TECHNICAL SPECIFICATION

ISO/TS 17444-2

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Electronic fee collection — Charging performance —

Part 2:
Examination Framework

Perception du télépéage — Performance d'imputation —

Partie 2: Cadre d'examen

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 17444-2 was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*, and by Technical Committee CEN/TC 278, *Road transport and traffic telematics* in collaboration.

ISO/TS 17444 consists of the following parts, under the general title *Electronic fee collection — Charging performance*:

— *Part 1: Metrics*

— *Part 2: Examination Framework*

Introduction

Electronic Tolling systems are complex distributed systems involving critical technology such as dedicated short range communication (DSRC) and global navigation satellite systems (GNSS) both subject to a certain random behaviour that may affect the computation of the charges. Thus, in order to protect the interests of the different involved stakeholders, in particular Service Users and Toll Chargers, it is essential to define metrics that measure the performance of the system as far as computation of charges is concerned and ensure that the potential resulting errors in terms of size and probability are acceptable. These metrics will be an essential tool when establishing requirements for the systems and also for examination of the system capabilities both during acceptance and during the operational life of the system.

In addition, in order to ensure the interoperability of different systems it will be necessary to agree on common metrics to be used and on the actual values that define the required acceptable performances although this is not covered in this Technical Specification.

This Technical Specification is defined as a toolbox standard of examination tests plus a method for defining and documenting Specific Examination Frameworks to meet specific needs. The detailed choice of the set of examination tests within an Examination Framework depends on the application and the respective context. Compliance with this specification is understood as using the definitions and prescriptions laid out in this Technical Specification whenever the respective system aspects are subjected to performance measurements, rather than using other definitions and examination methods than the ones specified in this Technical Specification.

ISO/TS 17444-1 defines a set of charging performance metrics with appropriate definitions, principles and formulations, which together make up a reference framework for the establishment of requirements for EFC systems and their later examination of the charging performance.

These charging performance metrics are intended for use with any toll scheme, regardless of its technical underpinnings, system architecture, tariff structure, geographical coverage, or organizational model. They are defined to treat technical details that may be different among technologies as a “black box”. They focus solely on the outcome of the charging process – i.e. the amount charged in relation to a pre-measured or theoretically correct amount – rather than intermediate variables from various components as sensors, such as positioning accuracy, signal range, or optical resolution. This approach ensures comparable results for each metric in all relevant situations.

The metrics are designed to cover the information exchanged on the front-end interface and the interoperability interfaces between Toll Service Providers and Toll Chargers as well as information on the end-to-end level.

Metrics for the following information exchanges are defined:

— charge reports;

— toll declarations;

— billing details and associated event data;

— payment claims on the level of user accounts;

— end to end metrics which assess the overall performance of the charging process.

The proposed metrics are specifically addressed to protect the interests of the actors in a toll system, such as Toll Service Providers, Toll Chargers and Service Users. The metrics can be used to define requirements (e.g. for requests for proposals) and for performance assessment.

Toll schemes take on various forms as identified in ISO/TS 17575 suite and ISO 14906. In order to create a uniform performance metric specification toll schemes are grouped into two classes, based on the character of their primary charging variable: Charging based on discrete events (charges associated to the fact that a vehicle is crossing or standing within a certain zone), and those based on a continuous measurement (duration or distance).

In all these toll schemes, tolls may additionally vary as a function of vehicle class characteristics such as trailer presence, number of axles, taxation class, operating function, and depending on time of day or day of week, such that e.g. tariffs are higher in rush hour and lower on the weekends.

With this degree of complexity, it is not surprising to find that the attempts to evaluate and compare technical solutions for Service User charging have been made uniquely each time a procurement or study is initiated, and with only limited ability to reuse prior comparisons made by other testing entities.

Examination Framework

The Examination Framework that is defined in this part of ISO/TS 17444 is designed for measuring the metrics defined in ISO/TS 17444-1. The general aim is to achieve a maximum of comparability and reproducibility of the results without restricting the technological choices in system design. Specific Examination Frameworks maybe defined for the Evaluation and Monitoring Phases of a project due to the differences in the availability of equipped vehicles.

Evaluation Phase

This phase encompasses system evaluation and selection as well as commissioning and ramp up during implementation. Important aspects of this phase are:

— relatively small sample sizes;

— well controlled behaviour of test vehicles.

Monitoring Phase

After the system has gone into operation, its behaviour needs to be monitored for several reasons, such as fine-tuning of the system performance, monitoring of SLAs between contractual partners (supplier, Toll Charger, Toll Service Provider, etc.). In this phase the following system aspects can be expected:

— very large sample sizes possible, but with unknown behaviour of the vehicles;

— in principle all measurements from implementation phase possible, too.

Readers Guide

To understand the content of this part of ISO/TS 17444, the reader should be aware of the methodology and assumptions used to develop the Examination Framework and associated examination tests; therefore a suggested reading order is given below:

1) Annex B provides details of the underlying considerations for developing the Examination Framework.

2) Annex C provides background statistical information which will enable the reader to determine sample sizes and confidence limits based on the defined performance requirements.

3) Clause 5 provides the definition of the Examination Framework for the evaluation of Charging Performance.

4) Clause 6 contains the toolbox of Examination Tests for the evaluation of charging performance for the identified scheme types.

5) Annex D contains methods which can be used to reduce the required sample sizes for metrics with high / low probabilities during the evaluation phase.

6) Annex E provides an example(s) of Specific Examination Frameworks which have been developed in accordance with the methodology in Clause 5.2.

Electronic fee collection — Charging performance — Part 2: Examination Framework

1 Scope

This part of ISO/TS 17444 defines the Examination Framework for the measurement of Charging Performance Metrics defined in ISO/TS 17444-1 to be used during Evaluation and/or on-going Monitoring.

It specifies a method for the specification and documentation of a Specific Examination Framework which can be used by the responsible entity to evaluate charging performance for a particular information exchange interface or for overall charging performance within a Toll Scheme.

It provides a toolbox of Examination Tests for the roles of Toll Charger and Toll Service Provider for the following Scheme types:

a) DSRC Discrete;

b) Autonomous Discrete;

c) Autonomous Continuous.

The detailed choice of the set of examination tests to be used depends on the application and the respective context. Compliance with this specification is understood as using the definitions and prescriptions laid out in this Technical Specification whenever the respective system aspects are subjected to performance measurements, rather than using other definitions and examination methods than the ones specified in this Technical Specification.

Out of scope of this specification are the following aspects:

— This Technical Specification does not propose specific numeric performance bounds, or average or worst-case error bounds in percentage or monetary units. Those decisions are left to the Toll Charger (or to agreements between Toll Charger and Service Provider).This Technical Specification does not consider the evaluation of the expected performance of a system based on modelling and measured data from trial at another place.

— This Technical Specification does not consider the specification of a common reference system which would be required for comparison of performance between systems.

— This Technical Specification defines measurements only on standardised interfaces. Proprietary interfaces are excluded, because it is not possible to define standardised metrics on such system properties. These excluded interfaces are among others the link between Toll Charger RSE and central systems in DSRC systems, and the additional sensor input of GNSS modules (inertial sensors, CAN-bus for wheel ticks, etc.).

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/TS 17444-1, *Electronic fee collection — Charging performance — Part 1: Metrics*

ISO 12855:2012, *Electronic fee collection — Information exchange between service provision and toll charging*

ISO/TS 17575-1:2010, *Electronic fee collection — Application interface definition for autonomous systems — Part 1: Charging*

ISO 17573:2010, *Electronic fee collection — Systems architecture for vehicle-related tolling*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
absolute charging error
difference between the measured charge (toll) value and the actual value (as measured by a reference system)

Note 1 to entry: A positive error means that the measurement exceeds the actual one.

[SOURCE: ISO/TS 17444-1:2012, definition 3.1]

3.2
accepted charging error interval
interval of the Relative Charging Error varying from a negative (undercharge) to a positive (overcharge) value that the Toll Charger considers as acceptable, i.e. correct charging

[SOURCE: ISO/TS 17444-1:2012, definition 3.2]

3.3
average relative charging error
ratio between the sum of computed charges associated to a set of vehicles during a certain period of time and the actual due charge (for the same set of vehicles and the same period) minus 1

[SOURCE: ISO/TS 17444-1:2012, definition 3.3]

3.4
billing detail
for a given Transport Service, all necessary data required to determine and/or verify the amount due for the Service User

Note 1 to entry: If the data is accepted by both the Toll Charger and the Toll Service Provider, then it is called a concluded Billing Detail which can be used to issue a Payment Claim.

Note 2 to entry: For a given Transport Service, the Billing Detail is referring to one or several valid Toll Declaration(s). A valid Billing Detail" has to fulfil formal requirements, including security requirements, agreed between the Toll Service Provider and the Toll Charger.

[SOURCE: ISO 12855:2012, definition 3.1]

3.5
chargeable event
event in which a vehicle passes through a Charge Object that implies that vehicle has to be charged or a different rate (e.g. price per kilometre) applied

Note 1 to entry: This event refers to the use of a certain object and not to the mechanisms by which detection is produced.

[SOURCE: ISO/TS 17444-1:2012, definition 3.5]

3.6
charge object
any object that is part of the toll context description that may be charged for its use under certain conditions

[SOURCE: ISO/TS 17575-1:2010, definition 3.6]

3.7
charging period
period of time which is used to define the frequency of the Toll Declarations, when Charge Reports are aggregated to form Toll Declarations

Note 1 to entry: If the Charging Period is set to 24 h then in the Toll Context Data a single Toll Declaration is submitted for each 24 h period for each Service User.

[SOURCE: ISO/TS 17444-1:2012, definition 3.7]

3.8
Charge Relevant Event
event occurring within a tolling system, which is relevant for charge calculation, but not for the detection of a Charge Object itself

Note 1 to entry: Examples of this type of event are changes in vehicle category or time zone.

[SOURCE: ISO/TS 17444-1:2012, definition 3.8]

3.9
charge report
data structure transmitted from the Front End to the Back End to report road usage data and supplementary related information

Note 1 to entry: In 2009/750/EC, Charge Report is referred to as “Toll Declaration”.

[SOURCE: ISO 12855:2012, definition 3.2]

3.10
discrete toll scheme
toll scheme where the charge is calculated based on distinct events associated with the identification of Charge Objects such as crossing a cordon, passing a bridge, being present in an area, etc.

Note 1 to entry: Each event is associated with a certain charge.

[SOURCE: ISO/TS 17444-1:2012, definition 3.10]

3.11
continuous toll scheme
toll scheme where the charge is calculated based on the accumulation of continuously measured parameter(s), such as, distance, time, etc.

[SOURCE: ISO/TS 17444-1:2012, definition 3.11]

3.12
event detection
element of the system responsible for detecting Chargeable Events associated with a Charge Object

Note 1 to entry: The output of this element provides the key information to compute a charge in a discrete scheme, or act as input for a function in a continuous scheme (e.g. for zones where distance tariffs apply).

[SOURCE: ISO/TS 17444-1:2012, definition 3.12]

3.13
evaluation
process applied for measuring a specific metric or set of metrics during an evaluation phase

[SOURCE: ISO/TS 17444-1:2012, definition 3.13]

3.14
Front End
part(s) of the toll system where road usage data for an individual Service User are collected, processed and delivered to the Back End

Note 1 to entry: The Front End comprises the on-board equipment and an optional proxy.

[SOURCE: ISO/TS 17575-1, definition 3.13]

3.15
false positive event
Chargeable Event that did not take place but is recorded by the system

[SOURCE: ISO/TS 17444-1:2012, definition 3.15]

3.16
missed recognition event
Chargeable Event that takes place but is not recorded by the system

[SOURCE: ISO/TS 17444-1:2012, definition 3.16]

3.17
monitoring
process within a distributed system for collecting and storing state data

Note 1 to entry: This can be used to observe metrics during operation.

[SOURCE: ISO/TS 17444-1:2012, definition 3.17]

3.18
overcharging
situation when the calculated charge is above the Accepted Charging Error Interval

[SOURCE: ISO/TS 17444-1:2012, definition 3.18]

3.19
payment claim
recurring statement referring to concluded Billing Details made available to the Toll Service Provider by the Toll Charger who indicated and justified the amount due

Note 1 to entry: The payment claim is used by the Toll Service Provider to issue financial objects to its customers (e.g. invoices on behalf of the Toll Charger). A given toll payment claim is referring to concluded Billing Details and takes into account any specific commercial conditions applicable to a vehicle, a fleet of vehicles, a customer of a Toll Service Provider and/or a Toll Service Provider. A valid “payment claim” has to fulfil formal requirements, including security requirements, agreed between the Toll Service Provider and the Toll Charger.

[SOURCE: ISO 12855:2012, definition 3.14]

3.20
performance metrics
specific calculations used to describe the charging performance of a system. These calculations are technology- and schema-independent

[SOURCE: ISO/TS 17444-1:2012, definition 3.20]

3.21
population
totality of items under consideration

[SOURCE: ISO 3534-1:2006]

3.22
relative charging error
ratio between the Absolute Charging Error and the actual value, i.e. Relative Charging Error = Absolute Charging Error / Actual Value

Note 1 to entry: The topic of Actual Values and how to handle them will be dealt with in the Examination Framework.

[SOURCE: ISO/TS 17444-1:2012, definition 3.21]

3.23
representative trips
trips that are of a distance larger than a defined threshold and so have to be considered by the related metrics

Note 1 to entry: Only trips which exceed the threshold and cover the specific types of roads of the Toll Regime have to be considered.

Note 2 to entry: The threshold may be defined as zero.

[SOURCE: ISO/TS 17444-1:2012, definition 3.22]

3.24
sample
subset of a population made up of one of more of the individual parts in which the population is divided

[SOURCE: ISO 3534-1:2006, modified]

3.25
service user
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

[SOURCE: ISO 12855:2012, definition 3.29]

3.26
specific examination framework
particular instance of a set of Examination Tests defined by an entity to determine the performance of specific selected Charging Metrics during either Evaluation and or Monitoring

3.27
successful charging
situation where the user has been correctly charged according to the rules of the system

Note 1 to entry: For discrete Toll Schemes this means that for a given chargeable journey the Chargeable Events have been correctly identified and for continuous schemes that the Charge determined is within the Accepted Charging Error Interval.

[SOURCE: ISO/TS 17444-1:2012, definition 3.24]

3.28
Toll Charger
legal entity charging toll for vehicles in a toll domain

Note 1 to entry: In other documents the terms operator or toll operator can be used.

[SOURCE: ISO 17573:2010, definition 3.16]

3.29
Toll Service Provider
legal entity providing customer toll services on one or more toll domains for one or more classes of vehicle

Note 1 to entry: In other documents the terms issuer or contract issuer can be used.

Note 2 to entry: The Toll Service Provider can provide the OBE or can provide only a magnetic card or a smart card to be used with OBE provided by a third party (just as a mobile telephone and a SIM card can be obtained from different parties).

Note 3 to entry: The Toll Service Provider is responsible for the operation (functioning) of the OBE with respect to tolling.

[SOURCE: ISO 17573: 2010, definition 3.23]

3.30
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 1 to entry: A valid Toll Declaration has to fulfil formal requirements, including security requirements, agreed between the Toll Service Provider and the Toll Charger.

[SOURCE: ISO 12855 2012, declaration 3.19]

3.31
trip
part of space-time trajectory of a particular vehicle within a Toll Scheme

Note 1 to entry: The exact definition of the start and end of trip is dependent on the Toll Regime and technology approach.

[SOURCE: ISO/TS 17444-1:2012, definition 3.28]

3.32
undercharging
situation where the calculated charge is below the Accepted Charging Error Interval

[SOURCE: ISO/TS 17444-1:2012, definition 3.29]

3.33
user
generic term used for the 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

[SOURCE: ISO 12855, definition 3.29]

3.34
user account
assets, liabilities, income, expenses, and equity of a Service User in his relationship to his Toll Service Provider

[SOURCE: ISO/TS 17444-1:2012, definition 3.31]

3.35
user complaint
complaints related to service provision received by the Toll Service Provider from its Users via contact channels

[SOURCE: ISO/TS 17444-1:2012, definition 3.32]

4 Symbols and Abbreviated terms

ARCE Average Relative Charging Error

BD Billing Details

CCR Continuous Charge Report

CCTV Closed Circuit Television (ISO/TS 17444-1)

CELB Charging Error Interval Lower Bound

CEUB Charging Error Interval Upper Bound

CI Charging Input

CM Charging Metric

CR Charge Report

CTD Continuous Toll Declaration

DCR Discrete Charge Report

DSRC Dedicated Short Range Communications (EN ISO 14906)

DTD Discrete Toll Declaration

DO Dedicated OBE Testing

E2E End to End (ISO/TS 17444-1)

EFC Electronic Fee Collection (ISO 17573)

EETS European Electronic Toll Service (ISO 17573)

ESA Enforcement System ANPR

ESD Enforcement System DSRC

FE Front End (ISO/TS 17575-1)

GNSS Global Navigation Satellite System (ISO/TS 17444-1)

GPP GNSS path post processing

ICT Information and Communications Technology

IS Independent Reference System

ITS Intelligent Transport Systems (ISO/TS 17444-1)

KPI Key Performance Indicator

MBDD Maximum Billing Details Delay

MPCD Maximum Payment Claim Delay

MTDD Maximum Toll Declaration Delay

MUSD Maximum User Statement Delay

OBE On-Board Equipment (ISO 17573)

PC Payment Claim

SLA Service Level Agreement (ISO/IEC 20000-1)

SO Simulated OBE / FE

TSP Toll Service Provider (ISO 17573)

TSP-BO Toll Service Provider back office

TC Toll Charger (ISO 17573)

TC-BO Toll Charger back office

TD Toll Declaration

UA User Account

5 Examination Framework

5.1 General

Clauses 6.1 to 6.4 contain a toolbox of Examination Tests for the following scheme types:

a) DSRC Discrete (Clause 6.1 & optionally Clause 6.2);

b) Autonomous Discrete (Clause 6.3);

c) Autonomous Continuous (Clause 6.4).

NOTE These Scheme Types are defined in ISO/TS 17444-1.

Each of these clauses contains the specific examination tests for the applicable Charging Metrics identified in ISO/TS 17444-1.

Clause 5.2 defines the process that should be followed to define a specific Examination Framework for a particular purpose.

Clause 5.3 provides a definition of the sources of data that can be used by the Examination Tests to calculate the Charging Metrics.

Clause 5.4 provides the definitions of the methods of generating Charging Input referenced in the Examination Tests defined in Clause 5.5.

Clause 5.5 defines the applicability of the defined Charging Metrics for the Roles of Toll Charger and Toll Service Provider for the 3 identified scheme types.

Clause 5.6 provides tables for the selection of Charging Metrics and associated Examination Tests for the Roles of Toll Charger and Toll Service Provider for each identified Scheme Type.

5.2 Method for defining a Specific Examination Framework

Figure 1 provides an overview of the process that should be followed to define a specific instance of an Examination Framework for the evaluation of Charging Metrics for the roles of Toll Service Provider and/or Toll Charger in a particular Toll Scheme. Further details are provided in the Clauses 5.2.1 to 5.2.6.

