An example of a view on (EETS) performance in interoperable toll systems

This draft may still contain contentious issues Please, comment

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Foreword

The aim of the EETS, the European Electronic Toll Service, is to allow the user of a vehicle to conclude one service contract and to use one OBE for circulating a vehicle within all the electronic toll domains in Europe.

Within the EETS a toll charger has to accept vehicles with onboard equipment (OBE) from a third party, the EETS provider, and to utilise toll declarations received from this provider.

This paper discusses measures for a toll charger to assess the performance of a toll service provider and, if applicable, vice versa. Not included are measures to assess ones own performance or to access the performance of an EETS provider in relation to its customers[1].

This paper aims to bridge the gap between the layman and the professional. By focussing on the high-level, conceptual issues it should be comprehensible for those with only a common knowledge of the EETS and performance indicators. Technical details that may be of interest only to experts are provided in the footnotes.

This paper is written in a top down fashion. High level requirement are step by step refined to more detailed requirements an when dealing with some issue the basic concept is presented before its applicability and before elaborating on any drawbacks. Consequently, a reader may need some patients or may want to skip at a first reading to a next section before trying to grasp all details presented.

Although out of the scope of this paper Annex B provides an introduction to the difficulties for setting (procedures for) a fair commercial threshold for the various performance metrics in an EETS context. Basically, new developments should be frustrated unnecessary. Therefore a change procedure may be a prerequisite for further harmonisation decisions.

Disclaimer
Although the Dutch Ministry of Infrastructure and the Environment pursues the EETS, this paper is a technical paper and does not represent or imply any official position of the ministry.

[1] However, included are EETS provider - customer implications on the EETS provider toll charger interface.

Contents

Foreword **2**
Contents **3**
1 Introduction **4**
1.1 Overview 4
1.2 The EETS 4
1.2.1 Toll 4
1.2.2 The organisational model 4
1.2.3 The overall architecture 5
1.2.4 Metering: self metering versus third party metering 6
1.2.5 Metering: discrete versus continuous 6
1.2.6 Legal requirements 7
1.3 Metrics 8
1.3.1 Performance metrics, measures and indicators 8
1.3.2 Examination versus monitoring 8
1.3.3 Verifiability 9
1.3.4 Equipment life cycles and tolling processes 9
2 Interoperability performance metrics **10**
2.1 Overview 10
2.2 Metrics for procurement 10
2.2.1 Introduction 10
2.2.2 Using dedicated test routes 10
2.2.3 Undercharging metrics for discrete metering 10
2.2.4 Overcharging metrics for discrete metering 11
2.2.5 Charging performance for continuous metering 12
2.2.6 DSRC transaction metrics 12
2.3 Customisation metrics 13
2.4 Toll declaration performance 13
2.4.1 Overview 13
2.4.2 Metrics that do not depend on the business model for metering 14
2.4.3 Additional metrics for DSRC based systems 14
2.5 Toll collection performance 15
2.5.1 Introduction 15
2.5.2 Outstanding debts metrics 15
3 Glossary and abbreviations **15**
3.1 Glossary 15
3.2 Abbreviations 18
4 References **19**
Annex A. Metrics **20**
A.1 Introduction 20
Annex B. The fair threshold problem **22**
B.1 Introduction 22
B.2 Legal provisions for setting fair thresholds 22
B.3 Fair thresholds in the technical specifications 22
B.4 Additional threshold required for the suitability for use 23
B.5 Setting fair commercial thresholds 23
B.6 Additional requirements because of new tolling policies 23
Annex C. Location accuracy **25**
C.1 Introduction 25
C.2 The location accuracy of passages 25
C.3 Measurement of the distance driven 25

1 Introduction

1.1 Overview

This introduction provides a brief description of the EETS and the need for performance metrics with the major terms an concepts.

For the EETS, details can be found in the EETS Directive [1] and the EETS Decision [2]. The overall system architecture is described in the CEN standard ISO 17573 [3].

1.2 The EETS

1.2.1 Toll

A toll is a charge, tax, fee, or duty in connection with using a vehicle within a toll domain. The definition is a generalization of the classic definition of a toll as "a charge, a tax, or a duty for permission to pass a barrier or to proceed along a road, over a bridge, etc."

A toll domain is an area, a part of a road network, or a structure like a bridge or ferry where a toll regime, i.e. a set of rules governing the collection of the toll, is applied.

A toll domain may contain one or more tolled objects, distinguished parts of the toll domain for which one or more tariff schemes apply.

EXAMPLE An area, all public roads within an area, a bridge, a zone, or a stretch of road (network).

In other words, the toll domain constitutes the area of jurisdiction for a toll charger while the tolled objects are the actual objects for which a toll has to be paid[2].

1.2.2 The organisational model

The organisational model is the so-called CESARE III model as depicted below.

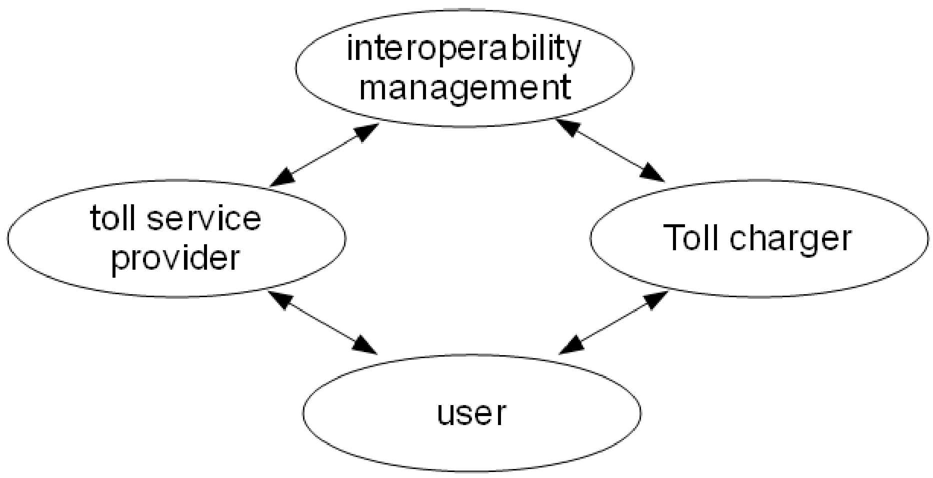

Figure 1-1 The organisational model

The toll charger is the legal entity charging[3] toll for vehicles in a toll domain.

