,107	348,925	192,270	250,381	100,251	73,687	68,643	75,163	72,828
CNSS Cradle	0,000	0,000	0,000	23,034	17,454	24,554	15,851	13,086	13,802	14,517	15,232
CNSS enabled handset	0,000	0,000	0,000	2,021	11,704	11,918	5,922	4,218	4,287	2,550	2,584
Sum of OBU Invest	0,000	26,158	103,107	373,980	221,427	286,852	122,024	90,991	86,732	92,231	90,644
OBU Installation Cost											
EETS	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Thin Client	0,000	4,890	18,605	65,762	43,342	52,233	24,122	15,194	14,819	14,424	14,007
CNSS Cradle	0,000	0,000	0,000	4,895	3,785	5,433	3,579	3,015	3,245	3,482	3,728
CNSS enabled handset	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Sum of OBU Installation Cost	0,000	4,890	18,605	70,656	47,126	57,666	27,700	18,208	18,064	17,907	17,736
Customer Care											
Service Points	0,382	0,000	1,556	6,113	3,076	3,884	0,300	0,306	0,312	0,319	0,325
Points of Sales	14,028	4,564	4,564	4,564	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Sum of Customer Care	14,410	4,564	6,120	10,677	3,076	3,884	0,300	0,306	0,312	0,319	0,325
Enforcement											
Enforcement Gantries	44,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Mobile Equipment	0,115	1,151	0,000	0,575	0,000	0,575	0,000	0,000	0,000	0,000	0,000
Sum of Enforcement	44,115	1,151	0,000	0,575	0,000	0,575	0,000	0,000	0,000	0,000	0,000
Central IT System											
Basic Development & GeoData	22,000	0,000	5,000	0,000	3,000	0,000	0,000	2,000	0,000	0,000	0,000
OBU declaration of mileage	0,000	0,751	3,060	12,021	6,050	7,639	0,590	0,602	0,614	0,627	0,639
OBU Billing	0,000	0,779	3,174	12,470	6,276	7,924	0,612	0,625	0,637	0,650	0,663
Sum of Central IT System	22,000	1,531	11,233	24,491	15,326	15,562	1,203	3,227	1,251	1,277	1,302
Sum of Direct Investment	80,525	38,293	139,065	480,379	285,956	364,540	151,228	112,733	106,360	111,733	110,007
Overhead	8,052	3,829	13,906	48,038	28,606	36,454	15,123	11,273	10,636	11,173	11,001
Project Costs markup	3,548	1,687	6,126	21,163	12,642	16,060	6,662	4,966	4,686	4,922	4,846
Marketing & Communication, initial	1,183	0,562	2,042	7,054	4,214	5,353	2,221	1,655	1,562	1,641	1,615
Sum Investment	93,307	44,372	161,140	556,635	332,508	422,407	175,234	130,628	123,244	129,469	127,470
discounted	93,307	40,822	136,389	433,445	238,206	278,401	106,254	72,870	63,251	61,130	55,371
Present Value	1.579,447										
Operations											
Direct											
Distribution Sales	0,000	15,705	60,266	91,700	101,247	143,382	125,951	121,489	118,188	120,626	123,101
Stationary Enforcement	0,000	17,908	16,219	14,712	13,367	12,167	11,095	10,139	9,286	8,524	7,844
Mobile Communication	0,000	4,534	22,788	92,779	123,670	166,147	156,081	166,014	165,948	165,882	165,815
Central IT System											
Operation & GeoData	0,000	2,364	2,919	4,159	3,893	4,147	3,550	3,551	3,552	3,553	3,554
Invoicing	0,000	0,112	0,447	1,722	0,849	1,051	0,080	0,080	0,080	0,080	0,079
Sum of Central IT System	0,000	2,476	3,367	5,881	4,742	5,198	3,630	3,631	3,632	3,633	3,634
Operation EETS (foreign only)	0,000	8,408	28,940	26,728	25,119	24,611	24,857	25,106	25,357	25,610	25,866
Payment Collection (foreign only)	0,000	-0,151	-0,521	4,545	8,651	16,996	17,166	17,338	17,511	17,686	17,863
Sum of Direct Operation	0,000	48,930	131,060	236,346	279,797	368,502	348,781	343,716	339,922	341,961	344,123
Overhead	0,000	4,893	13,106	23,635	27,980	36,850	34,878	34,372	33,992	34,196	34,412
Interests	0,000	7,465	-24,612	-45,253	-28,291	-22,721	-1,263	2,120	2,029	1,000	0,483
Sum Operations	0,000	61,287	119,554	214,728	279,486	382,631	382,396	380,208	375,943	377,157	379,019
discounted	0,000	56,384	101,190	167,206	200,222	252,185	231,868	212,098	192,941	178,079	164,641
Present Value	1.756,814										
Sum	93,307	105,659	280,694	771,363	611,994	805,038	557,630	510,836	499,187	506,626	506,489
Sum discounted	93,307	97,206	237,579	600,651	438,428	530,585	338,121	284,968	256,192	239,209	220,013
Present Value	3.336,260										