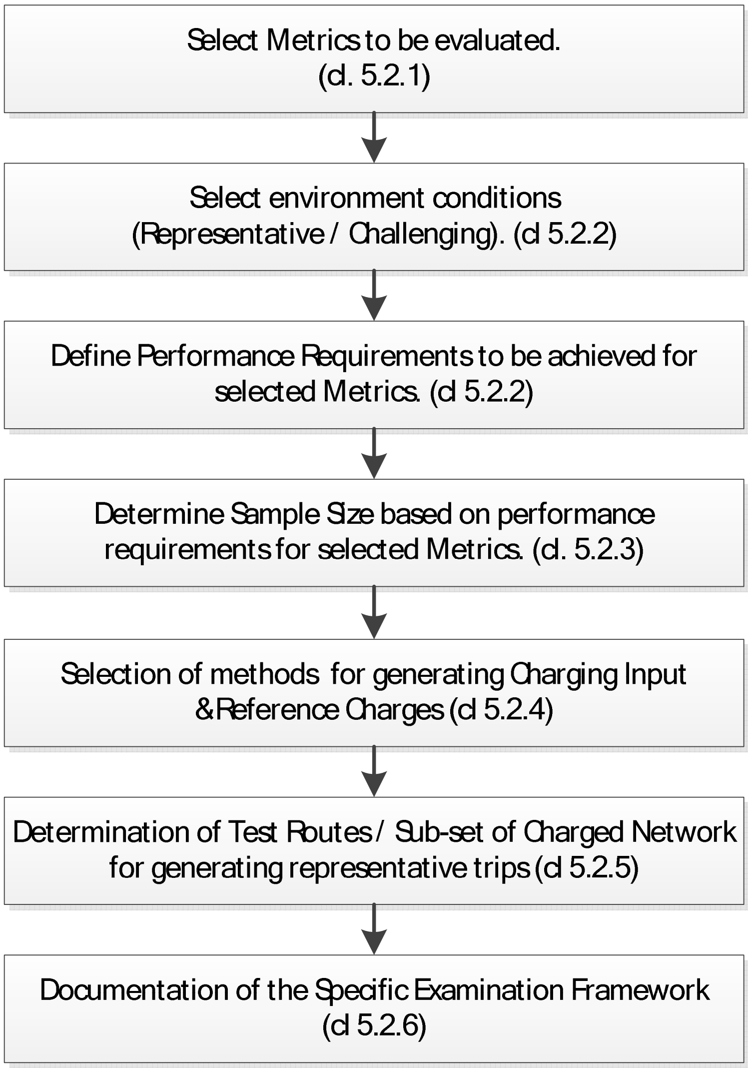

Figure 1 — Method for Defining a Specific Examination Framework

5.2.1 Selection of Metrics to be evaluated

The entity responsible for the definition of the specific Examination Framework shall determine the metrics to be measured in the phases of Evaluation and Monitoring for the roles of Toll Service Provider and / or Toll Charger using the appropriate tables in Clause 5.6

a) DSRC Discrete

- Table 5 — DSRC Discrete - Metric Selection Table
- Table 6 — DSRC Discrete – Optional DSRC Toll Declaration Metric Selection Table

b) Autonomous Discrete

— Table 7 — Autonomous Discrete - Metric Selection Table

c) Autonomous Continuous

— Table 8 — Autonomous Continuous - Metric Selection Table

5.2.2 Definition of environmental conditions and associated performance requirements

The entity responsible for the definition of the specific Examination Framework shall determine the environmental conditions (Representative / Challenging) and associated performance requirements to be met for each metric selected in 5.2.1.

NOTE 1 Assessment of Charging Metrics in a Representative Environment allows performance in the operational environment to be assessed. However care is to be taken to ensure that the Charging Data Input / selection of representative trips is comparable to that expected for the operational environment.
The choice of representative environmental conditions will in practice result in a multidimensional parameter space (e.g. air moisture, topography, electromagnetic environment, etc.). It is important to choose these parameters and their values with care to ensure that tests are performed in all realistic sets of conditions (or at least the most probable ones) while keeping the number of necessary tests to a minimum.

NOTE 2 Assessments of Charging Metrics in a Challenging Environment are typically used to determine behaviour for worst case scenarios in the operational environment. Due to the non-linear dependence of system performance on the environmental conditions it is difficult to transpose measured performance levels to those in operational systems.

The environmental conditions and associated performance requirements to be met for each metric selected should be documented in each Examination Test within the specific Examination Framework.

NOTE 3 In cases where comparative testing is chosen (e.g. a new population of OBE is introduced into an existing tolling system), the influence of the environmental conditions on the comparison results could be reduced if the tests were performed in parallel. In this case both populations are exposed to the same conditions. Nonetheless it still necessary to perform the step described in Clause 5.2.2. This is important to ensure that the comparative test is performed under all relevant conditions; it also helps to pinpoint dependencies of performance differences to issues with robustness to certain environmental conditions, i.e. one population of equipment being more sensitive to certain environmental conditions than the other.

5.2.3 Determination of Required Sample Sizes

Based on the performance requirements set for each metric selected in Clause 5.2.2 the entity responsible for the definition of the specific Examination Framework shall determine the sample sizes required to provide statistically significant measurements based on the respective formulas for discrete and continuous systems in Annex C. The required sample sizes shall be documented for each Examination Test in the specific Examination Framework.

5.2.4 Selection of methods for generating Charging Input and Reference Data

For each Examination Test in the Specific Examination Framework that requires specific Charging Input to be generated, the responsible entity shall document which identified option for the generation of the Charging Input shall be used (Clause 5.4). Where reference data are required for the calculation of the metric within a specific Examination Test, the method of generating the reference data shall be documented in the Examination Test.

As a reference for the definition of the methods for generating input data, an analysis of different data sources that can be used for that generation are identified in Clause 5.3.

5.2.5 Determination of Test Routes / Sub-set of Charged Network for generating representative trips

For each selected Examination Test in the Specific Examination Framework that requires the generation of specific Charging Input / Representative Trips, the responsible entity shall determine and document the Test Route of the Charged Network which shall be used to generate the representative trips.

NOTE 1 As indicated in Clause 5.2.2, particular care has to be taken to ensure that the selected test routes of charged network are selected to meet the required test environment conditions.

NOTE 2 In cases where the test vehicles are not under control of the test, this step is still useful and necessary: It helps in the selection of suitable test vehicles, which should be expected to drive as much as possible on the sub-set of the charged network. Additionally it might be necessary to prepare the OBE for the test, e.g. generating geo-data defining the sub-set of the charged network and loading those data into the Front End.

5.2.6 Documentation of the Specific Examination Framework

By following the process defined in Clause 5.2.1 to Clause 5.2.5 the entity responsible for the definition of the Specific Evaluation Framework will have fully defined and documented the selected Examination Tests within its Specific Examination Framework. A template for the documentation of Examination Tests is provided in Annex A and examples can be found in Annex E.

5.3 Sources of Data

The selection of the methods for generating input data is very much constrained by the availability of the different data sources that can be of very different nature depending on:

— the different phases (evaluation/monitoring);

— the type of system (discrete/continuous);

— the available technologies (e.g. DSRC, GNSS, ANPR).

Because the definition of metrics involves in general the comparison of measured system values to expected values, their computation requires both the outputs of the charging system under test and reference data that represent those expected values. The establishment of expected values is, obviously, the most complex task as it requires some independent system that has to provide expected values (which are an estimation of the truth with much higher accuracy and reliability than the operational charging system to be analysed.) or a concise statistical analysis applied to a sufficiently large data set, or in most cases both.

Data from the system under test need to be acquired at the different interfaces for which metrics are established including:

— outputs from Front-End (Charge Reports);

— outputs from Toll Service Provider back office (Toll Declarations and User Account);

— outputs from Toll Charger back office (Billing Details and Payment Claims).

The following sources of data are identified:

a) **The Operational Charging** System for the provision of the charges computed by the system that needs to be compared with the reference. These references can be obtained by any of the means described in the following items.

b) **The Operational Enforcement** System.

c) **Independent detection systems** (e.g. road side cameras, a second toll charging system or other records) that allow the determination that a vehicle has or has not passed through a particular road segment.

d) **Simulated OBEs and Front-Ends** (to feed the back office) that allow analyzing the capabilities of that back office having as reference the known (simulated) data generated by those OBEs.

e) **Reference systems installed in vehicles** (e.g. highly accurate positioning system based on GPS + inertial measurement unit, Odometer, etc.).

f) **Dedicated probe vehicles**. Depending on the type of metric to be computed (in particular if it refers to discrete or continuous systems) two types of approaches can be used to know the detailed trajectory (and hence the charge due) of these probe vehicles:

1) Known routes: the basis for the reference data is known by the a priori definition of those routes. This is only applicable to discrete systems since continuous systems require a detailed knowledge of the actually followed trajectory;

2) Use of reference systems as described in item E.

g) **Data from OBE testing** based for instance in the use of GNSS signal simulators or DSRC simulators.

The potential use of these data for the different cases considered is summarized in the following table:

Table 1 — Identification of where different sources of data can be used (valid for both DSRC and autonomous systems)

Identifier	Source of Data	Valid for:			
		Phase		Scheme Type	
		Evaluation	Monitoring	Discrete	Continuous
A	Operational charging system	As far as available	Yes	Yes	Yes
B	Operational Enforcement	As far as available	Yes	Yes	Yes
C	Independent detection systems	Yes	Yes	Yes	Yes
D	Simulated OBEs and FE	Yes	Yes	Yes	Yes
E	Reference systems installed in vehicles	Yes	Yes	Yes	Yes
F	Dedicated probe vehicles	Yes	Yes	Yes	Yes
G	Data from OBE Testing	Yes	Yes	Yes	Yes

Figure 2 and Figure 3 analyse for each of the levels for which metrics are defined:

— What are the performance drivers, i.e. the key elements of the system that affects the performances.

— What is the key data (identifier from Table 1) required for the metrics computation.

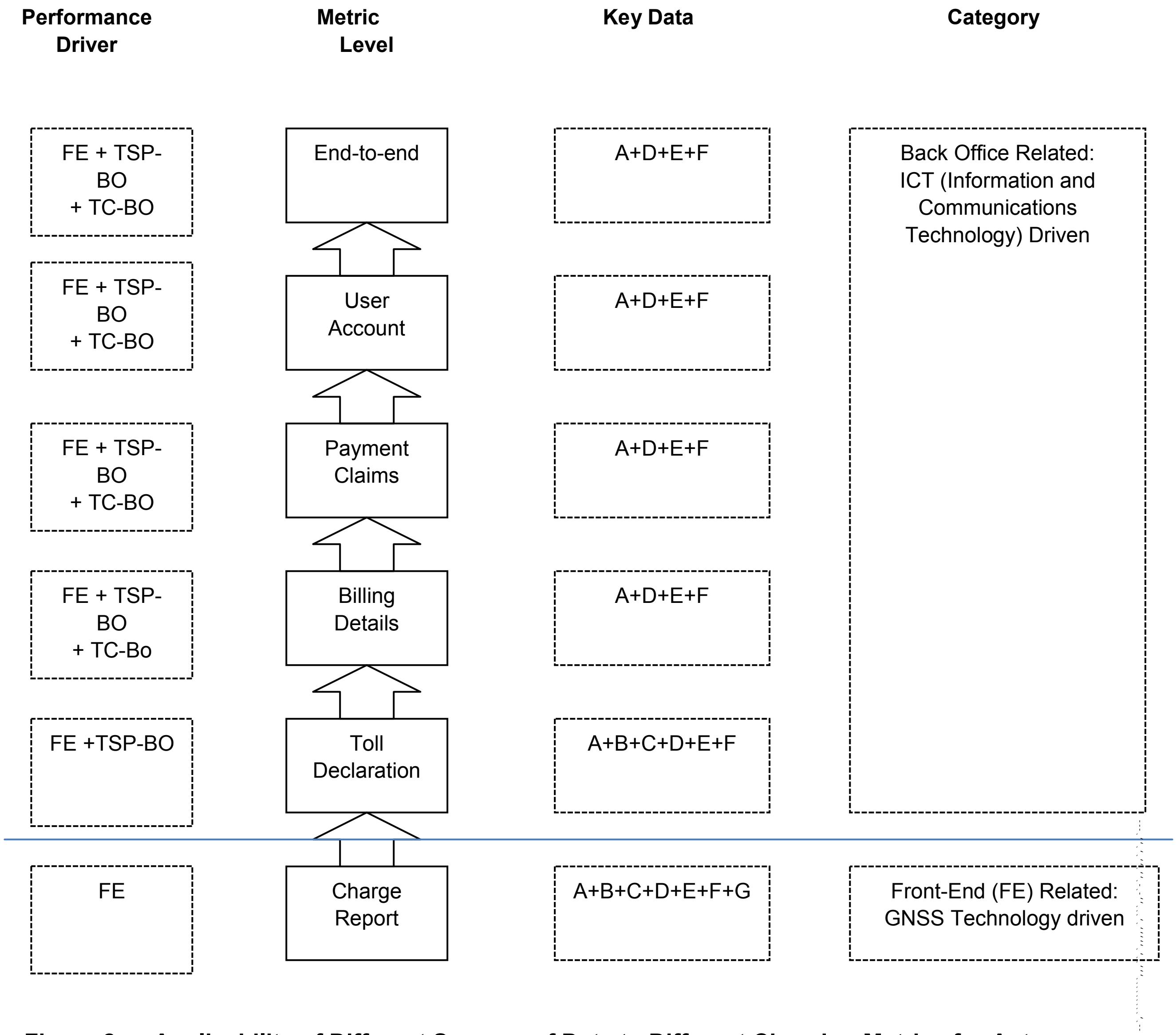

Figure 2 — Applicability of Different Sources of Data to Different Charging Metrics for Autonomous Systems, both discrete and continuous; Key Data refers to identifier from Table 1

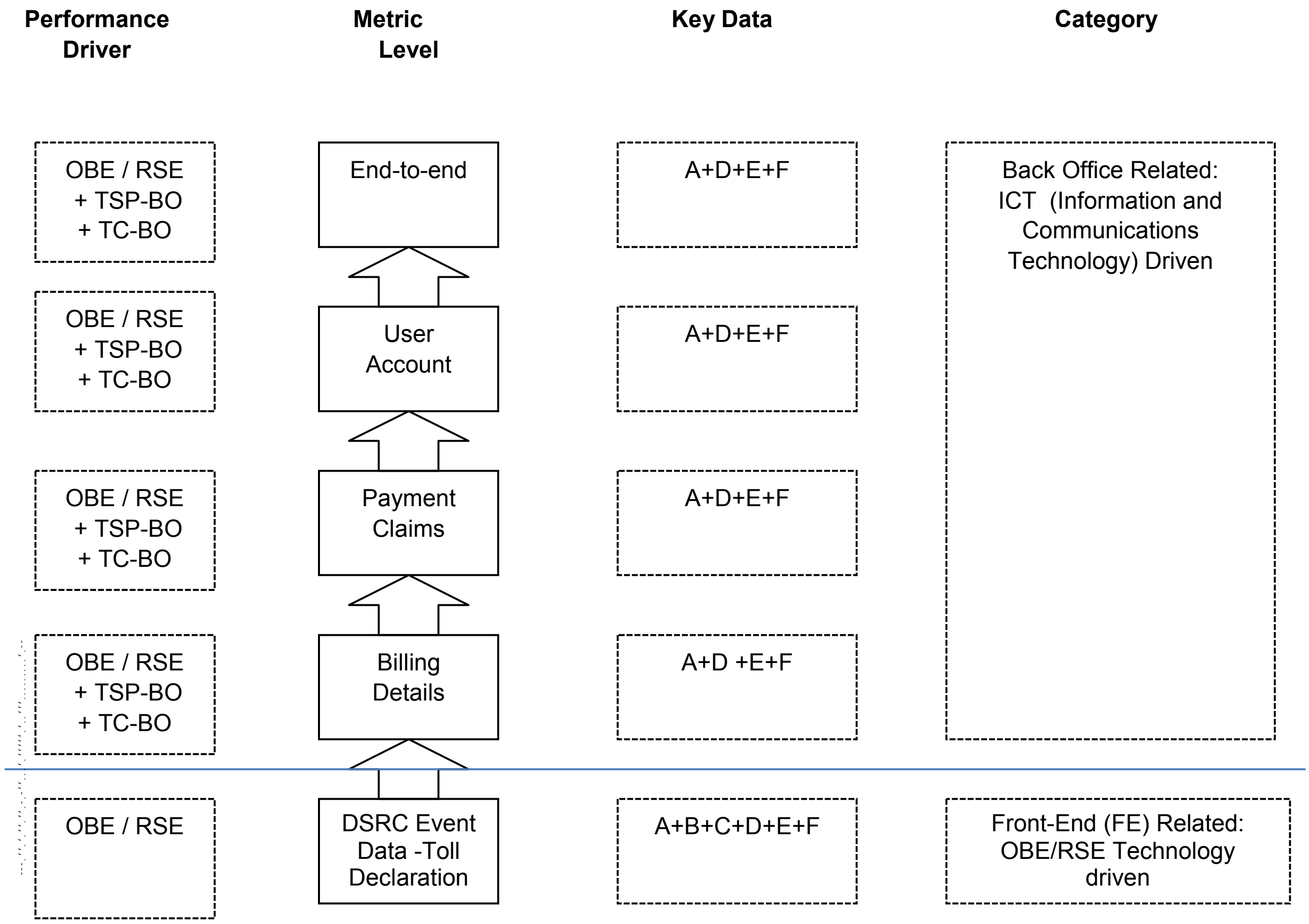

Figure 3 — Applicability of Different Sources of Data to Different Charging Metrics for DSRC based Systems, Key Data refers to identifier from Table 1

As a result of this analysis it can be easily derived that two groups of metrics require data and methodology that are of a very different nature:

— Charge Reports and / or Toll Declaration metrics require specific data to determine a reference, which makes the process complex.

— Billing Details, Payment Claims, User Account and E2E metrics can be derived from the Charge Report / Toll Declaration metrics and including additional data that can be easily simulated.

This implies that a major complexity is required for the definition of the Examination Framework at Charge Report / Toll Declaration level.

5.4 Methods of generating charging input

The decisions for one or a combination of methods for generating charging input shall take into account the advantages and disadvantages of the respective examination methods. Particular attention has to be paid to:

— number of OBE tested (and what kind of variation of OBEs is necessary);

— number of toll objects verses number of different toll objects examined;

— cost vs. benefit;

— statistics.

Table 2 gives an overview over the methods of generating charging input within the Toll Scheme. In Table 3, a subset of those methods are ordered according to whether the vehicle generating the input is a Service User vehicle ("UVR"), the driver of which might not even be aware that they are participating in performance measurements, or a possibly dedicated probe vehicle ("PV"). The meaning of "predefined routes" and "reference system" are described in the following clauses.