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[2] In case the location of the tolled object coincides with the location of the toll domain (with is often the case), the term toll domain may be used as a synonym for the tolled object.

[3] Because the actual collection of the toll is not covered in the CEN standards, 'charging and collecting' would be more precise.

The toll service provider is the legal entity providing its customers toll services on one or more toll domains for one or more classes of vehicle. The toll service provider is responsible for the operation (functioning) of the OBE with respect to tolling.

Within the EETS a toll service provider is called an EETS provider.

An EETS provider acts towards a toll charger as the representative of its clients (and the ones liable for toll)[4]

Note that in the CESARE model a toll charger or a toll service provider may delegate / subcontract any task to a third a third party. However, this shall have no impact on its responsibilities / liability towards the other parties.

A user is a customer of a toll service provider, a one liable for toll, the owner of the vehicle, a fleet operator, a driver, etc. depending on the context.

1.2.3 The overall architecture

The overall architecture is depicted below.

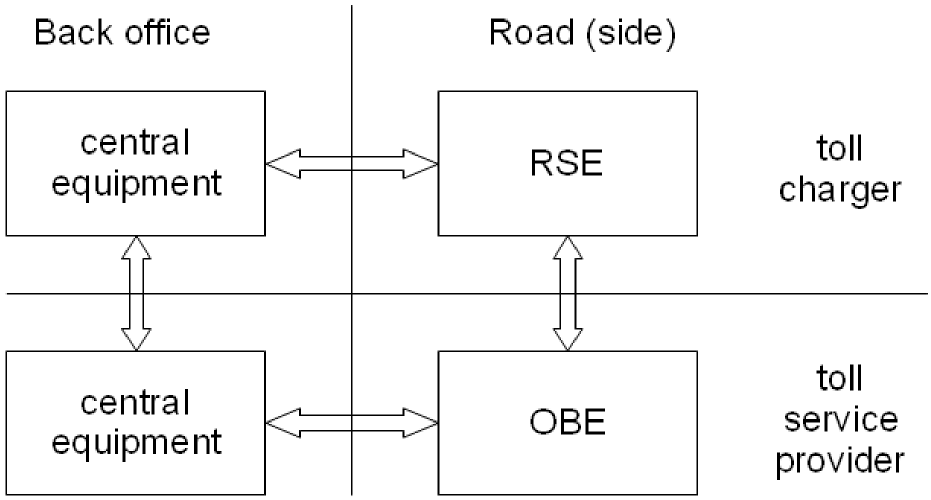

Figure 1-2 Overall system architecture

The toll charger's equipment consists of its central equipment[5] and his roadside (including mobile) equipment (RSE). The communication between its central equipment and his RSE is considered propriety.

The toll service provider's equipment consists of its central equipment and onboard equipment (OBE). The communication between its central equipment and its OBE is considered propriety.

This paper focuses in the interoperability interfaces between the toll charger and the toll service provider, i.e. between OBE and RSE and between the TC's and TSP's central equipment[6].

[4] In other toll charging environments a toll service provider may merely act as a reseller or as a (non-) transparent agent of the toll charger.
[5] Also called back office or back office equipment

1.2.4 Metering: self metering versus third party metering

The process of measuring values needed to determine the toll due is called metering.

From a business point of view a distinction should be made between:

- Self metering,
  when the toll charging is doing the metering for the toll due itself, and
- Third party metering
  when the EETS provider is doing the metering and the toll charger needs undisputable means to access the performance of the EETS provider in this respect.

EXAMPLE 1 Typical systems with self metering are DSRC systems in which the toll charger measures itself the vehicle characteristics to determine the fee due[7].

EXAMPLE 2 Typical systems with third party metering are autonomous systems (also called GNNS of GPS based systems) for which the EETS provider performs the metering.

Note that with third party metering the toll chargers depends much more on the performance of the EETS provider than in the case of self metering. The difference between both it therefore not only a difference with respect to the technology[8], but it is also essential for the business cases, for the required trust between the parties and for the need for performance measures.

1.2.5 Metering: discrete versus continuous

From a more technical point of view a distinction should be made between[9]:

- discrete metering
  In case the metering does not depend on values that have to be measured continuously.
- continuous metering
  In case the metering is based on values that have to be measured continuously.

With discrete metering an event, usually a passage, is triggering the measurement. The toll usually depends in one or two events/measurements.

EXAMPLE 1 Discrete metering is used for DSRC based systems and by Toll Collect. In the latter case the event / passage can be defined as entering a road segment.

EXAMPLE 2 Discrete metering where the toll due is determined by two measurements are closed road networks or a car park. In either case, the toll due depends on the entrance and exit (location or time).

EXAMPLE 3 Distance related continuous metering is used in the Swiss system and was proposed for the basic fee in the Dutch ABvM project.

EXAMPLE 4 Time related continuous metering could be used in a car park.

Note that a tariff scheme that is officially defined as toll per km may be implemented with discrete metering[10].

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[6] Performance indicators related to the user or to services provided to the user are not included. In terms if the schema presented in [6] only areas 7 and 10 are covered. Over/undercharging and fraud (the areas 2 and 5 in [6]) are dealt with only in connection to the TC / TSP relation.

[7] The use declared vehicle parameters in DSRC systems can be regarded as a kind of third party metering. However these values can be easily checked with the official vehicle register. In this paper these declared parameters are therefore not regarded as special case.

[8] Ignoring technical differences just because they are technical differences is, in general, not to be recommended. On the contrary, exploiting typical technical characteristics may lead to better results.

[9] This distinction correspond to the distinction between 'discrete charging schemes' and continuous charging schemes' in [8] and [9].

[10] In such a case the tariff scheme may be called (functional) continuous although the (technical) metering is definitely discrete.

EXAMPLE 4 A notable example is the German LKW Maut. It is officially defined as a tariff per kilometre but its implementation is based on discrete metering, i.e. as a toll per road segment that is proportional to its length.

1.2.6 Legal requirements

The Commission Decision on the definition of the European Electronic Toll Service and its technical elements [2] addresses performance issues on several places. At least the flowing can be found:

- **Article 2(f)** - 'suitability for use' means the ability of an interoperability constituent to achieve and maintain a specified performance when in service, integrated representatively into EETS in relation with a Toll Charger's system

  NOTE 1 This performance referred to in this provision can be assessed before procurement, see 1.3.4, and the corresponding metrics are covered in 2.2.