Figure 8-10: Expenditures under the „No EETS“ scenario

	Year										
	J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
Revenues											
Toll Revenues	0,000	1.250,502	4.304,396	5.259,357	6.215,748	8.117,166	8.198,337	8.280,321	8.363,124	8.446,755	8.531,223
OBU service fee	0,000	1,273	5,186	20,375	10,255	12,947	1,001	1,021	1,041	1,062	1,083
Sum	0,000	1.251,776	4.309,582	5.280,232	6.226,003	8.130,112	8.199,338	8.281,341	8.364,165	8.447,817	8.532,306
Sum discounted	0,000	1.151,634	3.647,630	4.111,654	4.460,265	5.358,407	4.971,710	4.619,718	4.292,647	3.988,733	3.706,335
Present Value	40.308,732										
Toll Collection Ratio	8,3%										
Dropped Tax											
Revenues	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Revenues discounted	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Present Value	0,000										
Toll Collection Ratio including dropped Vignette Revenues	8,3%										
Mobile Enforcement											
Manpower Costs	1,075	10,754	11,292	17,785	18,674	26,144	23,333	20,825	18,586	16,588	14,805
Costs discounted	1,075	9,894	9,558	13,849	13,378	17,231	14,148	11,617	9,539	7,832	6,431
Present Value	114,552										
Toll Collection Ratio including Mobile Enforcement	8,6%										
Minimal Toll Opertor's Fee	0,000	514,085	514,085	514,085	514,085	514,085	514,085	514,085	514,085	514,085	514,085
Yearly Toll Collection Ratio including Mobile Enforcement based on Operators Fees		41,0%	12,2%	10,1%	8,6%	6,6%	6,6%	6,5%	6,4%	6,3%	6,2%
Sum Investment J0 to J5	1.610,368										
Sum Operations + Mobile Enforcement in J5	431,496										
Ratio Investment / Revenue in J0 to J5	6,4%										
Ratio Operation + Mobile Enforcement / Revenue in J5	5,3%										

Figure 8-11: Revenues, mobile enforcement and ratios under the „No EETS“ scenario