Table 2 — Overview of Methods of Generating Charging Input

Name	Description	Source of Data (cl 5.3)	Identifier for later reference	Link to Section 5.4.x
Probe Vehicles (PV)	Controlled / dedicated vehicles on either predefined routes (PVP) or in relation to a reference system (PVR)	A, B, C, E, F	PVP (for predefined routes) PVR (for reference system)	5.4.1 and 5.4.2
Service User vehicles (UVR)	Service Users vehicles in relation to a reference system	A, B, C, E	UVR	5.4.2
Complian ce Checking (CC)	Controlled / dedicated vehicles or Service User vehicles at known spots where compliance checking takes places	A, B	CCD (for DSRC system information) CCA (for ANPR system information)	5.4.2.1
Simulated OBE/FE	Simulators used to generate Chargeable Events	A, D	SO	5.4.3
Dedicated OBE Testing	White box OBE testing	G	DO	5.4.4

Table 3 — Overview of Methods of Generating Charging Input by vehicles using the Toll Scheme

	Type of vehicle used to generate data	
	Probe vehicle	**Service User vehicle**
Predefined routes	PVP	not applicable
Reference system *(one or more of CCD, CCA, PR, IS, GPP) see Clause 5.4.2*	PVR	UVR

5.4.1 Predefined routes (identifier: "PVP")

Testing charging performance via predefined routes is widely used in many toll schemes. Test routes are set up to sample realistic and challenging road conditions in order to evaluate the charging performances of the whole system, which includes the operation of OBEs, roadside equipment, back offices, etc. Owing to the nature of this set-up, predefined routes are only applied for vehicles under the control of the organisation responsible for the performance measurements ("probe vehicles"),

The routes shall be designed to be representative of the real Toll Domain. It will sample a driver's overall driving behaviour in combination with occasional complex geographical features and conditions expected to challenge the technologies. The probe vehicles, which could consist of dedicated vehicles and volunteer vehicles, will undertake a variety of specific manoeuvres/test routes designed to test different aspects of the system. The distance of the routes shall be long enough and the vehicle may drive repeatedly a number of times to ensure that the test results are statistically significant. This may require a significant time (over a period of weeks or months).

NOTE If performances of OBE of autonomous systems (the proposed method is not valid for continuous measurements) are to be compared, all those OBEs can be installed in only one test vehicle, thus reducing variations caused by external conditions and driving patterns (the OBEs also could be fitted in several vehicles to test).When comparing the performance of DSRC OBEs in a 'real' environment, only one OBE should be installed per test vehicle.

Although the paths of the test vehicles are known by definition, it shall be supported by a GNSS reference to account for the fact that even for predefined routes, deviations can occur, that need to be verified later on.

5.4.2 Reference System (used in combination with identifiers: “PVR” and “UVR”)

A reference system is defined as a set-up where a reliable reference is generated in respect the toll due of the vehicles in question. The vehicles can be either ones under the control of the organisation responsible for the performance measurements (PVR) or vehicles of Service Users (UVR).

NOTE 1 “UVR” also refers to cases where the tolling service is not operational yet, but data can already be obtained from customers of a Toll Service Provider.

NOTE 2 This reference may be obtained in a two-step process, where first a reference position or track is generated and then – based on this position or track – the toll reference data necessary for the respective test.

In the following, methods for establishing a reliable reference are described.

5.4.2.1 Reference System: Comparison with a compliance checking system (identifiers: "CCD" and "CCA")

In order to evaluate the charging accuracy of a toll scheme, DSRC transactions (CCD) or ANPR detections (CCA) from compliance checking infrastructure can be used as reference for comparison of the performance of the OBE. It assumes that such a comparison between an OBE passing a compliance checking gantry and the same OBE passing a “nearby” Charge Object can be made in a meaningful way. This procedure compares the detected Charge Object with the actual Charge Object. It enables a significant number of spot checks for all passing vehicles at all times.

The measurement basis of this method is the comparison of events (from DSRC compliance checks or ANPR compliance checks, or both) detected from gantries with (one or more) closely positioned Charge Objects and fulfilling certain other criteria. A corresponding *Charging Report* is searched in a certain time window around every enforcement event contained in the sampled Service User vehicle.

CCD and CCA will not have a detection accuracy of 100%, so the reference of passing Service Users will not be complete. However this does not limit the use of this method. The sub-set of detected vehicles can be used as the population for which charging performance is determined.

NOTE Real time comparison of DSRC transactions in the above mentioned way makes it possible to continuously and real-time monitor the toll scheme performance at all times. It is also low cost in terms of personnel required.

5.4.2.2 Reference System: Positioning reference system (identifier: "PR")

Vehicles (either probe vehicles or Service User vehicles) shall be equipped with a positioning reference system. This can be either a commercial positioning system or a high accuracy positioning system. For UVR, Service User vehicles need to be acquired and consented, depending on data protection laws special contracts have to be signed, an incentive scheme might be necessary.

NOTE As an example, the vehicles could be equipped with high performance GNSS, such as differential or kinematic GPS, for positioning, supplemented by an inertial measurement unit (IMU). This would be to meet the highest possible accurate measurement of distance. Front-ends under evaluation will be installed by a Toll Service Provider (TSP).

The vehicles can either run repeatedly on pre-defined routes or at random on not predefined routes in a way that is typical for the tolled vehicles. The data generated by these vehicles will be reported to central back office (possibly through the whole computations and interfaces to the billing information – to mirror the End-to-End process), analysed and compared with data generated by the reference position and/or distance as measured by the equipment in the vehicle.

Charge events are designed for the toll schemes. Reliable detection of the occurrence of certain events can be assessed as one of the Key Performance Indicators for the system. The accuracy of continuous charging (time, distance) can be assessed between discrete charging events.

5.4.2.3 Reference System: Independent reference system (identifier: "IS")

It is possible to compare events from an independent system against output from the system under test. Examples of such independent systems are manual analysis of passing traffic, a second toll charging system (which might be already in place) or other records.

The case of a second toll charging system is especially relevant for tests of new (discrete) interoperable toll systems or introduction of new technology, which is then compared with an established system. The key issue with this method is the identification of the charge liable vehicles from the passing traffic or the recording of charges liable with a second system. The reliability of the independent reference system has to be established as well as a procedure for reconciliation of charging/non-charging events when there is a difference between the IS and the system under test.

The method is similar to the comparison with a compliance checking system, but may use alternative traffic monitoring infrastructure not installed specifically for the Toll Scheme.

5.4.2.4 Reference System: GNSS path post processing (identifier: "GPP")

GNSS path post processing is defined as a set-up where a reference is generated by route analysis of the vehicle in question. The vehicles can be either ones under the control of the organisation responsible for the performance measurements (PVR) or vehicles of Service Users (UVR).

The method is based on the analysis of GNSS-based vehicle tracks, which allows positioning and tracking of a single or multiple vehicles, mapping their location onto charging objects along with the routes travelled and its detailed historical analysis. This mapping of GNSS tracks onto Charge Objects will be performed by a system independent from the EFC OBE.

NOTE The GNSS tracks may be obtained from the EFC OBE itself.

5.4.3 Simulated OBE / FE (identifier: “SO”)

Simulators / Emulators that can be used to generate simulated Chargeable Events from the Front-End of the Toll Service Provider (Charge Reports) or Toll Charger (DSRC Transaction Reports). This method can be used on one of two ways:

a) Evaluation of Charge Report Generation for given GNSS path

b) Generation of reference Charging Input for the evaluation of metrics for Toll Declaration, Payment Claims, User Account and End-2-End

Depending on the sophistication of the simulators it may be possible to simulate operational charging performance under certain defined conditions.

NOTE An example of the possible application of such method could be the suitability for use tests in EETS.

5.4.4 Dedicated OBE Testing (identifier: “DO”)

While “black box testing” (i.e. testing based only in the information available in the “public” interfaces) is intended as the main mechanism for the definition of the examination tests described in Clause 6, it is anticipated that some metrics, especially those involving very high or very low probabilities would require a huge sample size that can make “black box testing” unfeasible due to the high cost and long schedule required.

In those cases alternative testing methods are required and dedicated OBE testing (“white box testing) is one of those alternative methods. In this method either simulated inputs are injected to the OBE and/or internal data analysed. This sort of analysis is potentially technology dependent and, therefore, may require knowledge of the OBE design. As such they cannot be defined a priori and therefore they require special procedure to be agreed between the Toll Service Provider and the OBE supplier.

Dedicated OBE testing may involve the use of GNSS signal simulators (if no other position technology is hybridised within the OBE) to simulate demanding environment conditions as well as the access to intermediate data of the OBE from which metrics can be derived.

A more detailed description of alternative methods to the one described in Clause 6 including dedicated OBE testing are proposed in Annex D.

While the departure from the black box testing approach makes it all but impossible to provide input for reliable comparison, methods like that are widely used and expected to gain even more importance in the future. If used with care, dedicated OBE testing could provide valuable insight hard to obtain otherwise. In evaluating the result, the nonlinear system behaviour shall be taken into account (e.g. barely or just not quite receiving the signal of the fourth GNSS satellite, resulting in good or no position data).

5.5 Applicability of metrics scheme types

Table 4 defines the applicability of the defined Charging Metrics for the following types of Toll Schemes:

a) DSRC Toll Scheme (DD) – Toll Charger with one or more Toll Service Providers;

b) Autonomous Discrete Toll Scheme (AD) – Toll Charger with one or more Toll Service Providers;

c) Autonomous Continuous Toll Scheme (AC) – Toll Charger with one or more Toll Service Providers.

The entries in Table 4 Scheme Type have the following meaning when considering their inclusion in the definition of a specific Examination Framework: "Y" indicates that the metric is applicable, "O" indicates that this is an optional metric, " " indicates that the metric is not applicable.

In addition for each metric the following information is provided

a) Key Data Requirements- Data required to calculate the metric:

   1) RD – Reference Data;

   2) UA – User Account;

   3) PC - Payment Claims;

   4) BD – Billing Details;

   5) TD – Toll Declarations;

   6) CR – Charge Reports;

   7) CCR – Compliance Check Records.

b) Evaluation – Charging Input Method Options– the applicable methods that could be used (Clause 5.4), entries of PVR and UVR imply the use of one or more of the Reference Identifiers: CCD, CCA, PR, IS, GPP.

c) Monitoring – Charging Input Method Options – the applicable methods that could be used (Clause 5.4), entries of PVR and UVR imply the use of one or more of the Reference Identifiers: CCD, CCA, PR, IS, GPP.

Table 4 — Applicability of Charging Metrics for Scheme Types and Roles

	Metric ID	Metric Name	Scheme Type			Key Data Requirements	Evaluation Charging Input Method Options	Monitoring Charging Input Method Options
			DD	AD	AC			
End-to-End	CM-E2E-1	E2E Correct Charging Rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-E2E-2	E2E Overcharging Rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-E2E-3	E2E Undercharging Rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-E2E-4	E2E Late Charging Rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
User Account	CM-UA-1	UA - Correct Charging Rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-UA-2	UA - Overcharging Rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-UA-3	UA - Undercharging Rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-UA-4	UA - Accurate application of Payments and Refunds	Y	Y	Y	UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-UA-5	UA – Accurate Personalisation of OBUs	Y	Y	Y	CCR	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
Payment Claims	CM-PC-1	PC - Correct Charging Rate	Y	Y	Y	RD, PC	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-PC-2	PC – Overcharging Rate	Y	Y	Y	RD, PC	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-PC-3	PC - Undercharging Rate	Y	Y	Y	RD, PC	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-PC-4	PC - Latency – TC	Y	Y	Y	PC	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-PC-5	PC - Late Payment Claims	Y	Y	Y	PC	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-PC-6	PC – Rejected Payment Claim Rate	Y	Y	Y	RD, PC	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
Billing Details	CM-BD-1	BD - Correct Charging Rate	Y	Y	Y	RD, BD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-BD-2	BD – Overcharging Rate	Y	Y	Y	RD, BD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-BD-3	BD - Undercharging Rate	Y	Y	Y	RD, BD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-BD-4	BD - Incorrect Charging Rate	Y	Y	Y	RD, BD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-BD-5	BD - Latency – TC	Y	Y	Y	BD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-BD-6	BD – Late Billing Details	Y	Y	Y	BD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-BD-7	BD – Rejected Billing Details Rate	Y	Y	Y	RD, BD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-BD-8	BD – Incorrect rejected Billing Details Rate	Y	Y	Y	RD, BD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-BD-9	BD – Inferred Billing Details Rate	Y	Y	Y	RD, BD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO

Table 4 (continued)

	Metric ID	Metric Name	Scheme Type			Key Data Requirements	Evaluation Charging Input Method Options	Monitoring Charging Input Method Options
			DD	AD	AC			
Toll Declaration	CM-TD-1	TD - Correct Toll Declaration Generation	O	Y	Y	RD, TD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-TD-2	TD - Incorrect Toll Declaration Generation	O	Y	Y	RD, TD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-TD-3	TD – Late Toll Declarations	O	Y	Y	RD, TD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-TD-4	TD - TSP Event Detection	O	Y	Y	RD, TD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-TD-5	TD - TSP False Positive	O	Y	Y	RD, TD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-DTD-1	DTD - Correct Charging Rate (Chargeable Events)		Y		RD, TD	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO
	CM-DTD-2	DTD - Incorrect Charge Event recognition		Y		RD, TD	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO
	CM-DTD-3	DTD - Missed Charge Event Recognition		Y		RD, TD	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO
	CM-DTD-4	DTD Overcharging Rate		Y		RD, TD	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO
	CM-CTD-1	CTD Correct Charging Rate			Y	RD, TD	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO
	CM-CTD-2	CTD Overcharging Rate			Y	RD, TD	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO
	CM-CTD-3	CTD Accuracy of Distance / Time Measurement			Y	RD, TD	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO
Charge Report	CM-CR-1	CR - Correct Charge Report Generation		Y	Y	RD, CR	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-CR-2	CR - Incorrect Charge Report Generation		Y	Y	RD, CR	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-CR-3	CR - Charge Report Latency		Y	Y	RD, CR	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-CR-4	CR – TSP Front End Event Detection		Y	Y	RD, CR	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-CR-5	CR – TSP Front End False Positive		Y	Y	RD, CR	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-DCR-1	DCR - Correct Charging Rate (Chargeable Events)		Y		RD, CR	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO
	CM-DCR-2	DCR - Incorrect Charge Event recognition		Y		RD, CR	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO
	CM-DCR-3	DCR - Missed Charge Event Recognition		Y		RD, CR	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO
	CM-DCR-4	DCR - Overcharging rate (Incorrect false positive Charge Event Recognition)		Y		RD, CR	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO
	CM-CCR-1	CCR - Correct Charging Rate			Y	RD, CR	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO
	CM-CCR-2	CCR - Overcharging Rate			Y	RD, CR	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO
	CM-CCR-3	CCR - Accuracy of Distance / Time Measurement			Y	RD, CR	PVP,PVR,UVR,IS,SO,DO	PVP,PVR,UVR,IS,SO,DO

5.6 Charging Metric Selection Tables

5.6.1 General

The entity responsible for the definition of the specific Examination Framework shall use the appropriate table(s) from the following Clause5.6.2 to Clause5.6.4 to define, for each selected Metric to be measured during an Evaluation and/or Monitoring, the:

— Charging Input (CI) Method to be used;

— Target Value to be achieved.

The completed table(s) shall form part of the documentation of the specific Examination Framework.

5.6.2 DSRC Discrete

Table 5 should be used to define the examination tests to be performed for a specific Examination Framework in a DSRC Discrete Scheme.

Table 6 contains additional tests which might be helpful for DSRC systems, but which cannot be prescribed in a normative way, because the respective interfaces are proprietary.

Table 5 — DSRC Discrete - Metric Selection Table

		Evaluation		Monitoring	
Metric ID	**Examination Test**	**CI Method**	**Target Value**	**CI Method**	**Target Value**
CM-E2E-1 E2E Correct Charging Rate	cl. 6.1.2				
CM-E2E-2 E2E Overcharging Rate	cl.6.1.3				
CM-E2E-3 E2E Undercharging Rate	cl.6.1.4				
CM-E2E-4 E2E Late Charging Rate	cl.0				
CM-UA-1 UA - Correct Charging Rate	cl.6.1.6				
CM-UA-2 UA - Overcharging Rate	cl.6.1.7				
CM-UA-3 UA - Undercharging Rate	cl.6.1.8				
CM-UA-4 UA - Accurate application of Payments and Refunds	cl.6.1.9				
CM-UA-5 UA – Accurate Personalisation of OBUs	cl.6.1.10				
CM-PC-1 PC - Correct Charging Rate	cl.6.1.11				
CM-PC-2 PC – Overcharging Rate	cl.6.1.12				
CM-PC-3 PC - Undercharging Rate	cl.6.1.13				
CM-PC-4 PC - Latency – TC	cl.6.1.14				
CM-PC-5 PC - Late Payment Claims	cl.6.1.15				
CM-PC-6 PC – Rejected Payment Claim Rate	cl.6.1.16				
CM-BD-1 BD - Correct Charging Rate	cl.6.1.17				
CM-BD-2 BD – Overcharging Rate	cl.6.1.18				
CM-BD-3 BD - Undercharging Rate	cl.6.1.19				
CM-BD-4 BD - Incorrect Charging Rate	cl.6.1.20				
CM-BD-5 BD - Latency – TC	cl.6.1.21				
CM-BD-6 BD – Late Billing Details	cl.6.1.22				
CM-BD-7 BD – Rejected Billing Details Rate	cl.6.1.23				
CM-BD-8 BD – Incorrect rejected Billing Details Rate	cl.6.1.24				
CM-BD-9 BD – Inferred Billing Details Rate	cl.6.1.25				

Table 6 — DSRC Discrete – Optional DSRC Toll Declaration Metric Selection Table (informative)

Metric ID	Examination Test	Evaluation		Monitoring	
		CI Method	Target Value	CI Method	Target Value
CM-TD-1 TD - Correct Toll Declaration Generation	cl. 6.2.2				
CM-TD-2 TD - Incorrect Toll Declaration Generation	cl. 6.2.3				
CM-TD-3 TD – Late Toll Declarations	cl. 6.2.4				
CM-TD-4 TD - TSP Event Detection	cl. 6.2.5				
CM-TD-5 TD - TSP False Positive	cl. 6.2.6				

5.6.3 Autonomous Discrete

Table 7 should be used to define the examination tests to be performed for a specific Examination Framework an Autonomous Discrete Scheme.

Table 7 — Autonomous Discrete - Metric Selection Table

Metric ID	Examination Test	Evaluation		Monitoring	
		CI Method	Target Value	CI Method	Target Value
CM-E2E-1 E2E Correct Charging Rate	cl. 6.1.2				
CM-E2E-2 E2E Overcharging Rate	cl.6.1.3				
CM-E2E-3 E2E Undercharging Rate	cl.6.1.4				
CM-E2E-4 E2E Late Charging Rate	cl.0				
CM-UA-1 UA - Correct Charging Rate	cl.6.1.6				
CM-UA-2 UA - Overcharging Rate	cl.6.1.7				
CM-UA-3 UA - Undercharging Rate	cl.6.1.8				
CM-UA-4 UA - Accurate application of Payments and Refunds	cl.6.1.9				
CM-UA-5 UA – Accurate Personalisation of OBUs	cl.6.1.10				
CM-PC-1 PC - Correct Charging Rate	cl.6.1.11				
CM-PC-2 PC – Overcharging Rate	cl.6.1.12				
CM-PC-3 PC - Undercharging Rate	cl.6.1.13				
CM-PC-4 PC - Latency – TC	cl.6.1.14				
CM-PC-5 PC - Late Payment Claims	cl.6.1.15				
CM-PC-6 PC – Rejected Payment Claim Rate	cl.6.1.16				
CM-BD-1 BD - Correct Charging Rate	cl.6.1.17				
CM-BD-2 BD – Overcharging Rate	cl.6.1.18				
CM-BD-3 BD - Undercharging Rate	cl.6.1.19				
CM-BD-4 BD - Incorrect Charging Rate	cl.6.1.20				
CM-BD-5 BD - Latency – TC	cl.6.1.21				
CM-BD-6 BD – Late Billing Details	cl.6.1.22				
CM-BD-7 BD – Rejected Billing Details Rate	cl.6.1.23				
CM-BD-8 BD – Incorrect rejected Billing Details Rate	cl.6.1.24				
CM-BD-9 BD – Inferred Billing Details Rate	cl.6.1.25				
CM-TD-1 TD - Correct Toll Declaration Generation	cl.6.3.2				
CM-TD-2 TD - Incorrect Toll Declaration Generation	cl.6.3.3				
CM-TD-3 TD – Late Toll Declarations	cl.6.3.4				
CM-TD-4 TD - TSP Event Detection	cl.6.3.5				
CM-TD-5 TD - TSP False Positive	cl.6.3.6				
CM-DTD-1 DTD - Correct Charging Rate (Chargeable Events)	cl.6.3.7				
CM-DTD-2 DTD - Incorrect Charge Event recognition	cl.6.3.8				

CM-DTD-3 DTD - Missed Charge Event Recognition	cl.6.3.9				
CM-DTD-4 DTD Overcharging Rate	cl.6.3.10				
CM-CR-1 CR - Correct Charge Report Generation	cl.6.3.11				
CM-CR-2 CR - Incorrect Charge Report Generation	cl.6.3.12				
CM-CR-3 CR - Charge Report Latency	cl.6.3.13				
CM-CR-4 CR – TSP Front End Event Detection	cl.6.3.14				
CM-CR-5 CR – TSP Front End False Positive	cl.6.3.15				
CM-DCR-1 DCR - Correct Charging Rate (Chargeable Events)	cl.6.3.16				
CM-DCR-2 DCR - Incorrect Charge Event recognition	cl.6.3.17				
CM-DCR-3 DCR - Missed Charge Event Recognition	cl.6.3.18				
CM-DCR-4 DCR - Overcharging rate (Incorrect false positive Charge Event Recognition)	cl.6.3.19				

5.6.4 Autonomous Continuous

Table 8 should be used to define the examination tests to be performed for a specific Examination Framework in an Autonomous Continuous Scheme.