- **Article 4.4** - EETS Providers shall monitor the performance of their service level. They shall have in place audited operational processes which provide for appropriate measures to be taken where performance problems or integrity breaches are detected

  NOTE 2 They associated metrics are outside the scope of this paper.

- **Annex I – 2(b)** - procedures and Service Level Agreement (such as …, accepted percentage of missed/erroneous tolls, accuracy of toll declaration data, operational availability performance etc.);

  NOTE 3 This performance requirements for this provision must be assessed during deployment, see 1.3.4, and the corresponding metrics are covered in 2.4.

- **Annex III – 1.2** - The monitoring and maintenance of fixed or movable components that are involved in the functioning of EETS must be organised, carried out and quantified in such a manner as to maintain their operation under the intended conditions.

  NOTE 4 This performance implied by this provision must be assessed during deployment, see 1.3.4, and the corresponding metrics are covered in 2.4

- **Annex III – 1.5.2** - EETS shall provide security features relative to the protection of data stored, handled and transferred between stakeholders in the EETS environment. The security features shall protect the interests of EETS stakeholders from harm or damage caused by lack of availability, confidentiality, integrity, authentication, nonrepudiation and access protection of sensitive user data appropriate to a European multi-user environment.

  NOTE 5 For details about an implementations of performance metrics in accordance to the security requirements in this article see [10].

- **Annex III – 2.1.1.2** - EETS infrastructure shall ensure that the accuracy of toll declaration data is commensurate with the toll regime requirements in view to guarantee equality of treatment between EETS Users relative to tolls and charges (fairness).

  NOTE 6 This provision does not require specific requirements but only fairness and non-discrimination. A toll charger may not require a better performance from toll service providers when compared with the performance of its own organisations and/or equipment.

- **Annex III – 2.1.3** - EETS Providers shall monitor the availability of Navigation and Positioning satellite localisation data.
  EETS Providers shall inform Toll Chargers of difficulties they may have to establish toll

declaration data related to the reception of satellite signals. Toll Chargers shall use the information received to identify problem areas and, where necessary, provide augmentation localisation signals, in agreement with EETS Providers.

NOTE 7 They associated metrics are outside the scope of this paper.

- **Annex IV – 2(a)2 and 2(b)2 with respect to the suitability for use –** (the manufacturer, the EETS Provider or an authorised representative shall) monitor the in-service behaviour of the interoperability constituents by a procedure agreed and surveyed by the Toll Charger(s).

NOTE 8 This performance associated with this provision can be assessed before procurement, see 1.3.4, and the corresponding metrics are covered in 2.2.

1.3 Metrics

1.3.1 Performance metrics, measures and indicators

A metric is defined as a measure of some property[11]. A performance metric is a measure of an organization's activities and performance. In literature a performance metric is also called a performance measure.

The number of possible values for a performance metric may vary from 2 (e.g. ok, not ok) to any real value. A basic property of a performance metric is that it is ordinal scale, i.e. that a higher measured value represents a better or a lesser performance[12]. By using one of more thresholds any performance metric can be mapped (with loss of information) e.g. to a 2 point scale (bad, good), to a 3 point scale (bad, normal, good), or a 5 point scale etc.

This paper focuses in the metrics, not on the thresholds[13].

When establishing metrics one should avoid the so-called "measurement inversion", the selection of metrics because they can easily measured even if they are of low value or have counter productive side effects[14]. The focus should be on 'high value metrics'. A metric should be related as direct as possible to a relevant requirement or asset.

1.3.2 Examination versus monitoring

For practical purposes a fundamental difference should be noticed. Some performance metrics require a dedicated test/measurement environment for measuring their value while others can be measured while in actual use. In the latter case the performance metrics is often called a performance indicator or key performance indicator (KPI).

To this end the following terms and definitions from [7] are used:

The term examination is used for an assessment carried out during a limited time span, such as when identifying requirements, assessing and comparing systems for acquisition purposes, conducting acceptance testing, or as part of a certification procedure.

[11] See software metric and performance metric in the Wikipedia
[12] Using mathematical terms, the set of values for a metric must be totally ordered.
[13] Due to lack of experience, the setting of threshold should include also a adjustment agreements and processes.
[14] Example: A police force cutting on prevention because of a metric based on the number of tickets.

The term monitoring is used for an assessment as an ongoing supervision process throughout the lifetime of a system, in order to validate contracted service levels, to identify fraud or malfunction, or to support ongoing maintenance and performance improvement processes.

EXAMPLE: For OBE to be used in autonomous systems, a test environment may consist of a well selected route or set of routes for which the performance of OBE is measured or compared with a standard or other OBE for which the performance was measured before or is measured at the same time.

1.3.3 Verifiability

This document deals with performance metrics in an interoperability context. We are not dealing with metrics to measure one owns performance but with metrics that may be used in a service level agreement between an EETS provider and a toll charger.

Consequently, the focus is on metrics that can be measures by both parties, by a trusted third party (e.g. a notified body), or for which a measured values can be verified by the other party.

Basically, any metric, if effective, shall be based on undisputable data. Declared parameters (e.g. about vehicle parameters) may be checked by an authorised source (e.g. the keeper of the official register in which the vehicle and its owner or lessee are listed). Other data may be compared with undisputable[15] observations, e.g. images showing the presence of a vehicle or the response on compliance checking (DRSC) transactions[16].

1.3.4 Equipment life cycles and tolling processes

With respect to the use of (especially OBE and RSE) the following life cycle phases can be distinguished.

1. Procurement phase
2. Customisation / Personalisation phase
3. Deployment phase

Within the deployment phase two main processes can be distinguished:

a. Charging phase
   which results in toll declarations and includes dispute resolutions about the fee due
b. Collection phase
   which deals with the actual collection of the fee from a toll charger.

Note that supporting processes like enforcement and dispute resolution are not explicitly included. Requirements for interoperability should focus on the interaction between the main processes of the parties involved and it should be up to each party to design his supporting process in such a way that the interoperability (and its own) requirements can be met.

The main equipment life cycle phases and main processes are depicted in the figure below.

Figure 1-3 Equipment life cycle phases and main processes

[15] The technical term is non-reputable. See the definition in section 3.1.
[16] See [10] for details.