8.8.4 „Big Bang“ scenario

	Year										
	J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
Expenditures											
Investment											
Direct											
OBU Invest											
EETS	0,000	153,584	0,000	0,000	0,000	0,000	3,990	3,988	3,987	3,985	3,983
Thin Client	0,000	709,854	169,041	120,413	121,791	115,140	108,495	73,054	67,538	74,676	72,123
CNSS Cradle	0,000	0,000	0,000	45,172	15,085	16,216	17,345	14,320	15,103	15,886	16,668
CNSS enabled handset	0,000	0,000	0,000	3,962	13,941	6,288	6,402	4,538	4,614	2,713	2,750
Sum of OBU Invest	0,000	873,438	169,041	169,548	150,817	137,644	136,232	95,900	91,241	97,259	95,525
OBU Installation Cost											
EETS	0,000	50,077	0,000	0,000	0,000	0,000	1,351	1,378	1,406	1,434	1,463
Thin Client	0,000	145,678	19,764	20,159	24,384	23,866	23,317	14,443	13,990	13,513	13,012
CNSS Cradle	0,000	0,000	0,000	9,599	3,271	3,588	3,916	3,299	3,550	3,811	4,080
CNSS enabled handset	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Sum of OBU Installation Cost	0,000	195,754	19,764	29,758	27,655	27,454	28,585	19,121	18,947	18,758	18,554
Customer Care											
Service Points	15,175	0,000	0,303	0,310	0,316	0,322	0,329	0,335	0,342	0,349	0,356
Points of Sales	36,847	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Sum of Customer Care	52,022	0,000	0,303	0,310	0,316	0,322	0,329	0,335	0,342	0,349	0,356
Enforcement											
Enforcement Gantries	44,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Mobile Equipment	0,115	1,151	0,000	0,575	0,000	0,575	0,000	0,000	0,000	0,000	0,000
Sum of Enforcement	44,115	1,151	0,000	0,575	0,000	0,575	0,000	0,000	0,000	0,000	0,000
Central IT System											
Basic Development & GeoData	22,000	0,000	5,000	0,000	3,000	0,000	0,000	2,000	0,000	0,000	0,000
OBU declaration of mileage	0,000	23,875	1,391	2,679	1,826	0,595	0,937	0,626	0,639	0,651	0,664
OBU Billing	0,000	24,765	1,443	2,779	1,894	0,618	0,972	0,649	0,662	0,676	0,689
Sum of Central IT System	22,000	48,640	7,833	5,457	6,719	1,213	1,909	3,275	1,301	1,327	1,354
Sum of Direct Investment	118,137	1.118,983	196,941	205,648	185,507	167,209	157,054	118,631	111,831	117,693	115,788
Overhead	11,814	111,898	19,694	20,565	18,551	16,721	16,705	11,863	11,183	11,769	11,579
Project Costs markup	5,205	49,297	8,676	9,060	8,173	7,366	7,360	5,226	4,927	5,185	5,101
Marketing & Communication, initial	1,735	16,432	2,892	3,020	2,724	2,455	2,453	1,742	1,642	1,728	1,700
Sum Investment	136,890	1.296,610	228,204	238,293	214,955	193,751	193,572	137,462	129,582	136,375	134,168
discounted	136,890	1.192,881	193,152	185,556	153,992	127,698	117,373	76,683	66,504	64,391	58,281
Present Value	2.373,402										
Operations											
Direct											
Distribution Sales	0,000	150,666	148,300	148,806	140,064	130,538	122,070	117,841	114,786	117,212	119,676
Stationary Enforcement	0,000	17,908	16,219	14,712	13,367	12,167	11,095	10,139	9,286	8,524	7,844
Mobile Communication	0,000	182,097	182,024	181,951	181,878	181,806	181,733	181,660	181,588	181,515	181,442
Central IT System											
Operation & GeoData	0,000	4,323	2,778	3,367	3,535	3,550	3,579	3,553	3,554	3,555	3,556
Invoicing	0,000	3,561	0,203	0,384	0,256	0,082	0,126	0,083	0,083	0,083	0,083
Sum of Central IT System	0,000	7,884	2,981	3,751	3,791	3,632	3,706	3,636	3,637	3,638	3,639
Operation EETS (foreign only)	0,000	78,164	70,764	52,191	41,585	42,000	39,583	39,978	40,378	40,782	41,190
Payment Collection (foreign only)	0,000	-15,551	-10,807	0,653	7,336	7,410	9,136	9,278	9,371	9,465	9,560
Sum of Direct Operation	0,000	431,158	409,481	402,064	388,022	377,553	367,373	362,533	359,045	361,136	363,351
Overhead	0,000	43,116	40,948	40,206	38,802	37,755	36,737	36,253	35,904	36,114	36,335
Interests	0,000	10,951	86,428	86,600	85,955	84,264	78,524	70,957	57,263	40,441	21,655
Sum Operations	0,000	485,226	536,857	528,870	513,779	499,572	482,635	469,743	452,212	437,691	421,342
discounted	0,000	446,408	454,395	411,825	368,068	329,259	292,648	262,045	232,084	206,661	183,026
Present Value	3.186,417										
Sum	136,890	1.781,836	765,060	767,163	728,734	693,324	676,206	607,205	581,795	574,066	555,510
Sum discounted	136,890	1.639,289	647,547	597,381	522,060	456,957	410,021	338,727	298,588	271,052	241,307
Present Value	5.559,819										