Table 8 — Autonomous Continuous - Metric Selection Table

		Evaluation		**Monitoring**	
Metric ID	**Examination Test (cl.)**	**CI Method**	**Target Value**	**CI Method**	**Target Value**
CM-E2E-1 E2E Correct Charging Rate	cl. 6.1.2				
CM-E2E-2 E2E Overcharging Rate	cl.6.1.3				
CM-E2E-3 E2E Undercharging Rate	cl.6.1.4				
CM-E2E-4 E2E Late Charging Rate	cl.0				
CM-UA-1 UA - Correct Charging Rate	cl.6.1.6				
CM-UA-2 UA - Overcharging Rate	cl.6.1.7				
CM-UA-3 UA - Undercharging Rate	cl.6.1.8				
CM-UA-4 UA - Accurate application of Payments and Refunds	cl.6.1.9				
CM-UA-5 UA – Accurate Personalisation of OBUs	cl.6.1.10				
CM-PC-1 PC - Correct Charging Rate	cl.6.1.11				
CM-PC-2 PC – Overcharging Rate	cl.6.1.12				
CM-PC-3 PC - Undercharging Rate	cl.6.1.13				
CM-PC-4 PC - Latency – TC	cl.6.1.14				
CM-PC-5 PC - Late Payment Claims	cl.6.1.15				
CM-PC-6 PC – Rejected Payment Claim Rate	cl.6.1.16				
CM-BD-1 BD - Correct Charging Rate	cl.6.1.17				
CM-BD-2 BD – Overcharging Rate	cl.6.1.18				
CM-BD-3 BD - Undercharging Rate	cl.6.1.19				
CM-BD-4 BD - Incorrect Charging Rate	cl.6.1.20				
CM-BD-5 BD - Latency – TC	cl.6.1.21				
CM-BD-6 BD – Late Billing Details	cl.6.1.22				
CM-BD-7 BD – Rejected Billing Details Rate	cl.6.1.23				
CM-BD-8 BD – Incorrect rejected Billing Details Rate	cl.6.1.24				
CM-BD-9 BD – Inferred Billing Details Rate	cl.6.1.25				
CM-TD-1 TD - Correct Toll Declaration Generation	cl.6.4.2				
CM-TD-2 TD - Incorrect Toll Declaration Generation	cl.6.4.3				
CM-TD-3 TD – Late Toll Declarations	cl.6.4.4				
CM-TD-4 TD - TSP Event Detection	cl.6.4.5				
CM-TD-5 TD - TSP False Positive	cl.6.4.6				

CM-CTD-1 CTD Correct Charging Rate	cl.6.4.7				
CM-CTD-2 CTD Overcharging Rate	cl.6.4.8				
CM-CTD-3 CTD Accuracy of Distance/Time Measurement	cl.6.4.9				
CM-CR-1 CR - Correct Charge Report Generation	cl.6.4.10				
CM-CR-2 CR - Incorrect Charge Report Generation	cl.6.4.11				
CM-CR-3 CR - Charge Report Latency	cl.6.4.12				
CM-CR-4 CR – TSP Front End Event Detection	cl.6.4.13				
CM-CR-5 CR – TSP Front End False Positive	cl.6.4.14				
CM-CCR-1 CCR - Correct Charging Rate	cl.6.4.15				
CM-CCR-2 CCR - Overcharging Rate	cl.6.4.16				
CM-CCR-3 CCR - Accuracy of Distance/Time Measurement	cl.6.4.17				

6 Examination Tests

6.1 Common (and DSRC Discrete) Examination Tests

6.1.1 General

The Examination Tests defined in Clause 6.1.2 to 6.1.25 are applicable to all Scheme Types, they may be used in combination with Evaluation Tests defined in Clause 6.2 to 6.4 depending on the Scheme Type.

The Reference Data are collected using the methods and prescriptions of Clause 5.4.

6.1.2 ET-CM-E2E-1 E2E Correct Charging Rate

6.1.2.1 Metric Definition

The probability that for set of representative trips travelled by a set of Users during a time span Δt the Average Relative Charging Error is within the Accepted Charging Error Interval.

6.1.2.2 Intended Use

Typically this is the view of the Road Operator who receives the revenue from the Toll Collection System, it measures the overall correct charging performance across all users.

Traditionally metrics like this were used to specify overall charging performance where the roles of Toll Charger and Toll Service Provider were performed by the same organisation.

6.1.2.3 Metric Calculation Method

$$E2E\ Correct\ Charging\ Rate = \frac{A}{B}$$

Where

A = Number of representative trips where the Relative Charging Error (RCE) is within the Accepted Charging Error Interval

B = the total number of representative trips within the time span

And

RCE = (C/D) - 1

Where

C = Actual Charge for representative trip

D = Expected Charge for representative trip

And

Accepted Charging Error Interval Lower bound (CELB) = -x%

Accepted Charging Error Interval Upper Bound (CEUB) = + y%

6.1.3 ET-CM-E2E-2 E2E Overcharging Rate

6.1.3.1 Metric Definition

The probability that for any set of *representative trips* travelled by a set of Users during a time span Δt the Average Relative Charging Error is above the Accepted Charging Error Interval.

6.1.3.2 Intended Use

Typically this is the view of the Road Operator who receives the revenue from the Toll Collection System, it measures the overall overcharging across all users.

Traditionally metrics like this were used to specify overall charging performance where the roles of Toll Charger and Toll Service Provider were performed by the same organisation.

6.1.3.3 Metric Calculation Method

$$E2E\ OverCharging\ Rate = \frac{A}{B}$$

Where

A = Number of representative trips where the Relative Charging Error (RCE) is greater than the Upper Bound of the Accepted Charging Error Interval

B = the total number of representative trips within the time span

And

RCE = (C/D) - 1

Where

C = Actual Charge for representative trip

D = Expected Charge for representative trip

And

Accepted Charging Error Interval Lower bound (CELB) = -x%

Accepted Charging Error Interval Upper Bound (CEUB) = + y%

6.1.4 ET-CM-E2E-3 E2E Undercharging Rate

6.1.4.1 Metric Definition

The probability that for set of *representative trips* travelled by a set of Users during a time span Δt the Average Relative Charging Error is below the Accepted Charging Error Interval.

6.1.4.2 Intended Use

Typically this is the view of the Road Operator who receives the revenue from the Toll Collection System, it measures the overall undercharging across all users.

Traditionally metrics like this were used to specify overall charging performance where the roles of Toll Charger and Toll Service Provider were performed by the same organisation.

6.1.4.3 Metric Calculation Method

$$E2E\ UnderCharging\ Rate = \frac{A}{B}$$

Where

A = Number of representative trips where the Relative Charging Error (RCE) is less than the Lower bound of the Accepted Charging Error Interval

B = the total number of representative trips within the time span

And

RCE = (C/D) - 1

Where

C = Actual Charge for representative trip

D = Expected Charge for representative trip

And

Accepted Charging Error Interval Lower bound (CELB) = -x%

Accepted Charging Error Interval Upper Bound (CEUB) = + y%

6.1.5 ET-CM-E2E-4 E2E Late Charging Rate

6.1.5.1 Metric Definition

The probability that for any set of *representative trips* travelled by a set of Users during a time span Δt that the Charge Events appear on the User Statement later than defined period for the Charging Scheme

6.1.5.2 Intended Use

Typically this is the view of the Road Operator who receives the revenue from the Toll Collection System, it measures the overall late charging across all users.

Traditionally metrics like this were used to specify overall charging performance where the roles of Toll Charger and Toll Service Provider were performed by the same organisation.

6.1.5.3 Metric Calculation Method

$$E2E\ Late\ Charging\ Rate = \frac{A}{B}$$

Where

A = Number of representative trips where the Charge Events appear on the User Statement later than the defined Maximum User Statement Delay (MUSD)

B = the total number of representative trips within the time span

Where

MUSD = x units of time

6.1.6 ET-CM-UA-1 UA - Correct Charging Rate

6.1.6.1 Metric Definition

The probability that for any set of *representative trips* travelled by a given User during the invoicing period the Average Relative Charging Error is within the Accepted Charging Error Interval.

6.1.6.2 Intended Use

Metrics defined at the User Account level, define the charging performance at the level of the individual Service Users.

This metric should be used when there is a defined requirement for average Correct Charging for individual Service Users, it can be measured by the Toll Service Provider.

6.1.6.3 Metric Calculation Method

$$UA\ Correct\ Charging\ Rate = \frac{A}{B}$$

Where

A = Number of Users where the Average Relative Charging Error (ARCE) is within the Accepted Charging Error Interval during the invoicing period

B = the total number of Users

And

ARCE = (C/D) - 1

Where

C = Sum of Actual Charges for representative trips for a User

D = Sum of Expected Charge for representative trips for a User

And

Accepted Charging Error Interval Lower bound (CELB) = -x%

Accepted Charging Error Interval Upper Bound (CEUB) = + y%

6.1.7 ET-CM-UA-2 UA - Overcharging Rate

6.1.7.1 Metric Definition

The probability that for any set of *representative trips* travelled by a given User during the invoicing period the Average Relative Charging Error is above the Accepted Charging Error Interval.

6.1.7.2 Intended Use

Metrics defined at the User Account level, define the charging performance at the level of the individual Service Users.

This metric should be used when there is a defined requirement for average Over Charging for individual Service Users, it can be measured by the Toll Service Provider.

6.1.7.3 Metric Calculation Method

$$UA\ Over\ Correct\ Charging\ Rate = \frac{A}{B}$$

Where

A = Number of Users where the Average Relative Charging Error (ARCE) is above the Accepted Charging Error Interval Upper Bound during the invoicing period

B = the total number of Users

And

ARCE = (C/D) - 1

Where

C = Sum of Actual Charges for representative trips for a User

D = Sum of Expected Charge for representative trips for a User

And

Accepted Charging Error Interval Upper Bound (CEUB) = + y%

6.1.8 ET-CM-UA-3 UA - Undercharging Rate

6.1.8.1 Metric Definition

The probability that for any set of *representative trips* travelled by a given User during the invoicing period the Average Relative Charging Error is below the Accepted Charging Error Interval.

6.1.8.2 Intended Use

Metrics defined at the User Account level, define the charging performance at the level of the individual Service Users.

This metric should be used when there is a defined requirement for average Under Charging for individual Service Users, it can be measured by the Toll Service Provider.

6.1.8.3 Metric Calculation Method

$$UA\ Under\ Charging\ Rate = \frac{A}{B}$$

Where

A = Number of Users where the Average Relative Charging Error (ARCE) is below the Accepted Charging Error Lower bound during the invoicing period

B = the total number of Users

And

ARCE = (C/D) - 1

Where

C = Sum of Actual Charges for representative trips for a User

D = Sum of Expected Charge for representative trips for a User

And

Accepted Charging Error Interval Lower bound (CELB) = -x%

6.1.9 ET-CM-UA-4 UA - Accurate application of Payments and Refunds

6.1.9.1 Metric Definition

The probability that payment transactions associated to a User Account are correct.

6.1.9.2 Intended Use

This metric focuses on the ability of the TSP to correctly apply received payments and credits to User Accounts.

6.1.9.3 Metric Calculation Method

$$UA\ Accurate\ application\ of\ Payments\ and\ Refunds = \frac{A}{B}$$

Where

A = Total Number Correctly Applied Payments & Refunds on User Accounts in Measurement Period

B = Total Number of Applied Payments & Refunds on User Accounts in Measurement Period

6.1.10 ET-CM-UA-5 UA – Accurate Personalisation of OBUs

6.1.10.1 Metric Definition

The probability that the personalisation for any set of Users during a time span Δt is correct

6.1.10.2 Intended Use

This metric can be measured by Toll Chargers using their existing compliance checking infrastructure, it is in the Toll Charger's interest to ensure that this is maximised as incorrectly personalised OBEs will potential lead to detected non-compliance.

6.1.10.3 Metric Calculation Method

$$UA - Accurate\ Personalisation\ of\ OBUs = \frac{A}{B}$$

Where

A = Number of OBEs where the agreed sub-set of OBE Parameters have been verified as correct by the Toll Charger Compliance Equipment in the selected time period

B = Total number of OBEs checked by the Toll Charger Compliance Equipment in the selected time period

6.1.11 ET-CM-PC-1 PC - Correct Charging Rate

6.1.11.1 Metric Definition

The probability, that for any given Payment Claim, the Average Relative Charging Error is within the Accepted Charging Error Interval.

This measures the probability that the relative error in the Payment Claim used for invoicing is within defined limits to protect the interest of both the Toll Charger and the Service User.

6.1.11.2 Intended Use

This metric can be used to measure the average level of correct charging at the level of Payment Claims on the User Account Statement.

6.1.11.3 Metric Calculation Method

$$PC\ Correct\ Charging\ Rate = \frac{A}{B}$$

Where

A = Number of Payment Claims where the Average Relative Charging Error (ARCE) is within the Accepted Charging Error Interval

B = the total number of Payment Claims

And

ARCE = (C/D) - 1

Where

C = Sum of Actual Charges for the Payment Claim

D = Sum of Expected Charge for the Payment Claim

And

Accepted Charging Error Interval Lower bound (CELB) = -x%

Accepted Charging Error Interval Upper Bound (CEUB) = + y%

6.1.12 ET-CM-PC-2 PC – Overcharging Rate

6.1.12.1 Metric Definition

The probability, that for any given Payment Claim, the Average Relative Charging Error is above the Accepted Charging Error Interval Upper Bound (CEUB).

This measures the probability that the relative error in the Payment Claim used for invoicing is above a defined limit. Protecting the interest of the Service User (i.e. avoiding excessive overcharging) requires that this probability is below a very small value.

6.1.12.2 Intended Use

This metric can be used to measure the average level of overcharging at the level of Payment Claims on the User Account Statement.

6.1.12.3 Metric Calculation Method

$$PC\ Overcharging\ Rate = \frac{A}{B}$$

Where

A = Number of Payment Claims where the Average Relative Charging Error (ARCE) is above the Accepted Charging Error Interval

B = the total number of Payment Claims

And

ARCE = (C/D) - 1

Where

C = Sum of Actual Charges for the Payment Claim

D = Sum of Expected Charge for the Payment Claim

And

Accepted Charging Error Interval Upper Bound (CEUB) = + y%

6.1.13 ET-CM-PC-3 PC - Undercharging Rate

6.1.13.1 Metric Definition

The probability, that for any given Payment Claim, the Average Relative Charging Error is below the Accepted Charging Error Interval.

6.1.13.2 Intended Use

This metric can be used to measure the average level of undercharging at the level of Payment Claims on the User Account Statement.

6.1.13.3 Metric Calculation Method

$$PC\ Undercharging\ Rate = \frac{A}{B}$$

Where

A = Number of Payment Claims where the Average Relative Charging Error (ARCE) is below the Accepted Charging Error Lower Bound (CELB)

B = the total number of Payment Claims

And

ARCE = (C/D) - 1

Where

C = Sum of Actual Charges for the Payment Claim

D = Sum of Expected Charge for the Payment Claim

And

Accepted Charging Error Interval Lower bound (CELB) = -x%

6.1.14 ET-CM-PC-4 PC - Latency – TC

6.1.14.1 Metric Definition

Average Time it takes between the approval for a Billing Detail being received by the Toll Charger and the time the associated Payment Claim is created / sent by the Toll Charger.

6.1.14.2 Intended Use

This metric provides an indication of the average processing time for Toll Chargers to create Payment Claims following the receipt of approved Billing Details from the Toll Service Provider

6.1.14.3 Metric Calculation Method

$$PC\ Latency\ TC = \frac{A}{B}$$

Where

A = Sum of the total Payment Claim Delay in the measurement period

B = Number of Payment Claims sent in the measurement period

And

Payment Claim Delay = C-D

Where

C = Time the Payment Claim was sent

D = Time of receipt of 1st associated approved Billing Detail

6.1.15 ET-CM-PC-5 PC - Late Payment Claims

6.1.15.1 Metric Definition

The proportion of Payment Claims received by the TSP in a defined period where the time between the Chargeable Event and the receipt of the associated Payment Claim is greater than the defined period for the charging scheme.

6.1.15.2 Intended Use

6.1.15.3 Metric Calculation Method

$$PC\ Late\ Payment\ Claims = \frac{A}{B}$$

Where

A = Number of Late Payment Claims in the measurement period

B = Number of Payment Claims received in the measurement period

And

Late Payment Claim is where the Payment Claim Delay is greater than the Maximum Payment Claim Delay (MPCD)

6.1.16 ET-CM-PC-6 PC – Rejected Payment Claim Rate

6.1.16.1 Metric Definition

Ratio of correctly rejected Payment Claims in relation to the total number of Payment Claims received in the measurement period.

6.1.16.2 Intended Use

This metric measures the rate at which the Toll Charger generates in-correct Payment Claims that are detected by the Toll Service Provider

6.1.16.3 Metric Calculation Method

$$Rejected\ Payment\ Claims\ Rate = \frac{A}{B}$$

Where

A = Number of Payment Claims Correctly Rejected by the Toll Service Provider in the measurement period

B = Total Number of Payment Claims sent by the Toll Charger in the measurement period

6.1.17 ET-CM-BD-1 BD - Correct Charging Rate

6.1.17.1 Metric Definition

The probability, that for any given Billing Detail, the Average Relative Charging Error is within the Accepted Charging Error Interval.

This measures the probability that the relative error in the billing details used for invoicing is within a defined limit to protect the interest of both the Toll Charger and the Service User.

6.1.17.2 Intended Use

This metric can be used to measure the average level of correct charging at the level of trips or line items on the User Account Statement.