The performance metrics of these phases and main processes are described in the next chapter.

2 Interoperability performance metrics

2.1 Overview

This section provides the performance metrics for the various life cycle phases and main processes as depicted in Figure 1-3.

2.2 Metrics for procurement

2.2.1 Introduction

In the EETS, the interoperability performance is examined is a two step process:
1. Certification and testing to check whether or not the technical specifications are met
2. Examining the suitability for use (see Annex IV of [2]).

Both examinations can be performed in a test environment with dedicated test routes (see 2.2.2).

The following type of metrics are distinguished:
- undercharging metrics for discrete metering,
- overcharging metrics for discrete metering,
- charging performance metrics for continuous metering, and
- DSRC transaction performance metrics.

2.2.2 Using dedicated test routes

Performance metrics before procurement can be measured in a controlled test environment.

In such a test environment measurements can be:
- compared with actually values
  (e.g. a recorded vehicle location may be compared with the actual location)
- repeated to arrive at average values and/or to measure values with small probabilities
- compared with values measured with others equipment of the same type, e.g. with a reference OBE, that is assessed under the same conditions

Moreover, for a fixed route a metric based on one of the followings is essentially equivalent with a metric based on the other ones:
- a metric per trip,
- a metric per unit of distance driven, and
- if the speed is fixed as well, a metric per unit of length of stay.

Note that the test route should mimic the tolled objects in the toll domain as close as possible. It does make sense to use a test route that is more demanding than the actual toll domain or vice verse[17].

2.2.3 Undercharging metrics for discrete metering

The following metrics can be used to measure undercharging with discrete metering:

[17] Or more demanding than a combination of toll domains in case a common test environment is used.

Fraction[18] of not recorded events[19,20]
The number of not recorded events (passages) divided by the number of events that should be recorded.

Fraction of not recorded fee
The not recorded fee divided by the fee actually due.

Note that for both measures the events / passages to be recorded should be known. For a GNSS based system this implies that the route of the vehicle should be known.

Both metrics result in the same value in case the same amount of toll is associated with each event.

But note also that there may be subtle differences between these metrics that have to be taken into account:

a. The toll due may vary from passage to passage
   In this case the fraction of missed events might be preferred in order to keep things simple.
b. In a DSRC based system the fee may be recorded by the RSE while the transaction was not completely performed in the perception of the OBE (see 2.2.6 for details).
c. In a DSRC based system some fee may be missed also because of a wrong declared or measured vehicle parameters.
d. A missed event might result in an higher fee
   Which may be e.g. the case in a car park if the entrance event is missed[21,22].

2.2.4 Overcharging metrics for discrete metering

The following metrics can be used to measure overcharging[23] with discrete metering:

Fraction of false events[24]
The number of false events (passages) divided by the number of events that should be recorded.

Fraction of false fee
The falsely recorded fee divided by the fee actually due.

For these metrics similar arguments as for the undercharging metrics for discrete metering apply.

Moreover, it should be noted that:

a. A falsely recorded event might result is less recorded toll[25]
b. A falsely recorded event might be an incorrectly detected event (passages) used for a nearby route (e.g. a parallel road). This requires a test environment in which not only the

[18] Equivalently a percentage, a permillage etc. may be used.
[19] This metric is essentially equivalent to the 'charging availability' metric for discrete charging schemes as defined in [7] and [8].
[20] A better 'performance' metric might be '1 – the fraction of missed events'. However, such subtleties are kept out of the scope of this paper.
[21] As may also be the case in a traditional car park when the entrance ticket is lost.
[22] Note although out of the scope of this paper, these cases can be easily dealt with in an actual test environment.
[23] Although overcharging is primarily a user problem and not a toll charger problem, it may also affect the toll charger (it may affect its reputation or he might be dragged into a dispute between a user and its toll service provider on this matter.
[24] This metric is essentially equivalent to the 'charging integrity' metric for discrete charging schemes as defined in [7] and [8].
[25] Like a false entry ticket for a car park may be used to pay less.

events that should be taken into account should mimic those in the actual toll domain, but also the events that may produce false recordings should not be taken into account.

2.2.5 Charging performance for continuous metering

Performance metrics for continuous metering can be based of the relative error value, i.e. the value of error (= measured value – actual value) divided by the actual value.

For negative values of the relative error, the term 'relative undercharging error' is used. For positive values, the term 'relative overcharging error' is used..

The following metric can be used to measure the charging accuracy with continuous metering:

Average relative (fee) error
The average of the relative (fee) error (for a number of predefined trips)

Standard deviation of the relative (fee) error
The standard deviation of the relative error (for a number of predefined trips).

Note that these metric are not suitable if under- and overcharging are valued differently. In this case the following metrics can be used:

Relative undercharging level probability
The fraction of predefined trips for which the relative undercharging error has exceeded a predefined level.

Relative overcharging level probability
The fraction of predefined trips for which the relative overcharging error has exceeded a predefined level [26].

The undercharging level probability and the overcharging level probability can be combined also in one metric that expresses the probability that the toll charger is sufficiently paid while at the same time the use of the vehicle is not unacceptably being overcharged;

Acceptable relative charging interval probability
The fraction of predefined trips for which the relative error remained within a predefined interval[27].

2.2.6 DSRC transaction metrics

The following metrics can be used to measure the performance of the DSRC transactions[28]:

The fraction of transaction completed as perceived by the RSE
The number of transaction for with the RSE has sent the final acknowledgement divided by the total number of transaction that should be performed.

The fraction of transactions completed as perceived by the OBE

[26] This metric is essentially equivalent to the 'charging integrity' metric defined in [7] and [8].
[27] This metric is essentially equivalent to the 'charging availability' metric defined in [7] and [8]
[28] See 2.2.3 for the subtle differences between these metrics and the ones for under- and overcharging defined above.

The number of transaction for with the OBE has received the final acknowledgement divided by the total number of transaction that should be performed.

Note that in case the OBE did not receive the final acknowledgment sent by the RSE it may generate a 'false' alarm for the driver.

The fraction of 'false' OBE alarms
The number of transaction for which the OBE has not received the final acknowledgement sent by the RSE divided by the total number of transaction that should be performed.

Note that these metrics may be used also for other DSRC transaction like compliance checking transactions.