Figure 8-12: Expenditures under the „Big Bang“ scenario

	Year										
	J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
Revenues											
Toll Revenues	0,000	8.008,459	8.088,554	8.169,439	8.251,134	8.333,645	8.416,981	8.501,151	8.586,163	8.672,024	8.758,745
OBU service fee	0,000	50,532	1,012	1,032	1,053	1,074	1,095	1,117	1,139	1,162	1,165
Sum	0,000	8.059,051	8.089,565	8.170,471	8.252,185	8.334,718	8.418,076	8.502,268	8.587,302	8.673,186	8.759,930
Sum discounted	0,000	7.414,327	6.847,008	6.362,248	5.911,808	5.493,259	5.104,343	4.742,961	4.407,165	4.095,143	3.805,212
Present Value	54.183,475										
Toll Collection Ratio	10,3%										
Dropped Tax											
Revenues	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Revenues discounted	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Present Value	0,000										
Toll Collection Ratio including dropped Vignette Revenues	10,3%										
Mobile Enforcement											
Manpower Costs	1,075	10,754	11,292	17,785	18,674	26,144	23,333	20,825	18,586	16,588	14,805
Costs discounted	1,075	9,894	9,558	13,849	13,378	17,231	14,148	11,617	9,539	7,832	6,431
Present Value	114,552										
Toll Collection Ratio including Mobile Enforcement	10,5%										
Minimal Toll Opertor's Fee	0,000	849,330	849,330	849,330	849,330	849,330	849,330	849,330	849,330	849,330	849,330
Yearly Toll Collection Ratio including Mobile Enforcement based on Operators Fees		10,7%	10,6%	10,6%	10,5%	10,5%	10,4%	10,2%	10,1%	10,0%	9,9%
Sum Investment J0 to J5	2.308,703										
Sum Operations + Mobile Enforcement in J5	441,452										
Ratio Investment / Revenue in J0 to J5	5,6%										
Ratio Operation + Mobile Enforcement / Revenue in J5	5,3%										

Figure 8-13: Revenues, mobile enforcement and ratios under the „Big bang“ scenario

8.8.5 „ HGVs and vans only“ scenario

	Year										
	J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
Expenditures											
Investment											
Direct											
OBU Invest											
EETS	0,000	4,118	12,262	0,000	0,000	0,000	0,499	0,499	0,499	0,499	0,499
Thin Client	0,000	17,871	77,526	15,075	15,248	14,415	13,583	9,146	8,455	9,349	9,029
CNSS Cradle	0,000	0,000	0,000	5,655	1,889	2,030	2,172	1,793	1,391	1,989	2,087
CNSS enabled handset	0,000	0,000	0,000	0,496	1,745	0,787	0,802	0,568	0,578	0,340	0,344
Sum of OBU Invest Σ	0,000	21,989	89,787	21,227	18,881	17,232	17,056	12,006	11,423	12,176	11,959
OBU Installation Cost											
EETS	0,000	1,261	3,830	0,000	0,000	0,000	0,169	0,173	0,176	0,180	0,183
Thin Client	0,000	3,668	14,616	2,524	3,053	2,988	2,919	1,808	1,752	1,692	1,629
CNSS Cradle	0,000	0,000	0,000	1,202	0,410	0,449	0,490	0,413	0,444	0,477	0,511
CNSS enabled handset	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Sum of OBU Installation Cost Σ	0,000	4,928	18,447	3,726	3,462	3,437	3,579	2,394	2,372	2,348	2,323
Customer Care											
Service Points	0,382	0,000	1,556	0,039	0,040	0,040	0,041	0,042	0,043	0,044	0,045
Points of Sales	14,028	4,564	4,564	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Sum of Customer Care Σ	14,410	4,564	6,120	0,039	0,040	0,040	0,041	0,042	0,043	0,044	0,045
Enforcement											
Enforcement Gantries	44,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Mobile Equipment	0,115	1,151	0,000	0,575	0,000	0,575	0,000	0,000	0,000	0,000	0,000
Sum of Enforcement Σ	44,115	1,151	0,000	0,575	0,000	0,575	0,000	0,000	0,000	0,000	0,000
Central IT System											
Basic Development & GeoData	22,000	0,000	5,000	0,000	3,000	0,000	0,000	2,000	0,000	0,000	0,000
OBU declaration of mileage	0,000	0,601	2,562	0,335	0,229	0,075	0,117	0,078	0,080	0,082	0,083
OBU Billing	0,000	0,623	2,658	0,348	0,237	0,077	0,122	0,081	0,083	0,085	0,086
Sum of Central IT System Σ	22,000	1,225	10,220	0,683	3,466	0,152	0,239	2,160	0,163	0,166	0,169
Sum of Direct Investment Σ	80,525	33,857	124,573	26,249	25,849	21,437	20,914	16,602	14,001	14,735	14,496
Overhead	8,052	3,386	12,457	2,625	2,585	2,144	2,091	1,660	1,400	1,473	1,450
Project Costs markup	3,548	1,492	5,488	1,156	1,139	0,944	0,921	0,731	0,617	0,649	0,639
Marketing & Communication, initial	1,183	0,497	1,829	0,385	0,380	0,315	0,307	0,244	0,206	0,216	0,213
Sum Investment	93,307	39,231	144,348	30,416	29,952	24,840	24,234	19,237	16,223	17,073	16,797
discounted	93,307	36,093	122,176	23,685	21,453	16,371	14,694	10,731	8,326	8,061	7,296
Present Value	362,200										
Operations											
Direct											
Distribution Sales	0,000	10,523	44,448	42,483	39,661	36,782	34,221	33,111	32,175	32,864	33,563
Stationary Enforcement	0,000	17,908	16,219	14,712	13,367	12,167	11,095	10,139	9,286	8,524	7,844
Mobile Communication	0,000	4,534	22,788	22,779	22,770	22,761	22,752	22,743	22,734	22,725	22,716
Central IT System											
Operation & GeoData	0,000	2,351	2,877	3,168	3,399	3,506	3,510	3,507	3,507	3,507	3,507
Invoicing	0,000	0,090	0,374	0,048	0,032	0,010	0,016	0,010	0,010	0,010	0,010
Sum of Central IT System Σ	0,000	2,441	3,252	3,216	3,431	3,517	3,526	3,517	3,517	3,517	3,517
Operation EETS (foreign only)	0,000	8,408	28,940	29,230	29,522	29,817	30,115	30,417	30,721	31,028	31,338
Payment Collection (foreign only)	0,000	-0,151	-0,521	-0,526	-0,531	-0,537	-0,542	-0,547	-0,553	-0,559	-0,564
Sum of Direct Operation Σ	0,000	43,712	115,127	111,895	108,220	104,507	101,168	99,379	97,880	98,099	98,414
Overhead	0,000	4,371	11,513	11,189	10,822	10,451	10,117	9,938	9,788	9,810	9,841
Interests	0,000	7,465	2,114	10,601	11,043	11,205	10,651	9,667	7,968	5,624	2,993
Sum Operations	0,000	55,548	128,754	133,686	130,090	126,163	121,936	118,984	115,636	113,534	111,249
discounted	0,000	51,104	108,977	104,099	93,195	83,152	73,936	66,375	59,347	53,605	48,325
Present Value	742,117										
Sum	93,307	94,779	273,102	164,102	160,042	151,003	146,170	138,221	131,859	130,607	128,046
Sum discounted	93,307	87,197	231,153	127,784	114,653	99,523	88,631	77,106	67,673	61,668	55,622
Present Value	1.104,317										