6.1.17.3 Metric Calculation Method

$$BD\ Correct\ Charging\ Rate = \frac{A}{B}$$

Where

A = Number of Billing Details where the Average Relative Charging Error (ARCE) is within the Accepted Charging Error Interval

B = the total number of Billing Details

And

ARCE = (C/D) - 1

Where

C = Sum of Actual Charges for the Billing Detail

D = Sum of Expected Charge for the Billing Detail

And

Accepted Charging Error Interval Lower bound (CELB) = -x%

Accepted Charging Error Interval Upper Bound (CEUB) = + y%

6.1.18 ET-CM-BD-2 BD – Overcharging Rate

6.1.18.1 Metric Definition

The probability, that for any given Billing Detail, the Average Relative Charging Error is above the Accepted Charging Error Interval

This measures the probability that the relative error in the billing details ultimately used for invoicing is above a defined limit. Protecting the interest of the Service User (i.e. avoiding excessive overcharging) requires that this probability is below a very small value

6.1.18.2 Intended Use

This metric can be used to measure the average level of overcharging at the level of trips or line items on the User Account Statement.

6.1.18.3 Metric Calculation Method

$$BD\ Overcharging\ Rate = \frac{A}{B}$$

Where

A = Number of Billing Details where the Average Relative Charging Error (ARCE) is above the Accepted Charging Error Interval

B = the total number of Billing Details

And

ARCE = (C/D) - 1

Where

C = Sum of Actual Charges for the Billing Detail

D = Sum of Expected Charge for the Billing Detail

And

Accepted Charging Error Interval Upper Bound (CEUB) = + y%

6.1.19 ET-CM-BD-3 BD - Undercharging Rate

6.1.19.1 Metric Definition

The probability, that for any given Billing Detail, the Average Relative Charging Error is below the Accepted Charging Error Interval.

6.1.19.2 Intended Use

This metric can be used to measure the average level of undercharging at the level of trips or line items on the User Account Statement.

6.1.19.3 Metric Calculation Method

$$BD\ Undercharging\ Rate = \frac{A}{B}$$

Where

A = Number of Billing Details where the Average Relative Charging Error (ARCE) is below the Accepted Charging Error Lower Bound (CELB)

B = the total number of Billing Details

And

ARCE = (C/D) - 1

Where

C = Sum of Actual Charges for the Billing Detail

D = Sum of Expected Charge for the Billing Detail

And

Accepted Charging Error Interval Lower bound (CELB) = -x%

6.1.20 ET-CM-BD-4 BD - Incorrect Charging Rate

6.1.20.1 Metric Definition

The probability that for any predefined Chargeable Event that is recorded a respective Billing Detail is incorrectly generated (the incorrect data is not detected).

“Predefined” may be defined by random measurements of determined Charge Events.

6.1.20.2 Intended Use

This metric can be used to measure the proportion of Billing Details which contain one or more errors.

6.1.20.3 Metric Calculation Method

$$BD - Incorrect\ Charging\ Rate = \frac{A}{B}$$

Where

A = Number of Chargeable Events associated to Billing Details incorrectly, i.e. total number of Chargeable Events assigned to Billing Details in the measurement period which are not correctly representing Reference Data.

B = Total number of Chargeable Events, i.e. Total number of Chargeable Events resulting from the Reference Data in the measurement period.

6.1.21 ET-CM-BD-5 BD - Latency – TC

6.1.21.1 Metric Definition

Average Time it takes between a Chargeable Event occurring and the time the associated Billing Detail is created / sent by the Toll Charger.

6.1.21.2 Intended Use

This metric can be used where there is a requirement for the timeliness of providing Charging information to the Service User, it may be used in conduction with similar metrics defined for Toll Declarations and Payment claims, to identify the average processing times for each step of the charging process.

6.1.21.3 Metric Calculation Method

$$BD\ Latency\ TC = \frac{A}{B}$$

Where

A = Sum of the total Billing Detail Delay in the measurement period

B = Number of Billing Details sent in the measurement period

And

Billing Detail Delay = C-D

Where

C = Time the Billing Detail was sent

D = Time of 1st associated Chargeable Event

6.1.22 ET-CM-BD-6 BD – Late Billing Details

6.1.22.1 Metric Definition

The proportion of Billing Details received by the TSP in a defined period where the time between the Chargeable Event and the receipt of the associated Billing Detail is greater than the defined period for the charging scheme.

6.1.22.2 Intended Use

This metric can be used where there is a requirement for the timeliness of providing Charging information to the Service User, it may be used in conduction with similar metrics defined for Toll Declarations and Payment claims.

6.1.22.3 Metric Calculation Method

$$BD\ Late\ Billing\ Details = \frac{A}{B}$$

Where

A = Number of Late Billing Details in the measurement period

B = Number of Billing Details received in the measurement period

And

Late Billing Detail is where the Billing Detail Delay is greater than the Maximum Billing Detail Delay (MBDD)

6.1.23 ET-CM-BD-7 BD – Rejected Billing Details Rate

6.1.23.1 Metric Definition

Ratio of correctly rejected Billing Details in relation to the total number of Billing details received in the measurement period.

6.1.23.2 Intended Use

This metric can be used to measure the performance of the Toll Charger in its ability to correctly generate Billing Details, the expectation is that this should be a small value.

6.1.23.3 Metric Calculation Method

$$Rejected\ Billing\ Details\ Rate = \frac{A}{B}$$

Where

A = Number of Billing Details Correctly Rejected by the Toll Service Provider in the measurement period

B = Total Number of Billing Details sent by the Toll Charger in the measurement period

6.1.24 ET-CM-BD-8 BD – Incorrectly rejected Billing Details Rate

6.1.24.1 Metric Definition

The ratio of the incorrectly rejected Billing Details in relation to the total number of rejected Billing Details in the measurement period.

6.1.24.2 Intended Use

This metric can be used to measure the Toll Service Provider's performance in terms of in-correctly rejecting Billing Details, i.e. those which contain no errors and in case of Autonomous Schemes are based on Toll Service Provider Toll Declarations.

6.1.24.3 Metric Calculation Method

$$\textit{Incorrect Rejected Billing Details Rate} = \frac{A}{B}$$

Where

A= Number of Billing Details Incorrectly Rejected by the Toll Service Provider in the measurement period

B = Total Number of Billing Details sent by the Toll Charger in the measurement period

6.1.25 ET-CM-BD-9 BD – Inferred Billing Details Rate

6.1.25.1 Metric Definition

The ratio of inferred Billing Details in relation to the total number of Billing Details in the measurement period.

6.1.25.2 Intended Use

This metric is most applicable to discrete schemes where based on the information in received Toll Declarations, the Toll Charger is able to identify missing charges and generate inferred Billing Details.

In a DSRC discrete system this can be used as a measure of DSRC detection performance for different OBE populations.

6.1.25.3 Metric Calculation Method

$$\textit{Inferred Billing Details Rate} = \frac{A}{B}$$

Where

A = Number of Billing Details Generated by the Toll Charger without an associated Toll Declaration in the measurement period

B = Total Number of Billing Details sent by the Toll Charger in the measurement period

6.2 DSRC Discrete – Optional DSRC Toll Declaration Metrics

6.2.1 General

For DSRC Discrete Schemes Evaluation Tests maybe selected from Clause 6.1, in addition the metrics in Clause 6.2.2 to 6.2.6 may be selected to measure the internal performance of the DSRC Toll Charger.

NOTE Formally these metrics can only be specified for autonomous systems, where the interfaces for Charge Reports and Toll Declarations are standardised. On the other hand it could also be used in DSRC systems. In this case the DSRC transactions on the air interface OBE – RSE replace the ISO/TS 17575-1 Charge Reports. The Toll Declarations of proprietary format on the interface RSE – TC back office replace the Toll Declarations defined in ISO 12855.

6.2.2 ET-CM-TD-1 TD - Correct Toll Declaration Generation

6.2.2.1 Metric Definition

The probability that a DSRC Toll Declaration is correctly generated.

6.2.2.2 Intended Use

This metric measures the performance of a TC system in generating correct DSRC Toll Declarations.

6.2.2.3 Metric Calculation Method

$$\textit{TD Correct Toll Declaration Generation} = \frac{A}{B}$$

Where

A = Number of correctly generated Toll Declarations, i.e. number of Toll Declarations generated during the measurement period by the TC Front End which are consistent with the respective total number of Chargeable Events resulting from the Reference Data correctly assigned to Toll Declarations in the measurement period. Consistency requires correct representation of all Chargeable Events.

B = Total number of Toll Declarations, i.e. number of Toll Declarations generated by the TC Front End in the measurement period.

6.2.3 ET-CM-TD-2 TD - Incorrect Toll Declaration Generation

6.2.3.1 Metric Definition

The probability that a DSRC Toll Declaration is incorrectly generated.

6.2.3.2 Intended Use

This metric measures the performance of a TC system in generating incorrect Toll Declarations.

6.2.3.3 Metric Calculation Method

$$\textit{TD Incorrect Toll Declaration Generation} = \frac{A}{B}$$

Where

A = Number of incorrectly generated Toll Declarations, i.e. the number of Toll Declarations generated during the measurement period by the TC Front End which are inconsistent with the respective total number of Chargeable Events resulting from the Reference Data correctly assigned to Toll Declarations in the measurement period. Consistency requires correct representation of all Chargeable Events.

B = Total number of Toll Declarations, i.e. the number of Toll Declarations generated by the TC Front End in the measurement period.

6.2.4 ET-CM-TD-3 TD – Late Toll Declarations

6.2.4.1 Metric Definition

The proportion of Toll Declarations generated by the Toll Charger in a defined period where the time between the Chargeable Event and the generation of the associated Toll Declaration is greater than the defined period for the charging scheme.

6.2.4.2 Intended Use

This metric measures the performance of the TC system in terms of the delays occurring in the process of generating Toll Declarations. Late Toll Declarations are most likely to occur when there is a communication outage between the RSI and the TC Back end.

6.2.4.3 Metric Calculation Method

$$\boldsymbol{TD\ Late\ Toll\ Declarations} = \frac{\boldsymbol{A}}{\boldsymbol{B}}$$

Where

A = Number of late Toll Declarations, i.e. the number of toll declarations generated during the measurement period by the TC Front End which are delayed by a time longer than Maximum Toll Declaration Delay (MTDD) after the actual occurrence of the respective charging events as determined from the Reference Data.

B = Total Number of Toll Declarations, i.e. the number of Toll Declarations generated by the TC Front End in the measurement period.

MTDD = Maximum Toll Declaration Delay, i.e. maximum acceptable delay. This value shall be chosen before performing the test and agreed upon by the parties involved, e.g. with an SLA.

6.2.5 ET-CM-TD-4 TD - TSP Event Detection

6.2.5.1 Metric Definition

The probability that for any predefined Charge-Relevant Event that takes place the TC properly detects it.

6.2.5.2 Intended Use

This metric measures the reliability of the detection and representation in Toll Declarations of DSRC Charge-Relevant Events in the TC system.

NOTE Be aware of the distinction between Charge-Relevant Events and Charging Events.

6.2.5.3 Metric Calculation Method

$$TD\ Event\ Detection = \frac{A}{B}$$

Where

A = Number of correct Toll Declarations, i.e. the number of Toll Declarations containing the DSRC Charge-Relevant Events expected based on the Reference Data during the measurement period.

B = Total number of Toll Declarations generated by the TC in the measurement period

6.2.6 ET-CM-TD-5 TD - TSP False Positive

6.2.6.1 Metric Definition

For the vehicles not using the infrastructure, it is the probability that for any defined Chargeable Event the TC improperly detects it during the creation of Toll Declarations.

6.2.6.2 Intended Use

The rate of false positives is a critical parameter of system performance, because it is directly related to customer satisfaction, the number of user complaints and the public perception of a system. This metric measures the rate of occurrence of DSRC Toll Declarations containing false positives in the TC system.

6.2.6.3 Metric Calculation Method

$$\mathrm{TD\,False\,Positive} = \frac{A}{B}$$

Where

A = Number of Toll Declarations containing False Positives which occur during the measurement period

B = Total number of Toll Declarations generated by the TC in the measurement period

6.3 Autonomous Discrete Specific Examination Tests

6.3.1 General

For autonomous discrete systems all tests of Clause 6.1 are applicable. On top of that the measurements of this Clause 6.3 can be used.

The Toll declarations are sent by the TSP Back End on the respective interface to the TC. This interface conforms to ISO 12855 (see ISO 12855:2012, Clause 6.11, p.26).

The Charge Reports are sent by the TSP Front End to the TSP Back End. This interface is designed according to ISO/TS 17575-1:2010.

The Reference Data are collected using the methods and prescriptions of Clause 5.4.

6.3.2 ET-CM-TD-1 TD - Correct Toll Declaration Generation

6.3.2.1 Metric Definition

The probability that a DSRC Toll Declaration is correctly generated.

6.3.2.2 Intended Use

This metric measures the performance of a TSP system in generating correct Toll Declarations.

6.3.2.3 Metric Calculation Method

$$\textit{TD Correct Toll Declaration Generation} = \frac{A}{B}$$

Where

A = Number of correctly generated Toll Declarations, i.e. number of Toll Declarations generated during the measurement period by the TSP Back End which are consistent with the respective total number of Chargeable Events resulting from the Reference Data correctly assigned to Toll Declarations in the measurement period. Consistency requires correct representation of all Chargeable Events.

B = Total number of Toll Declarations, i.e. number of Toll Declarations generated by the TSP Back End in the measurement period.

6.3.3 ET-CM-TD-2 TD - Incorrect Toll Declaration Generation

6.3.3.1 Metric Definition

The probability that a Toll Declaration is incorrectly generated.

6.3.3.2 Intended Use

This metric measures the performance of a TSP system in generating incorrect Toll Declarations.

6.3.3.3 Metric Calculation Method

$$\textit{TD Incorrect Toll Declaration Generation} = \frac{A}{B}$$

Where

A = Number of incorrectly generated Toll Declarations, i.e. the number of Toll Declarations generated during the measurement period by the TSP Back End which are inconsistent with the respective total number of Chargeable Events resulting from the Reference Data correctly assigned to Toll Declarations in the measurement period. Consistency requires correct representation of all Chargeable Events.

B = Total number of Toll Declarations, i.e. the number of Toll Declarations generated by the TSP Back End in the measurement period.

6.3.4 ET-CM-TD-3 TD – Late Toll Declarations

6.3.4.1 Metric Definition

The proportion of Toll Declarations received by the Toll Charger in a defined period where the time between the Chargeable Event and the receipt of the associated Toll Declaration is greater than the defined period for the charging scheme.

6.3.4.2 Intended Use

This metric measures the performance of the TSP system in terms of the delays occurring in the process of generating Toll Declarations.

6.3.4.3 Metric Calculation Method

$$TD\ Late\ Toll\ Declarations = \frac{A}{B}$$

Where

A = Number of late Toll Declarations, i.e. the number of toll declarations generated during the measurement period by the TSP Back End which are delayed by a time longer than Maximum Toll Declaration Delay (MTDD) after the actual occurrence of the last of the respective charging events as determined from the Reference Data.

B = Total Number of Toll Declarations, i.e. the number of Toll Declarations generated by the TSP Back End in the measurement period.

MTDD = Maximum Toll Declaration Delay, i.e. maximum acceptable delay. This value must be chosen before performing the test and agreed upon by the parties involved, e.g. with an SLA.

6.3.5 ET-CM-TD-4 TD - TSP Event Detection

6.3.5.1 Metric Definition

The probability that for any predefined Charge-Relevant Event that takes place the TSP properly detects it.

6.3.5.2 Intended Use

This metric measures the reliability of the detection and representation in Toll Declarations of Charge-Relevant Events in the TSP system.

NOTE Be aware of the distinction between Charge-Relevant Events and Charging Events.

6.3.5.3 Metric Calculation Method

$$TD\ Event\ Detection = \frac{A}{B}$$

Where

A = Number of correct Toll Declarations, i.e. the number of Toll Declarations containing the Charge-Relevant Events expected based on the Reference Data during the measurement period.

B = Total number of Toll Declarations sent by the Toll Service Provider in the measurement period

6.3.6 ET-CM-TD-5 TD - TSP False Positive

6.3.6.1 Metric Definition

For the vehicles not using the infrastructure, it is the probability that for any defined Chargeable Event the TSP improperly detects it during the creation of Toll Declarations.

6.3.6.2 Intended Use

The rate of false positives is a critical parameter of system performance, because it is directly related to customer satisfaction, the number of user complaints and the public perception of a system. This metric measures the rate of occurrence of Toll Declarations containing false positives in the TSP system

6.3.6.3 Metric Calculation Method

$$\mathbf{TD\,False\,Positive} = \frac{A}{B}$$

Where

A = Number of Toll Declarations containing False Positives which occur during the measurement period

B = Total number of Toll Declarations sent by the Toll Service Provider in the measurement period

6.3.7 ET-CM-DTD-1 DTD - Correct Charging Rate (Chargeable Events)

6.3.7.1 Metric Definition

The probability that for any predefined Chargeable Event that is recorded the corresponding Toll Declaration is correctly generated. "Predefined" may be defined by random measurements of determined Charge Events.

6.3.7.2 Intended Use

Test if each single Chargeable Event in the Reference Data is represented accordingly in the respective Toll Declaration, measuring the performance of the TSP system for single Chargeable Events.

6.3.7.3 Metric Calculation Method

$$DTD\ Correct\ Charging\ Rate = \frac{A}{B}$$

Where

A = Number of Chargeable Events associated to Toll Declarations, i.e. total number of Chargeable Events resulting from the Reference Data correctly assigned to Toll Declarations in the measurement period.

B = Total number of Chargeable Events, i.e. Total number of Chargeable Events resulting from the Reference Data in the measurement period.

6.3.8 ET-CM-DTD-2 DTD - Incorrect Charge Event recognition

6.3.8.1 Metric Definition

The probability that for any predefined Chargeable Event that is recorded a respective Toll Declaration is incorrectly generated (the incorrect data is not detected).

“Predefined” may be defined by random measurements of determined Charge Events.

6.3.8.2 Intended Use

Measurement of the rate of Chargeable Events incorrectly detected by the TSP system, i.e. which contain incorrect information (e.g. vehicle category, time, road category etc.).

6.3.8.3 Metric Calculation Method

$$\textit{DTD Incorrect Charge Event recognition} = \frac{A}{B}$$

Where

A = Number of Chargeable Events associated to Toll Declarations incorrectly, i.e. total number of Chargeable Events assigned to Toll Declarations in the measurement period which are not correctly representing Reference Data.

B = Total number of Chargeable Events, i.e. Total number of Chargeable Events resulting from the Reference Data in the measurement period.

6.3.9 ET-CM-DTD-3 DTD - Missed Charge Event Recognition

6.3.9.1 Metric Definition

The probability that for any predefined Chargeable Event that an entry in the respective Toll Declaration is not generated.

6.3.9.2 Intended Use

This test measures the rate of missed recognition of Charge Events, i.e. the rate of Charge Events missing in the Toll Declarations.

6.3.9.3 Metric Calculation Method

$$\textit{DTD Missed Charge Event Recognition} = \frac{A}{B}$$

Where

A = Number of Chargeable Events not associated to Toll Declarations, i.e. total number of Chargeable Events resulting from the Reference Data in the measurement period not assigned to Toll Declarations.

B = Total number of Chargeable Events, i.e. the total number of Chargeable Events resulting from the Reference Data in the measurement period.

6.3.10 ET-CM-DTD-4 DTD Overcharging Rate

6.3.10.1 Metric Definition

For the vehicles not using the infrastructure, it is the probability that for any predefined Chargeable Event that an additional entry in the respective Toll Declaration is generated (False Positive)

6.3.10.2 Intended Use

While the test ET-CM-TD-5 TD - TSP False Positive counts the rate of Toll Declarations containing False Positives, this test measures the rate of single False Positives compared to the overall number of Charge Events.