2.3 Customisation metrics

Note that the EETS provider will be liable towards the toll charger for any accidental or deliberate (fraudulent) wrong customisation data. A toll charger should not be unnecessarily involved[29] in any dispute between a EETS provider and its customer in this matter.

Consequently, customisation is out of scope of this paper. However as a wrong customisation some may have an impact on some interoperability metrics customisation, these type of errors might be singled out (see the next sections for examples).

2.4 Toll declaration performance

2.4.1 Overview

The toll declaration performance metrics are the piece de resistance of performance metrics. Toll declaration defects and the detection of these defects are a major issue in interoperable tolling environments. A bad performance may cause significant loss of income while intensive detections efforts may be a major cost driver.

Note that most of the metrics defined above for the procurement phase are not suitable during the deployment of OBE. While deployed there are no predefined routes[30] and recorded values cannot be compared with actual values.

A performance metric for interoperability shall be based on (undisputable) verifiable observations, like the ones as defined for secure monitoring (see [10]). The feasibility of secure monitoring for performance metrics is justified also in Annex C.

Note that in case of third party metering with so-called thin OBE, an OBE performance metric will be of limited value as any location value measured by the OBE may changed considerably afterwards in the EETS provider's back office due to filtering and/or map matching processes.

Below the following types of metrics are presented:
a. Metrics that do not depend on the business model used for metering
b. Some additional metrics that may be useful for DRSC based systems

Details about a continuous metering of the distance travelled are elaborated in Annex C.

[29] Although a toll charger may be requested to pass some additional data resulting from its detection efforts to the toll service provider.
[30] Although a uses may compare values for his regular trips, these observations are not suited for an interoperability metric.

Note that this section focuses on undercharging. Overcharging is primarily an issue between a user and the toll service provider. Moreover, the possibility for a toll service provider to benefit from overcharging, i.e. by charging its customer more than he is charged for by the toll charger, can be avoided by making its role transparent, i.e. by providing a toll service provider with undisputable means to show to his customer the toll he has been charger for by the toll charger[31].

2.4.2 Metrics that do not depend on the business model for metering

In the end any dispute about the toll due is a dispute about more or less fee that has to be paid[32]. And as that dispute has a starting date and ending date the same kind of metrics as for outstanding debts can be applied.

Taking this into account the following metrics can be used in retrospect (i.e. after the dispute has been resolved and amount at stake has became clear):

The outstanding dept cost
The sum of the daily cost consisting of the amount of money at stake multiplied by a daily interest rate (e.g. an Euribor rate plus some fixed offset)[33]

Other metric that can be used are:

- *The number of disputes per unit charged*
  (e.g. per number of events, distance driven, length of stay, or the money due)
- *The average duration of a dispute*[34]
- *The number of penalties and the amount of money involved per unit charged*

In retrospect, the number of disputes per unit charged can be divided into:

- *The number resolved in favour of the originator*
- *The number resolved in favour of the other party*

If needed a metric defined above may be divided further into a metric regarding:

- *The recorded presence of a vehicle*
- *the application of the tariff scheme*
  (including disputes about measured or declared vehicle (usage) parameters)

Note that the resolution costs are less suited to be used as an interoperability metric as they depend on the (efficiency of the) internal processes of the parties involved and cannot be verified (easily) by the other party.

2.4.3 Additional metrics for DSRC based systems

In case of a DSRC based systems the following DSRC transaction metrics may be useful as well[35]:

The fraction of transaction per EETS provider completed as perceived by the RSE

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[31] However, a proposal to include this possibility in the draft CEN standard 12855 for the communication between back offices has been rejected recently.
[32] This disputed amount of fee should be clearly separated from the total amount of toll due as expressed in a toll declaration (with third party metering) or in billing details send by the toll charger (in case of self metering).
[33] Note that this cost shall be separately calculated for either party, the toll charger and the toll service provider
[34] A distinction might be made between the delay caused by the party who gained in the end and the other party.
[35] See also 2.2.6.

The number of transaction with OBE of an EETS provider for with the RSE has sent the final acknowledgement divided by the total number of transaction that should be performed.

The fraction of transactions per toll charger completed as perceived by the OBE
The number of transaction per toll charger for with the OBE has received the final acknowledgement divided by the total number of transaction that should be performed.

Note that for these two metrics neither party can verify the values measured by the other party. However, both metrics are to some extent comparable. The fraction of transactions completed in the perception of the OBE cannot be more then the fraction completed as perceived by the RSE.

2.5 Toll collection performance

2.5.1 Introduction

Toll collection performance metrics are metrics to access the collection process, i.e. the process of collection money. In essence there seem to be two types of metrics:

1. Metrics related to the time a toll charger has to wait until he is paid
2. Metrics related to the effort, i.e. the cost of the collection process itself.

The collection process costs are considered to be internal cost which no real significance for interoperability. Therefore, no metric for this cost is included.

2.5.2 Outstanding debts metrics

The following metrics can be used for outstanding debts:

The outstanding dept cost per EETS provider per period of time
The sum for the whole period of time of the daily cost consisting of the amount of the money due multiplied by a daily interest rate (e.g. an Euribor rate plus some fixed offset)[36]

Or more simply:

The average number of days before a bill is paid

To latter metric may be more suitable to compare the performance of several EETS providers[37].

3 Glossary and abbreviations

3.1 Glossary

availability
The ability of a functional unit to perform a required function under given conditions while the required external resources are provided and the functional unit is accessible to the user. [ISO2384-14]

[36] Note that this cost shall be separately calculated for either party, the toll charger and the toll service provider
[37] Note that 'normalisation' by dividing the value of the metric through the amount of money involved would result in an adding the daily interest values, i.e. of (more or less) constants that may be eliminated from the metric.

customer (of a Toll Service Provider)
person or legal entity that uses the service of a Toll Service Provider

NOTE Depending on the local situation, the customer can be the owner, lesser, lessee, keeper, (fleet) operator, holder of the vehicle's registration certificate, driver of the vehicle, or any other third person.

customize
make or modify to order or according to individual requirements

customization
The process of making or modifying to order or according to individual requirements

driver
person who drives a vehicle

NOTE: The driver is assumed to operate (use/serve) the OBE (e.g. the setting of the number of axles).