Figure 8-14: Expenditures under the „HGVs and vans only” scenario

	Year										
	J 0	J 1	J 2	J 3	J 4	J 5	J 6	J 7	J 8	J 9	J 10
Revenues											
Toll Revenues	0,000	1.250,502	4.304,396	4.347,440	4.390,915	4.434,824	4.479,172	4.523,964	4.569,203	4.614,896	4.661,044
OBU service fee	0,000	1,273	5,186	0,129	0,132	0,134	0,137	0,140	0,143	0,145	0,148
Sum	0,000	1.251,776	4.309,582	4.347,570	4.391,047	4.434,958	4.479,309	4.524,104	4.569,346	4.615,041	4.661,193
Sum discounted	0,000	1.151,634	3.647,630	3.385,400	3.145,715	2.922,999	2.716,052	2.523,756	2.345,075	2.179,044	2.024,768
Present Value	26.042,072										
Toll Collection Ratio	4,2%										
Dropped Tax											
Revenues	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Revenues discounted	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Present Value	0,000										
Toll Collection Ratio including dropped Vignette Revenues	4,2%										
Mobile Enforcement											
Manpower Costs	1,075	10,754	11,292	17,785	18,674	26,144	23,333	20,825	18,586	16,588	14,805
Costs discounted	1,075	9,894	9,558	13,849	13,378	17,231	14,148	11,617	9,539	7,832	6,431
Present Value	114,552										
Toll Collection Ratio including Mobile Enforcement	4,7%										
Minimal Toll Opertor's Fee	0,000	169,125	169,125	169,125	169,125	169,125	169,125	169,125	169,125	169,125	169,125
Yearly Toll Collection Ratio including Mobile Enforcement based on Operators Fees		14,4%	4,2%	4,3%	4,3%	4,4%	4,3%	4,2%	4,1%	4,0%	3,9%
Sum Investment J0 to J5	362,095										
Sum Operations + Mobile Enforcement in J5	141,102										
Ratio Investment / Revenue in J0 to J5	1,9%										
Ratio Operation + Mobile Enforcement / Revenue in J5	3,2%										

Figure 8-15: Revenues, mobile enforcement and ratios under "HGVs and vans only" scenario