6.3.10.3 Metric Calculation Method

$$\textit{DTD Overcharging rate} = \frac{A}{B}$$

Where

A = Number of Charge Events associated to Toll Declarations which do not result from the Reference Data, i.e. number of Charge Events in Toll Declarations which do not represent actual usage of charged infrastructure.

B = Total number of Chargeable Events, i.e. the total number of Chargeable Events resulting from the Reference Data in the measurement period

6.3.11 ET-CM-CR-1 CR - Correct Charge Report Generation

6.3.11.1 Metric Definition

The probability that a Charge Report is correctly generated

6.3.11.2 Intended Use

This test measures the rate of Charge Reports not containing errors.

6.3.11.3 Metric Calculation Method

$$\textit{CR Correct Charge Report Generation} = \frac{A}{B}$$

Where

A = Number of correctly generated Charge Reports, i.e. the number of Charge Reports which contain only Charge Events and Charge-Relevant Events consistent with the Reference Data.

B = Total number of Charge Reports, i.e. the total number of Charge Reports generated by the Toll Service Provider Front-End in the measurement period

6.3.12 ET-CM-CR-2 CR - Incorrect Charge Report Generation

6.3.12.1 Metric Definition

The probability that a Charge Report is incorrectly generated

6.3.12.2 Intended Use

This test measures the rate of Charge Reports containing errors.

6.3.12.3 Metric Calculation Method

$$\textit{CR Incorrect Charge Report Generation} = \frac{A}{B}$$

Where

A = Number of incorrectly generated Charge Reports, i.e. the number of Charge Reports which contain Charge Events that are not consistent with the Reference Data.

B = Total number of Charge Reports, i.e. the total number of Charge Reports generated by the Toll Service Provider Front-End in the measurement period

6.3.13 ET-CM-CR-3 CR - Charge Report Latency

6.3.13.1 Metric Definition

The average time it takes between a Charge Event and the time the Charge Report is created / received by the Service Provider

6.3.13.2 Intended Use

This test gives the average latency of Charge Events until they are received from the Front End. Therefore it gives information about the average Front End performance.

6.3.13.3 Metric Calculation Method

$$\textit{Charge Report Latency} = \frac{1}{n}\sum_{i=1}^{n} A_i$$

where

A_i = Time span between the occurrence of Chargeable Event with index i as determined from the Reference Data and the reception of the respective Charge Report from the Front End

n = Number of Chargeable Events in the measurement period

NOTE 1 If the measurement period was chosen accordingly, this test could be used to determine the average delay for the data in a single Charge Report. If a longer period was chosen, it could also give the average delay over multiple Charge Reports.

NOTE 2 Be aware that the reporting period influences this metric. If e.g. 24h is chosen, the average resulting latency must be greater 12h for evenly spaced chargeable events.

6.3.14 ET-CM-CR-4 CR – TSP Front End Event Detection

6.3.14.1 Metric Definition

The probability that the front-end properly detects any defined Charge-Relevant Event that takes place

6.3.14.2 Intended Use

This test measures the percentage of Charge-Relevant Events which are correctly reflected in Charge Reports generated by the TSP Front End.

NOTE Be aware of the distinction between Charge-Relevant Events and Charging Events.

6.3.14.3 Metric Calculation Method

$$CR\ Event\ Detection = \frac{A}{B}$$

Where

A = Number of Charge-Relevant Events which are correctly represented in Charge Reports received from the TSP Front End.

B = Total number of Charge-Relevant Events as determined from the Reference Data in the measurement period.

6.3.15 ET-CM-CR-5 CR – TSP Front End False Positive

6.3.15.1 Metric Definition

For the vehicles not using the infrastructure, it is the probability that for any predefined Chargeable Event the front-end improperly detects it.

6.3.15.2 Intended Use

The rate of False Positives is a critical parameter of system performance, because it is directly related to customer satisfaction, the number of user complaints and the public perception of a system. This metric measures the rate of occurrence of Charge Reports in the TSP system containing false positives.

6.3.15.3 Metric Calculation Method

$$CR\ Front\ End\ False\ Positive = \frac{A}{B}$$

Where

A = Number of Charge Reports containing False Positives, i.e. containing Charge Events relevant for the measurement period which do not correspond to actual usage of charged infrastructure.

B = Total number of Charge Reports, i.e. the total number of Charge Reports generated by the Toll Service Provider Front-End for the measurement period

6.3.16 ET-CM-DCR-1 DCR - Correct Charging Rate (Chargeable Events)

6.3.16.1 Metric Definition

The probability that for any predefined *Chargeable Event* that takes place the corresponding entry in the respective Charge Report is correctly generated. “Predefined” may be defined by random measurements of determined chargeable events.

6.3.16.2 Intended Use

This test measures the recognition rate of the TSP Front End, i.e. the percentage of road usage that is correctly detected by the Front End.

6.3.16.3 Metric Calculation Method

$$CR\ Event\ Detection = \frac{A}{B}$$

Where

A = Number of correctly detected Chargeable Events in all Charge Reports relevant for the measurement period.

B = Total number of Chargeable Events, i.e. the total number of Chargeable Events as determined from the Reference Data in the measurement period.

6.3.17 ET-CM-DCR-2 DCR - Incorrect Charge Event recognition

6.3.17.1 Metric Definition

The probability that for any predefined *Chargeable Event* that takes place an entry in the respective Charge Report is incorrectly generated. “Predefined” may be defined by random measurements of determined chargeable events.

6.3.17.2 Intended Use

This test measures the percentage of Charge Events in the Charge Reports containing errors, but which correspond to actual Chargeable Events.

6.3.17.3 Metric Calculation Method

$$DCR\ Incorrect\ Charge\ Event\ recognition = \frac{A}{B}$$

Where

A = Number of Charge Events in all Charge Reports containing wrong information (not detected correctly) relevant for the measurement period.

B = Total number of Charge Events, i.e. the total number of Charge Events as determined from the Charge Reports relevant for the measurement period.

6.3.18 ET-CM-DCR-3 DCR - Missed Charge Event Recognition

6.3.18.1 Metric Definition

The probability that for any predefined *Chargeable Event* that an entry in the respective Charge Report is not generated.

6.3.18.2 Intended Use

This test determines the percentage of Chargeable Events which are missed by the TSP Front End, resulting in undercharging.

6.3.18.3 Metric Calculation Method

$$DCR\ Missed\ Charge\ Event\ Recognition = \frac{A}{B}$$

Where

A = Number of Chargeable Events not represented in any Charge Report relevant for the measurement period.

B = Total number of Chargeable Events, i.e. the total number of Chargeable Events as determined from the Reference Data in the measurement period.

6.3.19 ET-CM-DCR-4 DCR - Overcharging rate (Incorrect false positive Charge Event Recognition)

6.3.19.1 Metric Definition

For the vehicles not using the infrastructure, it is the probability that for any predefined Chargeable Event that an additional entry in the respective Charge Report is generated (“False Positive”).

6.3.19.2 Intended Use

The rate of False Positives is a critical parameter of system performance, because it is directly related to customer satisfaction, the number of user complaints and the public perception of a system. This metric measures the rate of occurrence of Charge Events representing False Positives in the TSP system.

6.3.19.3 Metric Calculation Method

$$DCR\ Overcharging\ rate = \frac{A}{B}$$

Where

A = Number of Charge Events in the Charge Reports which do not correspond to actual infrastructure usage as determined from the Reference Data.

B = Total number of Chargeable Events, i.e. the total number of Chargeable Events as determined from the Reference Data in the measurement period.

6.4 Autonomous Continuous Specific Examination Tests

6.4.1 General

For autonomous continuous systems all tests of Clause 6.1 are applicable. On top of that the measurements of this Clause 6.4 can be used.

The Toll declarations are sent by the TSP Back End on the respective interface to the TC. This interface conforms to ISO 12855 (see ISO 12855:2012, Clause 6.11, p.26).

The Charge Reports are sent by the TSP Front End to the TSP Back End. This interface is designed according to ISO/TS 17575-1:2010.

The Reference Data are collected using the methods and prescriptions of Clause 5.4.

6.4.2 ET-CM-TD-1 TD - Correct Toll Declaration Generation

6.4.2.1 Metric Definition

The probability that a Toll Declaration (based on a GNSS OBE) is correctly generated

6.4.2.2 Intended Use

With this metric a TSP can measure the overall performance of the system including its own TSP Back End (in generating Toll Declarations) and its own TSP Front End (in generating Charge Reports)

6.4.2.3 Metric Calculation Method

$$TD\ Correct\ Toll\ Declaration\ Generation = \frac{A}{B}$$

Where

A = Number of correctly generated Toll Declarations during the measurement period by the TSP Back End.

B = Total number of Toll Declarations, i.e. number of Toll Declarations generated by the TSP Back End in the measurement period.

6.4.3 ET-CM-TD-2 TD - Incorrect Toll Declaration Generation

6.4.3.1 Metric Definition

The probability that a Toll Declaration (based on a GNSS OBE) is incorrectly generated

6.4.3.2 Intended Use

With this metric a TSP can measure the overall performance of the system including its own TSP Back End (in generating Toll Declarations) and its own TSP Front End (in generating Charge Reports)

6.4.3.3 Metric Calculation Method

$$TD\ Incorrect\ Toll\ Declaration\ Generation = \frac{A}{B}$$

Where

A = Number of incorrectly generated Toll Declarations, i.e. the number of Toll Declarations generated during the measurement period by the TSP Back End.

B = Total number of Toll Declarations, i.e. the number of Toll Declarations generated by the TSP Back End in the measurement period.

6.4.4 ET-CM-TD-3 TD – Late Toll Declarations

6.4.4.1 Metric Definition

The proportion of Toll Declarations received by the Toll Charger in a defined period where the time between the Chargeable Event and the receipt of the associated Toll Declaration is greater than the defined period for the charging scheme.

6.4.4.2 Intended Use

This metric measures the performance of the TSP system in terms of the delays occurring in the process of generating Toll Declarations.

6.4.4.3 Metric Calculation Method

$$TD\ Late\ Toll\ Declarations = \frac{A}{B}$$

Where

A = Number of late Toll Declarations, i.e. the number of toll declarations generated during the measurement period by the TSP Back End which are delayed by a time longer than Maximum Toll Declaration Delay (MTDD) after the actual occurrence of the last of the respective charging events.

B = Total Number of Toll Declarations, i.e. the number of Toll Declarations generated by the TSP Back End in the measurement period.

6.4.5 ET-CM-TD-4 TD - TSP Event Detection

6.4.5.1 Metric Definition

The probability that for any predefined Charge-Relevant Event that takes place the TSP properly detects it.

6.4.5.2 Intended Use

This metric measures the reliability of the detection of Charge-Relevant Events in the TSP system.

NOTE Be aware of the distinction between Charge-relevant Events and Charging Events.

6.4.5.3 Metric Calculation Method

$$TSP\ Event\ Detection = \frac{A}{B}$$

Where

A = Number of correctly detected Charge-Relevant Events in the Toll Declarations, during the measurement period.

B = Total number of detected Charge-Relevant Events in the Toll Declarations sent by the Toll Service Provider in the measurement period

6.4.6 ET-CM-TD-5 TD - TSP False Positive

6.4.6.1 Metric Definition

For the vehicles not using the infrastructure, it is the probability that for any defined Chargeable Event the TSP improperly detects it during the creation of Toll Declarations.

6.4.6.2 Intended Use

The rate of false positives is a critical parameter of system performance, because it is directly related to customer satisfaction, the number of user complaints and the public perception of a system. This metric measures the rate of occurrence of false positives in the TSP system.

NOTE In continuous systems the false positives may imply the application of a wrong tariff to the distance driven within a given infrastructure, e.g. being charged for distance driven within a congestion charging zone while actually only having passed close by.

6.4.6.3 Metric Calculation Method

$$\mathbf{TD\,False\,Positive} = \frac{A}{B}$$

Where

A = Number of False Positives identified in all Toll Declarations which are generated during the measurement period

B = Total Number of passes of vehicles in the proximity (but outside) the charging objects in the measurement period

6.4.7 ET-CM-CTD-1 CTD Correct Charging Rate

6.4.7.1 Metric Definition

The probability that for any set of *representative trips* travelled by a vehicle and during a certain period of time, the Average Relative Charging Error is within the Accepted Charging Error Interval.

6.4.7.2 Intended Use

This metric provides overall information for the TSP and the Toll Charger on the capabilities of the system, in particular the OBE, to compute Toll Declarations whose charges are within the Accepted Charging Interval, i.e. ensuring that charges cover a very high percentage of the due incomes (to ensure the viability of the system) and limiting the charges in excess (overcharging) to avoid claims and for providing credibility for the users and the authority.

6.4.7.3 Metric Calculation Method

$$CR\ \ Correct\ Charge\ Report\ Generation\ Rate = \frac{A}{B}$$

Where

A = Number of sets of representative trips travelled by a vehicle during a certain period of time whose Average Relative Charging Error is within the Accepted Charging Error Interval.

B = Overall number of sets of representative trips analysed

NOTE To be investigated whether sets of representative trips have to be independent for each sample or same trips can be used for more than one set. Second option seems to provide a more reliable metric.

6.4.8 ET-CM-CTD-2 CTD Overcharging Rate

6.4.8.1 Metric Definition

The probability that for any single predefined *representative trip*, the Relative Charging Error is above the upper bound of the Accepted Charging Error Interval.

6.4.8.2 Intended Use

This metric provides overall information for the Front-End provider; the TSP, the Toll Charger, Authority and Users on the capabilities of the system, in particular the OBE, to compute Toll Declarations whose charges are not larger than the Accepted Charging Interval. i.e. ensuring that the probability of probability of charges in excess (overcharging) is properly bounded providing credibility for the users and the authority.

6.4.8.3 Metric Calculation Method

$$CR\ \ Overcharging\ Rate = \frac{A}{B}$$

Where

A = Number of representative trips travelled by a vehicle during a certain period of time whose Relative Charging Error is above the Accepted Charging Error Interval.

B = Overall number of representative trips analysed during the mentioned period of time.

6.4.9 ET-CM-CTD-3 CTD Accuracy of Distance/Time Measurement

6.4.9.1 Metric Definition

Average and Standard Deviation of the relative distance or time error of a set of *representative trips* travelled by a vehicle during a certain period of time.

6.4.9.2 Intended Use

While above metrics (related to charges) measure the overall system performance (integrating errors in distance measurement and errors in event recognition) having direct observability of system capability to accurately measure distance and time also separating between systematic and random errors (that can be observed by the average and standard deviation values) provides a substantial value for the TSP.

6.4.9.3 Metric Calculation Method

$$Average = \frac{\left(\sum_{i=0}^{n} Error_i\right)}{n}$$

$$Standard\ Deviation = \sqrt{\frac{\left(\sum_{i=0}^{n} Error_i^{\ 2}\right)}{n}}$$

Where

$$Error_i = \frac{(measured\ distance - true\ distance)}{true\ distance}$$

n is the number of representative trips considered

measured distance is the one supplied by the system (could be also time)

true distance is the one measured by the reference system (could be also time)

6.4.10 ET-CM-CR-1 CR - Correct Charge Report Generation

6.4.10.1 Metric Definition

The probability that a Charge Report (based on a GNSS OBE) is correctly generated

6.4.10.2 Intended Use

With this metric a Front-End provider and a TSP can measure the performance of the Front-End as far as computation of Charge Reports is concerned.

6.4.10.3 Metric Calculation Method

$$CR\ Correct\ Charge\ Report\ Generation = \frac{A}{B}$$

Where:

A = Number of correctly generated Charge Reports during the measurement period and for a given number of vehicles by the Front- End.

B = Total number of Charge Reports, i.e. number of Charge Reports generated by a given number of vehicles the Front-End in the measurement period.

6.4.11 ET-CM-CR-2 CR - Incorrect Charge Report Generation

6.4.11.1 Metric Definition

The probability that a Charge Report (based on a GNSS OBE) is incorrectly generated

6.4.11.2 Intended Use

With this metric a Front-End provider and a TSP can measure the performance of the Front-End as far as computation of Charge Reports.

6.4.11.3 Metric Calculation Method

$$\textbf{\textit{CR Incorrect Charge Report Generation}} = \frac{A}{B}$$

Where

A = Number of incorrectly generated Charge Reports during the measurement and for a given number of vehicles period by the Front- End.

B = Total number of Charge Reports, i.e. number of Charge Reports generated by a given number of vehicles the Front-End in the measurement period.

6.4.12 ET-CM-CR-3 CR - Charge Report Latency

6.4.12.1 Metric Definition

The average time it takes between a Charge Event and the time the Charge Report is created / received by the Service Provider

6.4.12.2 Intended Use

This test gives the average latency of Charge Events until they are received from the Front End. Therefore it gives information about the average Front End performance.

6.4.12.3 Metric Calculation Method

$$\textbf{\textit{Charge Report Latency}} = \frac{1}{n}\sum_{i=1}^{n} A_i$$

where

A_i = Time span between the occurrence of Chargeable Event with index i as determined from the Reference Data and the reception of the respective Charge Report from the Front End

n = Number of Chargeable Events in the measurement period

NOTE 1 If the measurement period was chosen accordingly, this test could be used to determine the average delay for the data in a single Charge Report. If a longer period was chosen, it could also give the average delay over multiple Charge Reports.

NOTE 2 Be aware that the reporting period influences this metric. If e.g. 24h is chosen, the average resulting latency must be greater 12h for evenly spaced chargeable events.

6.4.13 ET-CM-CR-4 CR – TSP Front End Event Detection

6.4.13.1 Metric Definition

The probability that the front-end properly detects any defined Charge-Relevant Event that takes place

6.4.13.2 Intended Use

This test measures the percentage of Charge-Relevant Events which are correctly reflected in Charge Reports generated by the TSP Front End.

NOTE Be aware of the distinction between Charge-Relevant Events and Charging Events.

6.4.13.3 Metric Calculation Method

$$\boldsymbol{CR\ Event\ Detection = \frac{A}{B}}$$

Where

A = Number of Charge-Relevant Events which are correctly represented in Charge Reports received from the TSP Front End.

B = Total number of Charge-Relevant Events as determined from the Reference Data in the measurement period.

6.4.14 ET-CM-CR-5 CR – TSP Front End False Positive

6.4.14.1 Metric Definition

For the vehicles not using the infrastructure, it is the probability that for any predefined Chargeable Event the front-end improperly detects it.

6.4.14.2 Intended Use

The rate of False Positives is a critical parameter of system performance, because it is directly related to customer satisfaction, the number of user complaints and the public perception of a system. This metric measures the rate of occurrence of Charge Reports in the TSP system containing false positives.

6.4.14.3 Metric Calculation Method

$$\boldsymbol{CR\ Front\ End\ False\ Positive = \frac{A}{B}}$$

Where

A = Number of False Positives identified in all Charge Reports which are generated during the measurement period

B = Total Number of passes of vehicles in the proximity (but outside) the charging objects in the measurement period

6.4.15 ET-CM-CCR-1 CCR - Correct Charging Rate

6.4.15.1 Metric Definition

The probability that for any set of *representative trips* travelled by a vehicle and during a certain period of time, the Average Relative Charging Error is within the Accepted Charging Error Interval.

6.4.15.2 Intended Use

This metric provides overall information for the Front-End provider, the TSP and the Toll Charger on the capabilities of the system, in particular the OBE, to compute the charges within the Accepted Charging Interval, i.e. ensuring that charges cover a very high percentage of the due incomes (to ensure the viability of the system) and limiting the charges in excess (overcharging) to avoid claims and for providing credibility for the users and the authority.