EETS Provider
A legal entity providing its customers toll services on the EETS toll domains

EETS User
Customer of an EETS provider

European Electronic Toll Service (EETS)
A service which allows users to circulate a vehicle in all the toll domains falling under the scope of Directive 2004/52/EC and pay the corresponding tolls with a single contract and a single on-board equipment.

examination
an assessment carried out during a limited time span, such as when identifying requirements, assessing and comparing systems for acquisition purposes, conducting acceptance testing, or as part of a certification procedure.
(see [7] section 2.3)

metering
measuring values needed to determine the toll due

monitoring
an assessment as an ongoing supervision process throughout the lifetime of a system, in order to validate contracted service levels, to identify fraud or malfunction, or to support ongoing maintenance and performance improvement processes.
(see [7] section 2.3)

non-repudiation
The property that non of the parties involved in a communication can deny in all or in part its participation in the communication[38].

NOTE This definition which complies with the usual definition in the security literature differs from the much weaker definition in CEN 15509. Essentially, CEN 15509 support a non-reputable confirmation only. Resolution of dispute about a denial would require the disclosure of a secret key.

[38] Adapted from ISO 7498-2 [9].

onboard equipment (OBE)
A complete set of hardware and software components required for providing EETS which is installed on board of a vehicle in order to collect, store, process and remotely receive/transmit data.

one(s) liable for toll
person(s) or legal entity(ies) liable to pay toll under the operation of a toll regime

NOTE: A toll regime may designate more than one person to be (jointly and severally) liable for paying the toll.

performance (SOED)
the capabilities of equipment or a process measured under test

performance (IEEE)
The degree to which a system or component accomplishes its designated functions within given constraints, such as speed, accuracy, or memory usage.

secure monitoring
A service that allows a toll charger to check whether or not the observed presence of a vehicle has been correctly accounted for by the EETS provider.

suitability for use
the ability of an interoperability constituent to achieve and maintain a specified performance when in service, integrated representatively into EETS in relation with a Toll Charger's system (see [2])

toll
charge, tax, fee, or duty in connection with using a vehicle within a toll domain

NOTE The definition is a generalization of the classic definition of a toll as "a charge, a tax, or a duty for permission to pass a barrier or to proceed along a road, over a bridge, etc.".

toll charger
legal entity charging toll for vehicles in a toll domain

NOTE In other documents the terms operator or toll operator can be used.

toll declaration
statement to a toll charger that confirms the presence of a vehicle in a toll domain in a format agreed between the Toll Service Provider and the Toll Charger

NOTE A valid toll declaration has to fulfil formal requirements, including security requirements, agreed between the Toll Service Provider and the Toll Charger.

toll domain
area, a part of a road network, or a structure such as a tunnel, a bridge or a ferry where a toll regime is applied

toll regime
set of rules, including enforcement rules, governing the charging and collection of toll in a toll domain

toll scheme
generic term used for toll regime and/or toll domain and/or toll system depending on the context

toll service
service enabling users having only one contract and one set of OBE to use a vehicle in one or more toll domains

toll service provider
legal entity providing its customers toll services on one or more toll domains for one or more classes of vehicle

NOTE 1 In other documents the terms “issuer” or “contract issuer” can be used.

NOTE 2 The toll service provider is assumed to be responsible for the operation (functioning) of the OBE with respect to tolling.

toll system
off-board equipment and possible other provisions used by a toll charger for the collection of toll for vehicles

NOTE 1 The OBE is excluded from the definition.

NOTE 2 The actual payment (collection of the fee) can take place outside the toll system.

toll systems environment management
controlling enterprise object for the toll systems environment

NOTE The toll systems environment management can encompass several distinct entities, e.g. a political/legislative one, a regulatory one, private associations, standardization authorities, and so on.

tolled object
distinguished part of a toll domain for which one or more tariff schemes apply

EXAMPLE An area, all public roads within an area, a bridge, a zone, or a stretch of road (network).

user
generic term used for customer of a toll service provider, one liable for toll, the owner of the vehicle, a fleet operator, a driver, etc. depending on the context.

3.2 Abbreviations

CE	Central Equipment
DSRC	Dedicated Short Range Communication
EU	European Union
GMAR	GNSS Metering Association for Road user charging
GPAF	GMAR’s Performance Assessment Framework
EETS	European Electronic Toll Service
GNSS	Global Navigation Satellite System
OBE	On Board Equipment
RSE	RoadSide Equipment
SOED	Shorter Oxford English Dictionary
TC	Toll Charger
TSP	Toll Service Provider

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Annex A. Metrics

A.1 Introduction

A metric is defined as a measure of some property[39]. In literature a metric is also called a measure. Metrics or measures can be classified according to the type of their scale[40].

The following type of scales[41] can be distinguished[42].

1. Nominal
2. Ordinal
3. Interval
4. Log-Interval
5. Ratio
6. Absolute
7. Normalized[43]

Nominal scales

With a nominal scale labels (names or numbers) are assigned to categories. Examples with respect to vehicles are its make, its country of registration, vehicle type, power source, etc.

For a nominal scale there is no implied order of its values.

Permissible transformations are one-to-one function. With such a function one may transform one nominal scale to some other scale without loss of information.

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Nominal scale is not suited for a performance metric.

Ordinal scales

With an ordinal scale the values of a metric reflect an order / ranking of the measured attributes. However the 'distance' or ratio between values does not have any meaning.

Examples for vehicles are the classes N1, N2, and N3 for vehicles carrying goods or the environmental category Euotype. Another examples are the academic grades (A, B, ..).

Permissible transformation are strictly monotone functions. With such a function one may transform one ordinal scale to some other ordinal scale without loss of information.

An ordinal scale may be used for a performance metric.

Interval scales

An interval scale is an ordinal scale for which the difference between the values reflects a difference between the attributes.

Examples for vehicles are the maximum speed or the date of registration. More common examples are a temperature in degrees Fahrenheit or Celsius; a calendar date.

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[39] See software metric and performance metric in the Wikipedia
[40] See e.g. http://en.wikipedia.org/wiki/Level_of_measurement for details.
[41] In literature also the terms "levels of measurement", or "scales of measure" are used.
[42] See, e.g. ftp://ftp.sas.com/pub/neural/measurement.html
[43] .Not in ftp://ftp.sas.com/pub/neural/measurement.html but added as special case of an absolute metric useful for performance metrics.

Permissible transformations are the affine transformation f(x)= ax + b with constants a and b. In other words the origin and the unit a arbitrary.
Although an interval scale can be seen as an improved of an ordinal scale it is seldom used for a performance metric because it does not have an origin.

Log-interval scales
An log-interval scale is an ordinal scale for which the ratio between the values reflects an ratio of the attributes.

Examples for vehicles are fuel efficiency in kilometres per litre or densities.

Permissible transformation are the transformation $f(x)= ax^d$ with constants a and d.

Ratio scales
A ratio scale is a scale for which both differences and ratios reflect differences and ratios of the attribute.

Examples of a ratio scale are length measured in cm, duration measured in seconds or degrees measured in Kelvin.

Permissible transformations are the linear transformation f(x) = ax with constant a. In other words, the unit of measurement is arbitrary.

This scale may be used for performance metrics as it has a well defined origin (0 value).

Absolute scales
In absolute scale the all properties of the numerical values reflect analogous properties of the attribute.

Examples are the number of axles, of seats, or of trailers of a vehicle.

For an absolute scale there are no permissible transformations except the identity transformation f(x)=x.

Absolute scales, and especially a normalised scales (see below), are well suited for performance metrics.

Normalised scales
A normalized scale is a special case of the absolute scale with values in the interval [0.1].

Examples are a probability or a fraction.

NOTE A percentage or a permillage may be regarded equivalent to a normalised scale as their values can be easily and unambiguously transformed into a normalised value.

Annex B. The fair threshold problem

B.1 Introduction

A Member State (toll charger) is free to define its own toll policy.

For a toll service provider it is therefore of paramount importance that he will not be confronted overnight with overly performance requirements[44]. A most terrifying scenario for a toll service provider in this respect is that he has to replace all of his OBE at once because of new thresholds for performance requirements.

Problems with thresholds performance requirement for the EETS may result from:
1. The lack of technical requirements used for CE marking
2. The possibility that toll charger may add any additional suitability for use requirements
3. The lack of experience to build on for commercial requirements
4. The legal and undisputable freedom of Member States to define their toll policy, the required performance will increase if technological improvements allow for more sophisticated toll regimes.

However (although to a lesser extent for problem 2), these problems can and should be mitigated with procedural guarantees. And, although these procedural guarantees may not resolve everything, they may provide an absolute minimum of trust for a toll service provider that he does have to depreciate his investments suddenly, especially its investment in OBE.

B.2 Legal provisions for setting fair thresholds

The decision [2] stipulates that;
"The Conciliation Body shall especially be empowered to examine whether the contractual conditions imposed by a Toll Charger on different EETS Providers are non-discriminatory and a fair reflection of the costs and risks of the parties to the contract." (see article 10.1)

In this respect it should be emphasised that the decision speaks about "non-discriminatory" and not about "non-discriminatory with respect to other toll service providers". This implies that a toll charger may not discriminate a toll service provider to protect its own business, this implication is reflected also in the "fair reflection" requirement.

B.3 Fair thresholds in the technical specifications

The technical specifications for the EETS are far from complete. Although CEN standard 15906 specifies the requirements for the DSRC based systems, the technical requirements for GNSS (GPS) based systems[45] are still lacking.

In this respect the Decision stipulates that:
"When EETS relevant technical specifications are published after adoption of this Decision, the Commission shall consider their applicability in accordance with the procedure referred to in Article 5(2) of Directive 2004/52/EC."

In this context it is to be expected that EU member states would be reluctant to agree on technical specifications that may not accommodate their possible future interest.

[44] Note that the margins in business case for a toll service provider are already very small (if not negative).
[45] Also, and more precisely, called autonomous systems.

One way out of this dilemma is to base the technical specification first on the systems currently in place and, at the same time, to implement a reasonable procedure to accommodate future and more demanding toll policies and/or other security or performance requirement. (see [2], article 10.1)

B.4 Additional threshold required for the suitability for use

Even for OBE[46] with a CE mark, the decision requires that the equipment (OBE) may be subjected to a 'suitability for use test' that shall:
"give evidence to the Toll Charger(s) that the interoperability constituents meet all the interoperability requirements of this (these) Toll Charger(s)" (see Annex IV, 2.(a).3. and 2.(b).3).

Note that this provision does not contain any restriction, Therefore the toll charger's requirements in this respect are only bounded by the non-discriminatory / fairness provisions in article 10.1 of the Decision [2].

And, even worse, from the perspective of toll service provider, a toll charger may charge the EETS provider for its cost to make its system EETS compliant (see Annex I, article 1).

In summary, the provisions for the 'suitability for use' should be revised because the current decision provides any toll charger / member state with an opportunity to block the EETS[47,48].

B.5 Setting fair commercial thresholds

The lack of experience to build on, makes the setting commercial requirements a challenging task.

However, a toll charger willing to support the EETS and to comply to the provisions in article 10.1 of the decision (see B.2) may opt for a procedure in which:

- he justifies and, if needed, can adjust thresholds afterwards
- he is willing, if his judgement is contested by an EETS provider, to accept a verdict of the local conciliation body (and especially whether or not his thresholds are non-discriminatory and present a fair reflection of the costs and risks of the parties to the contracting parties).

B.6 Additional requirements because of new tolling policies

Any Member State has an undisputable freedom to define its toll policy. Consequently, the required performance will increase when technological improvements allow for more sophisticated toll regimes.

Although this may look challenging, it should be noted that:

- Not only a Member State but also a toll service provider should monitor technical progress and may be assumed anticipate to some extent to these develpments

[46] Formally the Decision speaks about interoperability constituents, but within the 'suitability for use' context this applies only to interoperability constituents used by a toll service provider.
[47] As a simple example, the Dutch 'Westerschelde tunnel' uses infrared technology. So, if the Netherlands should decide that this tunnel would be an EETS domain, the EETS providers could be required to pay for the installation of EETS compliant DSRC equipment.
[48] Another example is the German EETS domain statement. On one hand one might criticize this statement because it requires an EETS provider to measure the toll due in the same way as Toll Collect. On the other hand this allows the toll charger to use the same compliance checking methods. And, the latter is much cheaper for an EETS provider than to pay for the cost to make the German system compliant to more generic EETS requirements in accordance with article 1 of Annex I.

- Also the Member State / toll charger needs time to formulate its requirements and to allow industry to design, manufacture, test and supply this more sophisticated (onboard) equipment.

Taking this considerations into account, it should be possible to design a procedure the allows a toll service provider to cope with new requirements in due time.