6.4.15.3 Metric Calculation Method

$$CR\ \ Correct\ Charge\ Report\ Generation\ Rate = \frac{A}{B}$$

Where

A = Number of sets of representative trips travelled by a vehicle during a certain period of time whose Average Relative Charging Error is within the Accepted Charging Error Interval.

B = Overall number of sets of representative trips analysed

NOTE In order to have more observability of the process (i.e. the resulting metric to be closer to the reality) sets of representative trips do not need to be fully independent. I.e. different sets can share the same trips. For instance if the considered period is one month, one can consider periods of 30 days starting each day instead of considering a set each month.

6.4.16 ET-CM-CCR-2 CCR - Overcharging Rate

6.4.16.1 Metric Definition

The probability that for any single predefined *representative trip*, the Relative Charging Error is above the upper bound of the Accepted Charging Error Interval.

6.4.16.2 Intended Use

This metric provides overall information for the Front-End provider; the TSP, the Toll Charger, Authority and Users on the capabilities of the system, in particular the OBE, to compute the charges that are not larger than the Accepted Charging Interval, i.e. ensuring that the probability of charges in excess (overcharging) is properly bounded providing credibility for the users and the authority.

6.4.16.3 Metric Calculation Method

$$CR\ \ Overcharging\ Rate = \frac{A}{B}$$

Where

A = Number of representative trips travelled by a vehicle during a certain period of time whose Relative Charging Error is above the Accepted Charging Error Interval.

B = Overall number of representative trips analysed

6.4.17 ET-CM-CCR-3 CCR - Accuracy of Distance/Time Measurement

6.4.17.1 Metric Definition

Average and Standard Deviation of the relative distance or time error of a set of *representative trips* travelled by a vehicle during a certain period of time.

6.4.17.2 Intended Use

While above metrics related to charges measure the overall system performance (integrating errors in distance measurement and errors in event recognition) having direct observability of system capability to accurately measure distance and time also separating between systematic and random errors provides a substantial value for the TSP.

6.4.17.3 Metric Calculation Method

$$Average = \frac{\left(\sum_{i=0}^{n} Error_i\right)}{n}$$

$$Standard\ Deviation = \sqrt{\frac{\left(\sum_{i=0}^{n} Error_i^{\ 2}\right)}{n}}$$

Where

$$Error_i = \frac{(measured\ distance - true\ distance)}{true\ distance}$$

n is the number of representative trips considered

measured distance is the one supplied by the system (could be also time)

true distance is the one measured by the reference system (could be also time)

Annex A
(informative)

Examination Test Documentation Template

A.1 Examination Test Template

Annex A provides a template for the documentation of examination tests.

<table>
<tr><td colspan="2">Measured Metric:</td><td colspan="4"></td></tr>
<tr><td colspan="6">Metric Definition</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">Metric Measurement Data requirements</td></tr>
<tr><td>Reference Data</td><td>Charge Report</td><td>Toll Declaration</td><td>Billing Details</td><td>Payment Claim</td><td>User Account Charges</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Environmental Conditions</td><td colspan="4"></td></tr>
<tr><td colspan="2">Performance Requirement</td><td colspan="4"></td></tr>
<tr><td colspan="2">Sample Size</td><td colspan="4"></td></tr>
<tr><td colspan="2">Details of Method for Generating Charging Input</td><td colspan="4"></td></tr>
<tr><td colspan="2">Method for Generating Reference Data</td><td colspan="4"></td></tr>
<tr><td colspan="6">Test Route / Sub-set of charge Network</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">Metric Calculation Details</td></tr>
<tr><td colspan="6"></td></tr>
</table>

Annex B
(informative)

Examination Framework Considerations

B.1 General

For defining the Examination Framework, completeness is as important as efficiency and reliability. The measurements should be repeatable and comparable, considering the diverging requirements from scheme type, phase and technology.

A systematic three-step process was applied.

a) Identification of sources of relevant data: e.g. an operational enforcement system.

b) Measurement methods for collecting data from the sources identified in a): e.g. comparison with DSRC events collected by an enforcement system.

c) Definition of the Examination Framework for each metric: e.g. CM-DCR-1 DCR - Correct Charging Rate (Chargeable Events) in an operational tolling system.

This systematic approach allows for reliable and comparable results, but also maximises the opportunities for synergy. One measurement can be used for measuring several metrics at once. In many cases this gives more than one option of measurement for each metric. This is even necessary because of the varying circumstances due to phase, type and technology.

B.2 Criteria for definition of tests

To ensure that the results of the examinations (measurements of metrics) are reliable, accurate and reproducible, it is important to apply a comprehensive strategy in designing the examination methods. This strategy should take into account the possible sources of influences on metrics.

These influences might be controlled by the examination process (e.g. mounting position of OBE) or might not be accessible to manipulation (e.g. weather conditions).

Therefore, the following strategy of defining examination methods is used in this specification:

— identify possible sources of influences on metrics, considering differences due to phase, scheme type and technology;

— devise tests which “provoke” errors, exploit possible vulnerabilities.

The second point is especially useful in the case of rare events to be tested (e.g. CM-DCR-4, false positives).

B.3 Statistical Considerations

The quality of toll-collecting systems can be characterized by performance indices derived for specific aspects, called metrics. Using well defined sampling procedures, estimation of performance is possible, and can be characterized by confidence intervals for the parameters of interest. Statistical methods applied, have to be chosen appropriately, reflecting the type of distribution under investigation and the sampling design. For further information on the choice of statistical methods to be used please refer to the information in Annex B.

B.4 Dependency on Scheme Type

The design of a valid Examination Framework differs widely depending on the type of scheme:

a) Discrete systems: The results in a discrete system can only assume two values (detected or not). Therefore the result of a test can assume only four values, as elaborated in the introduction to part 1 of this standard. Percentages only come into play after collecting a sample of several measurements.

   — It is also easier to define a valid reference the system under test is to be compared to. E.g. the passage of a road section is much easier to define than a specific trajectory for a continuous system.

b) Continuous Systems: While the results in a discrete system can only assume two values (detected or not), the result in continuous systems is a value. Therefore the result of a test should be expressed as a continuous error value.

   — Additional problems occur because it is more difficult to reproduce a certain vehicle behaviour: e.g. the mileage for a given trip will vary simply because a vehicles can and will not drive exactly on the same trajectory repeatedly.

The type of scheme also has an impact on the information flows and on the metrics that can be defined. This is described at the end of Clause 5.1 of part 1 of this standard. While the metrics are independent of scheme on the higher levels (billing details to end-to-end), there are major differences for the low level metrics (charge report and toll declaration).

The roles in the collection of charge data differ: In autonomous systems the Toll Service Provider is operator of the front end, therefore charge reports and toll declarations are within his realm of responsibility. In DSRC based systems, the roadside equipment and the corresponding parts of the central system are under the control of the Toll Charger. In DSRC systems, the interface for exchanging the equivalent to Charge Reports in autonomous systems was not standardised until the preparation of the current document and therefore it is difficult to put metrics on them.

B.5 Dependency on Phase

The two main phases in the lifetime of a tolling system result in very different conditions for charging performance metrics measurement. These differences are detailed in the following clauses.

a) Evaluation Phase:

There are no Service Users yet. All tests should be performed with selected vehicles, either driven by personnel of the entity performing the tests, or volunteers which allow their vehicles to be equipped. This situation results in

— Relatively small sample sizes, potentially with controlled behaviour of test vehicles and controllable influences on metrics (e.g. mounting position of OBU).

b) Monitoring Phase:

Usually a large number of toll system users are active in the system. Therefore

— Very large sample sizes possible, but with unknown behaviour of the vehicles and potentially uncontrollable influences on metrics. In principle all measurements from implementation phase possible, too.

There might exist a period of transition between the two phases during the roll out of the system. More and more vehicles are equipped with OBEs, so the sample sizes are also rising.

B.6 Dependency on Technology

Sources of influences on metrics depend on technology.

Examples:

- In GNSS systems, performance is influenced by accuracy, availability of GNSS position data / events. Key issues are:
  - environment of the road (referred to obstacles, buildings, etc);
  - solar activity (affecting ionosphere), weather conditions…);
  - quality of Toll Context data from the Toll Charger (ISO 12855).
- In DSRC systems, performance is influenced by
  - traffic density;
  - vehicle speed;
  - OBU mounting position;
  - weather conditions;
  - Service User behaviour;
  - battery life.
- In both technologies interference (spoofing, jamming) in the respectively used frequency bands degrades performance.

Knowledge about these sources helps in designing useful tests, especially for measuring rare events. As already pointed out in Clause A.2, artificially stressing the system by creating challenging scenarios might provoke errors which can be used for estimation of metric values given that the actual probability of such conditions is known.

B.7 Simultaneous measurement of metrics

The metrics in the Examination Framework have been defined based on the sequential information flows within a charging system, as described in ISO/TS 17444-1:2012 Clause 5.1 which means that there is a hierarchy of metrics which means that an examination test designed to measure metrics at the E2E Level, can with additional observation points be used to simultaneously measure metrics at the Charge Report, Billing Details, Payment Claim and User Account metric levels.

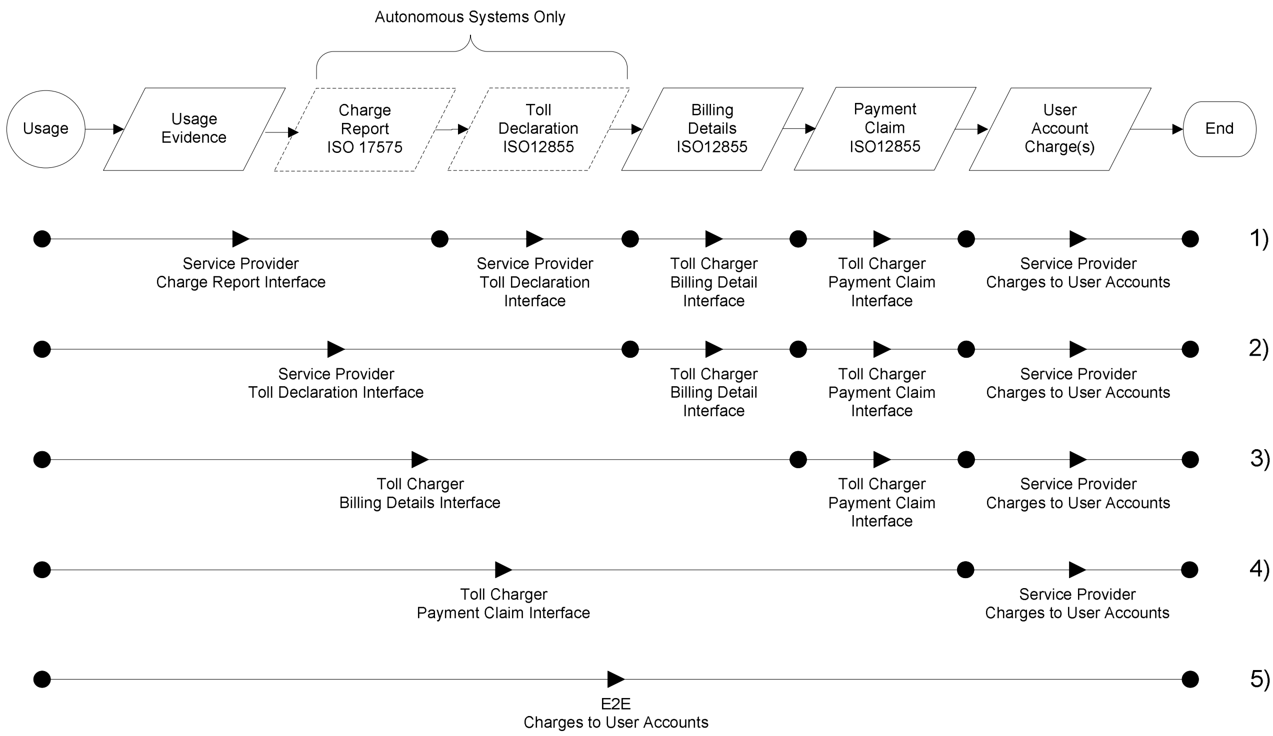

Figure B.1 — Hierarchy of Metric Measurement Observation Points

Annex C
(informative)

Statistical Considerations

C.1 Basics

All statistical considerations should reflect existing ISO standards, as described in **the standards catalogue 03.120.30: Application of statistical methods**. The catalogue can be found online under http://www.iso.org/iso/home/store/catalogue_ics/catalogue_ics_browse.htm?ICS1=3&ICS2=120&ICS3=30

The four most relevant standards for basic statistical analysis of EETS data can be found in the bibliography and are repeated here for completeness: ISO 3534-1:2006, ISO 3534-2:2006, ISO 2602:1980 and ISO 11453:1996/Cor.1:1999.

More specific aspects and alternative approaches can be found in the catalogue as well.

These ISO standards should be the base reference for all **Standard Operating Procedures** defining statistical characterizations of performance measures. Standard Operating Procedures should not only describe data analysis, but have to define unambiguously all steps of sampling, data ascertainment, data description, and statistical evaluation. When necessary, approaches for validation of measurement systems, identification of sources of bias and of extra variability, etc. have to be provided.

Development of more sophisticated statistical methods should be encouraged, when appropriate, scientifically sound, and in accordance with established ISO standards.

Vocabulary and terms used should be standardized and as precise as possible. Therefore, all documents should use ISO 3534 as common reference. In addition, there are internationally widely accepted glossaries of statistical terms. OECD offers an online statistics portal, with a glossary under http://stats.oecd.org/glossary/ . From this website a downloadable version is available as well. Translations into 31 languages are offered by the International Statistical Institute, and can be found at http://www.isi-web.org/glossary .

The following sections of this Appendix give a short overview of basic terminology, elementary formulae for computing estimates of performance parameters and confidence limits, including example calculations. They should not be understood as a replacement of the standards mentioned above.

C.2 Terminology

Table C.1 — Used Terminology

Term	Definition	Examples
Population	The statistical population is the total membership or population or “universe” of a defined class of people, objects or events.	Vehicles on a certain segment of a toll road On board devices of a certain type
Sample	Selection of elements of an entity and ascertainment of data for different metrics.	Detection of a toll road segment, by randomly selected vehicles passing Measurement using the GNSS device of an on board unit for randomly selected vehicles within a given time interval on a certain toll road.

Data Analysis	Parameter estimation and inference based on samples	Point and interval estimation, e.g. means, standard deviations, and proportions Comparisons of measurements to a reference system Characterization of distributions Selection of certain parametric types of probability distributions and fitting such models to data, e.g. using the normal distribution for characterization of measurements
Interval Estimation	Calculation of lower and upper bounds for unknown parameters, assuring a predefined coverage probability of the true value.	Confidence intervals: bounds that guarantee that the true parameter θ is covered by the interval (lower bound, upper bound) with probability $1-\alpha$. Tolerance intervals: bounds that guarantee that a proportion γ of the population is covered by the interval (lower bound, upper bound) with probability $1-\alpha$.
Sample Size Determination	statistical approaches for assessing the size of a sample, such that demands on precision of inference are met.	Methods related to statistical hypotheses rely on a demand for the power of an $\alpha-$ level significance test being able to detect a certain deviation from the null-hypothesis. Methods related to estimation rely on the precision (interval length) of $1-\alpha$ confidence intervals.
Probability Distributions	Actual probability distributions of the results:	For some measurements of continuous parameters (e.g. distance driven), the results will follow a probability distribution. For ease of analysis, normal distribution is often assumed. Often this is wrong. Some of the influences (e.g. GNSS fixes) of the errors show a behaviour distinctly different from normal distributions. In this case the calculations must be modified or only considered approximations

C.3 Point and interval estimation for binary and continuous data

C.3.1 Binary Data

These data arise if the measurement of interest is of type yes/no, failed/passed, usually coded as 0/1. Parameter of interest is the probability for observing a 1. A point estimation for samples of independent, identically distributed binary data is straight forward. Such data make up a so called Bernoulli process. A interval estimation can be based on normal approximation or other methods, as appropriate.

Formulae for the normal approximation approach (x = number of successes, n= sample size):

Point estimate: $\hat{p} = x/n$, **Confidence limits**: $\hat{p} \pm z_{1-\alpha/2} \sqrt{\hat{p}\ (1-\hat{p})/n}$ denoting the normal percentile by $z_{1-\alpha}$.

Alternative methods are described in the literature. Especially for probabilities near 0 and 1, more appropriate methods would be likelihood based, transformation based or the so called exact Clopper-Pearson intervals.

NOTE 1 As binary data are discrete by nature, the demanded coverage probability cannot be exhausted in all situations. Exact confidence intervals guarantying coverage of a least $1-\alpha$ are wider than alternatives. For large sample sizes these differences are getting smaller and smaller.

NOTE 2 Dependent observations or non-homogeneous data result in over-dispersion, which means, that the variability of the rate estimate is larger than under the Bernoulli sampling scheme. In this case, confidence intervals for the overall success probability have to be constructed taking over-dispersion into account.

NOTE 3 For very small underlying probabilities, samples with zero response occur quite often. In this case, one-sided confidence intervals can easily be constructed giving an upper bound.

NOTE 4 A testing based approach for inference on binary data can be found in ISO 2859.

NOTE 5 More sophisticated analysis of binary data is provided, when logistic regression models are used, giving the opportunity to model e.g. detection probabilities for different times, segments, devices etc.

C.3.1.1 Binary Data Examples

C.3.1.1.1 Probability

Estimation of probability / proportion

$\hat{p}$ = number of successful events / overall events

Margin of error

A simple approach for calculating the confidence interval of a binomial proportion is the normal approximation interval.

$$\hat{p} \pm z_{1-\alpha/2}\sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$$

where

$\hat{p}$ is the proportion of successes in a Bernoulli trial process estimated from the statistical sample,

$z_{1-\alpha/2}$ is the $1-\alpha/2$ percentile of a standard normal distribution,

α is the error percentile, and

n is the sample size.

For example, for a 95% confidence level the error (α) is 5%, so $1-\alpha/2 = 0{,}975$ and $z_{1-\alpha/2} = 1{,}96$.

(from http://en.wikipedia.org/wiki/Binomial_proportion_confidence_interval)

EXAMPLE Simple example with proportions near 50%.To analyse the proportion of defective units we draw a sample of 1000 units. 529 of the 1000 units are defective.

$$\hat{p} = \frac{529}{1000} = 0.529$$

The confidence interval is:

$$CI = 0.529 \pm 1.96\sqrt{\frac{0.529(1-0.529)}{1000}} = 0.529 \pm 0.031$$

C.3.1.1.2 Estimation of probabilities near 0 or 100%

EXAMPLE Significant estimation of the overall detection rate (most important Key Performance Indicator (KPI)) of segment based toll systems. To analyze the overall detection rate of a toll system 1000 detection events are considered as a sample. 995 of the events were successful.

$$\hat{p} = \frac{995}{1000} = 0.995$$

The confidence interval is:

$$CI = 0.995 \pm 1.96\sqrt{\frac{0.995(1-0.995)}{1000}} = 0.995 \pm 0.004$$

As one can see the margin of error of the second example is smaller.

C.3.1.1.3 One-sided confidence intervals

Often it is of more interest if a certain requested quality level is complied with or not than the calculation of an error margin. In this case one sided confidence intervals should be used.