An example of such a procedure with respect to vehicle parameters can be found already in the Decision (see article 3 and 4 of Annex V).

Annex C. Location accuracy

C.1 Introduction

In autonomous systems the toll due may not only depends on the vehicle's location but also on the distance driven. In case in such systems the distance driven is derived based on location measurements, the location accuracy requires special attention.

In autonomous systems the declared toll may depend on the measurement accuracy of the vehicle's location. In this respect there are two distinct cases to consider:

1. the inclusion of passages
2. the determination of the distance driven within a tolled object

Note that, in some cases, a tariff for a distance related toll may be implemented with a toll system that is based on passages. A notable example is the German Maut with a fee per kilometre that is implemented as a toll proportional to the length of segments that is charged when a vehicle enters the segment.

C.2 The location accuracy of passages

In case the toll due does not depend on the time of the distance travelled, the location accuracy of a passage may not be an issue. What counts is that a passage is recorded and be taken into account correctly, not whether this happens on a precisely defined location.

EXAMPLE: In case of a toll due for a segment, the vehicle should record its entrance of the segment somewhere at the beginning (to allow compliance checking further on). However in this case it may not matter whether or not this is done at the first meter of after a few hundred meters.

Nevertheless, in case of two nearby parallel roads, one tolled and one not, location accuracy is an issue. However, performance can be measured with spot checks at the tolled road to measure undercharging and the other road to detect overcharging (see [10] for details).

In case the toll for a tolled object depends also on the time and/or distance travelled accuracy might be an issue. In case the entrance of the tolled object is recorded too late and leaving is recorded too early, not all due may be taken into account. The impact will depend then on the size of the tolled object, or more precise on the ratio between the toll not declared and total amount due for the whole itinerary within the tolled object.

EXAMPLE: In case of a toll per kilometre driven in the Netherlands, an exact determination of the boarder may not be considered a real issue.

C.3 Measurement of the distance driven

Metrics for the accuracy of a distance related toll can be arrived at in a three step process:

1. Metrics related to gaps in the itinerary recorded by the toll service provider
2. Metrics related to the accuracy of the toll related to a continuous recorded itinerary.
3. Metrics related to the accuracy of the recorded itinerary itself (the main issue)

In case of a distance related toll, the itinerary through a tolled object has to be recorded as a continuous route[49]. Defects in this respect can be divided into:

a. gaps in the recorded itinerary (i.e. undercharging)
b. overlaps or extra routes in the recorded itinerary (i.e. overcharging)

[49] Note that there may be subtle measurement differences. First the units of measurement may be relative to the border of the tolled object. Second, the may be relative to the start of the usage of the OBE. In the latter case it has been decided whether such a unit lies within the tolled object or not.

Undercharging be monitored by observing[50] the vehicle and checking either on the spot[51] or after receiving the toll declaration[52] whether this presence was recorded or not.

Detection of overcharging may not be regarded as an issue related to the interoperability between a toll service provider and a toll charger. The toll declaration is drawn up by the toll service provider and the toll charger does not care. In this case the customer should be provided the complete account that underlies the toll service provider's toll declaration. The customer may then be able to check whether the recorded itinerary is correct or not. And even in case he is able to detect defects, the burden of proof might be a problem. Nevertheless, with proper procedures there seem to be not much room for fraud in this respect[53]. A remaining problem is that these proper procedures are not supported by the current draft of the CEN standards for the exchange of information between a toll service provider and a toll charger[54].

For a continuous itinerary the accuracy issue can be split further into two independent sub-issues:
1. the accuracy of the declared toll for a recorded itinerary (= step 2 above)
2. the accuracy of the recorded itinerary when compared this the vehicle’s actual itinerary (= step 3 above).

With respect to the first issue it should be noted that, in principle, the toll for a recorded itinerary can be calculated in whatever degree of accuracy. Variations (inaccuracies) in the length (or duration) of the various parts of the itinerary are immaterial. The itinerary is fully covered anyway. Nevertheless there is still a need for metrics covering the correct use of vehicle (use) characteristics by the toll service provider.

The second issue can again be subdivided as follows:
1. Issues regarding inaccuracies related to the passing of the border of the tolled object. (this issue has been dealt with above, see C.2)
2. Issues that only relate to the length the itinerary within a tolled object.

The latter can be split into:
a. a longer recorded itinerary, i.e. overcharging
b. a shorter recorded itinerary, i.e. undercharging
   (and the major interoperability issue with respect to location accuracy)

Overcharging may be caused by location measurement inaccuracies perpendicular to the actual itinerary. However as stated before, this a not a concern for the toll charger and will not have negative consequences for his trust in the toll declaration. Nevertheless, the similar arguments as for overlaps or extra routes apply (see above)

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[50] Note that compliance checking should be based always on an observed (presence of the) vehicle. If not, one cannot prove the vehicle's presence.
[51] However this only makes sense if the OBE is sufficiently 'thick', i.e. in case defects are not corrected later in the back office of the toll service provider. See the spot checking in [10] for details.
[52] See the declaration account checking in [10] for details.
[53] . On the other hand, it is unlikely that this type of overcharging results from technical defects. Also, a toll service provider has no insensitive for fraud if only the toll charger would gain from it. Consequently, if toll charger can show that the toll he collecting from is customer is the same as in his toll declarations (as incontestably acknowledged by the toll charger) or as in an incontestable invoice from the toll charger, there is not much, if any, room for fraud in this respect (except for case conspiracy between a toll service provider and a toll charger).
Note that requires that a toll charger would sign an acknowledgement of invoice per customer of the toll service provider.
[54] To be precise, a request for such a service has been rejected by the project team when dealing with the comments on version 7 of the draft.

Undercharging can only be caused if the recorded itinerary shortcuts bends in the actual one (one cannot shortcut a straight line)[55]. This can be detected by vehicle observations on the bend and checking either on the spot[56] or after receiving the toll declaration[57] whether the presence of the vehicle on the bend was correctly recorded or not. Note that the case of parallel roads with a different toll was already covered in C.2.

[55] Note this is not a real issue for a time based fee. Nowadays time can be measured accurately and, also, time does not contain bends.
[56] However this only makes sense if the OBE is sufficiently 'thick', i.e. in case defects are not corrected later in the back office of the toll service provider See the spot checking in [10] for details.
[57] See the declaration account checking in [10] for details.