For the special case of 0 events among n units under test, an upper $1-\alpha$ confidence limit for the underlying response probability is given by

$$\hat{p}_{low} = 1 - \sqrt[n]{\alpha}$$

For sample sizes of 100, 1 000, 10 000 we get as upper 95% limits: 0.0295, 0.0030, 0.0003.

C.3.2 Continuous Data

Continuous data can be of various shapes. For toll data, information on the expected value might be most important, as the total of charges equals the number of rides times the expected toll. Inference is supported by the central limit theorem of mathematical statistics. For large samples, approximations based on normal theory can be regarded as reliable. Point and interval estimates assume independent, identically distributed data.

Formulae for the normal approximation approach: ($x_1, x_2, \ldots, x_n$ denoting the sample data; data is assumed to be drawn from a distribution with expected value μ and variance σ^2 .):

Point estimate: $\hat{\mu} = \bar{x}$ (mean)

Confidence limits: , denoting the standard deviation by s . The standard deviation is the point estimate of σ .

Confidence limits for the median, non-parametric approach:

The interval ($\min(x_1,x_2,\ldots,x_n),\max(x_1,x_2,\ldots,x_n)$) is a $1-(1/2)^{n-1}$ confidence interval for the median of the underlying distribution. This holds true for arbitrary distributions. In general, the lower and upper limit can be calculated more appropriately according to a given confidence level $1-\alpha$ by suitably chosen order statistics.

NOTE 1 For normal data, the distribution would be perfectly characterized by the parameters μ and σ. For general distributions, interpretation of parameter estimates depends on the form of the distribution. A continuous variable is **not** fully characterized by the expected value and variance. At least, questions of symmetry should be addressed.

NOTE 2 The coverage of the above defined interval is exactly equal to $1-\alpha$ if the data is normally distributed, otherwise exact coverage is virtually achieved for large samples ($n > 100$), not too skewed.

NOTE 3 A testing based approach for inference on continuous data can be found in ISO 3951.

NOTE 4 Instead of the mean, the median or other percentiles of a distribution could be chosen as parameter of interest. There are non-parametric methods for interval estimates available, either based on empirical quantiles or on re-sampling methods including the bootstrap approach (see e.g. ISO 16269-7:2001Statistical interpretation of data -- Part 7: Median -- Estimation and confidence intervals).

NOTE 5 Tolerance interval estimation is also possible; however, this is a greater challenge for non-normal data.

NOTE 6 When samples are drawn under different conditions, covariates, useful for describing the distribution, should be recorded as well. Such data offer the chance for more sophisticated regression modelling, including so called random effects models, which could characterise sources of variability.

NOTE 7 Tolerance interval estimation is also possible; however, this is a greater challenge for non-normal data.

C.3.2.1 Continuous Data Example

The following example uses artificial data, five measurements of a distance: 3.351 km, 3.353 km, 3.349 km, 3.348 km, and 3.352 km. The true distance determined by a high precision reference is 3.35 km.

C.3.2.1.1 Normal approximation approach

The mean is $\bar{x} = 3.3506$, the standard deviation equals $s = 0.002073644$.

The 95% confidence interval is calculated as

$$3.3506 \pm 2.776 \cdot \frac{0.002073644}{\sqrt{5}} = 3.3506 \pm 0.002575 = (3.348025,\ 3.353175)$$ using the t-value $t_{4,\,0.975} = 2.776$.

This confidence interval covers the “true” value, there seems to be no systematic error in measurements.

C.3.2.1.2 Non-parametric approach

The interval given by minimum and maximum of the values is $(3.348, 3.352)$ virtually identical to the normal approximation. The confidence level equals $1-\left(1/2\right)^{5-1} = 93.74\%$.

In this case, the non-parametric approach gives almost identical information, however, with a slightly reduced level of confidence.

C.3.3 Dealing with non-normal data

GNSS based position information is not normally distributed. While the pseudo range measurement itself is (beside the systematic effects) nearly normally distributed, the resulting position solution no longer is.

Modelling of the real distribution based on pseudo range measurements is possible only theoretical. In practice the complexity of data processing and the missing information about the real methods don’t allow the calculations of error distributions.

So the real distribution of GNSS position data depends on the satellite segment, the receiver (and firmware version) and also atmospheric situations.

NOTE To overcome this situation a practical solution is to use a quantile based approach. All measurements are collected and need to fulfil a maximum deviation condition with given percentage (e.g. 99% below 40 m). Confidence levels must be defined using the number of samples.

C.3.4 Quality of reference systems

A reference system needed to determine deviations of the devices under test needs an accuracy some orders higher than the accuracy of the testing device. Typically values are factors above 3 to 5.

As the costs for reference systems are nearly exponentially linked with the required accuracy a typical approach would be to choose the quality of the reference based on practical considerations.
Based on available measurement systems with specified accuracy (and acceptable price range) it needs to be determined if the reachable accuracy fulfils the minimum requirements.
Afterwards the reachable confidence levels can be specified based on the specified accuracy of device under test and reference system.

Annex D
(informative)

Methods for reducing sample sizes for very high/low probability metrics during the Evaluation Phase

D.1 Rationale

Some metrics are used in requirements establishing values of very low (e.g. 10^{-6}) or very high (e.g. 99.99%) probability. While this might be possible to measure for the operation phase of a system assuming that a detailed knowledge of a reference may be established, the effort and cost for tests in the evaluation phase can be high, if those tests are feasible at all.

Typical examples of metrics of those characteristics are those related to false positives and overcharging rate.

If on the other hand, in order to avoid the mentioned high cost of exhaustive tests, small sample sizes are used for measuring such values close to 0 or 1, the effect is detrimental in two ways: Either unwanted behaviour of the system is missed because of the resulting inaccuracy, or events occurring by chance in the test give a strongly distorted picture. In both cases the results will be misleading and without practical relevance. In those sub-sampling scenarios one can only derive that, given the measured metric, the system is behaving normally or abnormally with a given confidence level but actual value of the metrics cannot be measured.

The first way out of this dilemma is to put the system under artificial stress. By that a higher probability for the events to be detected is created and can be measured with reasonable sample sizes and therefore with reasonable testing efforts. Extreme care must be taken, though, when deriving the “normal” behaviour of the system - normal meaning the behaviour under average conditions for the intended application of the system. The extrapolation to that “normal” behaviour requires the identification of some models on which that extrapolation are based. Alternatively, the customer may require a different (less demanding) value for the metric (e.g. different probability) when the system is under those stress situation,

It is important to emphasize that stress can be put on:

— the definition of the road network topology;
— the errors affecting the positioning/detection system.

It is also key to understand that those stress conditions can be technology dependent and, therefore, no general rules can be established for their definition but they have to be defined on a case by case basis as a negotiation process between the customer and system provider.

The first group (road network topology) can be “simply” established as a new input for the system. The second may require the use of simulation. Alternatively review of design can be also a valid mechanism if the mentioned design implements particular features to respond to those stress conditions.

The second way out of the dilemma (in isolation or in combination with the previous solution) is to increase the amount of testing data without largely increasing the testing effort and hence costs. This may be implemented, in particular in the cased of measuring false positives, by artificially adding new infrastructure elements to be charged. In any case the number of trips have to be big enough to be statistically significant of the different errors affecting the system[1].

---

[1] I.e. if we need n trips to have the required statistical significance and we introduce m segments to be detected, the resulting number of trips could be around n/m. But this number has to be still large enough, i.e. m=n, resulting in a single trip would be not a valid solution.

This derivation is founded on extrapolation of the system behaviour to less demanding circumstances. For ensuring that this process remains fair and reliable, the underlying model for the system behaviour is of critical importance. It is also recommended to subject the reference system to the same test scenario. This strategy can help to identify errors in the model or inherent limitations of the technology used.

While target is to define **black-box** & **technology independents** tests, it is anticipated that relaxation of these two objectives may facilitate the definition of those tests.

Table D.1 — Applicability of the use of real, emulated and artificial Charge Objects in metric measurements

		Trips		
		Real (n>> 1/p)	Real (n<1/p)	Simulated (worst case nuisance variables)
Charge Objects	Real	Possible. Very expensive	Not useful	Possible but only valid if "GNSS-only". Model needed to extrapolate
	Emulated	Not useful	Possible. Direct Metric	Possible but only valid if "GNSS-only". Model needed to extrapolate
	Artificial (worst cases)	Not useful	Possible. Model needed to extrapolate	Possible but only valid if "GNSS-only". Model needed to extrapolate

D.2 Identification of potential methods

D.2.1 Method 1: based on PC and PU and having as reference the real Chargeable Event

Trips for PC1 and PC2 selected to be in the nearest feasible proximity to zone/segment for which the chargeable event is defined. For PU1 selection only of the subset of users who travel in the proximity of the mentioned infrastructure.

Number of trips to be considered have to be in the order of 10 divided by the target probability defined in the requirement related to that metric (what makes these method 1 quite inefficient). Alternatively if metric does not need to be measured but only to define if the system fulfils a requirement with a certain level of confidence the number of allowed false positives may be established as a function of the number of trips and the mentioned level of confidence.

$$TSP\ False\ Positives\ probability = \frac{Number\ of\ trips\ that\ provoke\ a\ false\ positive}{Total\ Number\ of\ Trips}$$

This method is the "brute force" approach, which will lead to large sample sizes or to misleading results, as described in the last subclause.

D.2.2 Method 2: based on PC and PU and having as reference artificially defined Chargeable Event

Emulated chargeable infrastructure defined in the nearest proximity to the travelled trips. This can be based on the existing network (and then defined charging infrastructure has to be a real road) or to be theoretical (not based on a real road). This allows defining multiple chargeable events for a single trip. The ease of variation and duplication of the emulated charge objects decreases testing efforts, and also increases flexibility and room for variation.

Trips for PC1 and PC2 selected to be the ones where a potential infrastructure to be charged can be established in the proximity (if the realistic approach is used) or any one otherwise. For PU1 selection only of the subset of users who fulfils the above criteria.

Number of trips to be considered has to be in the order of 10 divided the number of defined chargeable events and divided by the target probability defined in the requirement related to that metric (what makes these method 1 quite inefficient). Alternatively if metric does not need to be measured but only to define if the system fulfils a requirement with a certain level of confidence number of allowed false positives may be established

$$TSP\ False\ Positives\ probability = \frac{Number\ of\ \ false\ positives}{Total\ Number\ of\ Trips\ x\ Number\ of\ Chargeable\ events}$$

This method should be applied in cooperation with the system supplier. This is important to ensure that the capabilities of the system are fully exploited.

Special care is also necessary when defining the artificial stress factors for the system. Selecting the location of an emulated charge object to coincide with a high building could result in almost 100% false positives because of the reflections from the building.

EXAMPLE The system might use the history (former trajectory) and the future behaviour of a vehicle to improve the quality of charge object recognition. Therefore the geographic data used for the emulated charge object must be sufficiently extensive to exploit these capabilities.

This approach is also useful in DSRC based systems. E.g. DSRC readers can be placed in varying proximity to a road. The successful transactions completed by these readers are considered false positives.

D.2.3 Method 3 based on simulation (D)

This approach is only valid for GNSS only solutions (not integrating other positioning technology such as INS or odometer). While cutting edge equipment such as GNSS simulators can also provide simulation data for sensor fusion of GNSS with INS etc., these interfaces are not standardised. Therefore it is not possible to define or require the capability to support these test modes from the system under test. (see scope of this standard, topic “out of scope of this standard”).

A GNSS signal simulator simulates a given trip according to the conditions defined in Method 1 and different errors defined according to the different nuisance variables (multipath, iono, clocks…) . Duration of simulated trip has to be as small as possible but respecting a minimum duration according with the definition of representative trips.

GNSS signal is fed to the OBE in real time

$$TSP\ False\ Positives\ probability = \frac{Number\ of\ trips\ that\ provoke\ a\ false\ positive}{Total\ Number\ of\ Simulated\ Trips}$$

D.2.4 Method 4: Review of design and analysis

Definition of a model of position errors according to the technology used and the environment situation covering different nuisance variables (multipath, iono, clocks…). Model has to be statistically defined to establish different error sources and its associated probabilities.

Given the OBE design, the mentioned model, a reference trip and a chargeable event, analysis can provide an estimate for the expected false positive probability.

D.2.5 Method 5: Increased density of virtual vehicles (DSRC only)

This method is only useful for DSRC based systems, because it generates additional stress only for this technology.

Test vehicles are equipped with a large number of OBEs. Varying this number can determine the limits of concurrent transactions the system is able to handle.

Annex E
(informative)

Example Specific Examination Frameworks

E.1 Examination Framework for DSRC Discrete: EETS Suitability for Use

E.1.1 Introduction

The specific Examination Framework example defined in this Annex has been developed to demonstrate how this standard can be used to document an EETS Suitability for Use Assessment for EETS Toll Service Providers in a specific DSRC Discrete Tolling Scheme.

The focus of the specific Examination Framework is to evaluate performance of:

— the EETS Toll Service Provider to correctly Charge Service Users;

— the EETS Toll Service Provider to correctly personalise the OBUs used for the assessment;

— DSRC detection performance for EETS Toll Service Provider OBUs;

— Toll Charger ability to correctly generate Toll Declarations from the DSRC Event Data.

E.1.2 Brief Scheme Description

The example scheme for this specific Examination Framework is based on the Polish ViaToll System (www.viatoll.pl).

All vehicles with a maximum permissible weight of above 3.5t are charged a distance based charge based on the distance travelled on Toll Sections on the Road network. The length of Toll Sections is publically available and the distance based charge is dependent on the road type, maximum permissible weight and EURO Class giving a total of 24 different distance charge rates.

The network consists of both Open and Closed Toll Sections.

E.1.3 Metrics to be Evaluated

The following Charging metrics have been selected to be evaluated during the Suitability for Use Assessment

Table E.1 — DSRC Discrete - Metric Selection Table

		Evaluation		Monitoring	
Metric ID	**Examination Test**	**CI Method**	**Target Value**	**CI Method**	**Target Value**
CM-E2E-1 E2E Correct Charging Rate	cl. 6.1.2	Y	100%		
CM-UA-1 UA - Correct Charging Rate	cl. 6.1.6	Y	100%		
CM-UA-5 UA – Accurate Personalisation of OBUs	cl. 6.1.10	Y	100%		
CM-BD-9 BD – Inferred Billing Details Rate	cl. 6.1.25	y	Δ +5%		

Table E.2 — DSRC Discrete - Optional DSRC Toll Declaration Metric Selection Table

Metric ID	Examination Test	Evaluation		Monitoring	
		CI Method	Target Value	CI Method	Target Value
CM-TD-1 TD - Correct Toll Declaration Generation	cl. 6.2.2	y	99.0%		
CM-TD-4 TD - TSP Event Detection	cl. 6.2.5	Y	99.0%		

E.1.4 Documented Examination Tests

E.1.4.1 ET-CM-E2E-1 E2E Correct Charging Rate

<table>
<tr><td>Measured Metric:</td><td colspan="5">CM-E2E-1 E2E Correct Charging Rate</td></tr>
<tr><td colspan="6">Metric Definition</td></tr>
<tr><td colspan="6">The probability that for set of representative trips travelled by a set of Users during a time span Δt the Average Relative Charging Error is within the Accepted Charging Error Interval.</td></tr>
<tr><td colspan="6">Metric Measurement Data requirements</td></tr>
<tr><td>Reference Data</td><td>Charge Report</td><td>Toll Declaration</td><td>Billing Details</td><td>Payment Claim</td><td>User Account Charges</td></tr>
<tr><td>Y</td><td></td><td></td><td></td><td></td><td>Y</td></tr>
<tr><td>Environmental Conditions</td><td colspan="5">No special requirements – performance will be measured for the encountered traffic conditions.</td></tr>
<tr><td>Performance Requirement</td><td colspan="5">100%</td></tr>
<tr><td>Sample Size</td><td colspan="5">Total of 6,000 Toll Sections
100 Representative Trips on each of the 4 categories of Road Type.</td></tr>
<tr><td>Details of Method for Generating Charging Input</td><td colspan="5">PVP – Probe Vehicles on pre-defined route
Fleet of 10 vehicles each equipped with an OBU so that each vehicle category for charging is covered.
Fleet of vehicles drives 10 circuits of the Defined Test Route
PVP Vehicle 1 – Car +trailer MPW > 3.5t
PVP Vehicle 2 – 3.5t <MPW > 12t – Euro Class 2
PVP Vehicle 3 – 3.5t <MPW > 12t – Euro Class 4
PVP Vehicle 4 – 3.5t <MPW > 12t – Euro Class 5
PVP Vehicle 5 – MPW >12t – Euro Class 1 or 2
PVP Vehicle 6 – MPW > 12t – Euro Class 3
PVP Vehicle 7 – MPW > 12t – Euro Class 4
PVP Vehicle 8 – MPW > 12t – Euro Class 5
PVP Vehicle 9 – Bus - Euro Class 4
PVP Vehicle 10 – Bus - Euro Class 5</td></tr>
<tr><td>Method for Generating Reference Data</td><td colspan="5">For each vehicle the expected charges for each circuit of the defined test route is calculated based on the Toll Sections using the publically available Toll Calculator (www.viatoll.pl)</td></tr>
</table>

Test Route / Sub-set of charge Network		
From	**To**	**km**
A4,Granica państwa	A4,Bocheńskiego	335.30
A4,Bocheńskiego	DK81,Granica m. Mikołów	17.23
DK81,Granica m. Mikołów	DK81,Droga do Rudziczki	15.93
DK81,Droga do Rudziczki	DK81,Droga do Borek	2.40
DK81,Droga do Borek	DK81,Droga do Międzyświeca	25.88
DK81,Droga do Międzyświeca	S1,Krasna	9.78
S1,Krasna	S1,Cieszyn-Boguszewie	4.66

Metric Calculation Details

$$E2E\ Correct\ Charging\ Rate = \frac{A}{B}$$

Where

A = Number of representative trips where the Relative Charging Error (RCE) is within the Accepted Charging Error Interval

B = the total number of representative trips within the time span

And

RCE = (C/D) - 1

Where

C = Actual Charge for representative trip

D = Expected Charge for representative trip

And

Accepted Charging Error Interval Lower bound (CELB) = -1.0%

Accepted Charging Error Interval Upper Bound (CEUB) = + 0.0%

E.1.4.2 ET-CM-UA-1 UA - Correct Charging Rate

<table>
<tr><td>Measured Metric:</td><td colspan="5">CM-UA-1 UA – Correct Charging Rate</td></tr>
<tr><td colspan="6">Metric Definition</td></tr>
<tr><td colspan="6">The probability that for any set of representative trips travelled by a given User during the invoicing period the Average Relative Charging Error is within the Accepted Charging Error Interval.</td></tr>
<tr><td colspan="6">Metric Measurement Data requirements</td></tr>
<tr><td>Reference Data</td><td>Charge Report</td><td>Toll Declaration</td><td>Billing Details</td><td>Payment Claim</td><td>User Account Charges</td></tr>
<tr><td>Y</td><td></td><td></td><td></td><td></td><td>Y</td></tr>
<tr><td>Environmental Conditions</td><td colspan="5">No special requirements – performance will be measured for the encountered traffic conditions.</td></tr>
<tr><td>Performance Requirement</td><td colspan="5">100%</td></tr>
<tr><td>Sample Size</td><td colspan="5">10 Measurements UA Correct Charging rate to be calculated for each test vehicle based on the following use of the network
600 Toll Sections
10 Representative Trips on each of the 4 categories of Road Type.</td></tr>
<tr><td>Details of Method for Generating Charging Input</td><td colspan="5">PVP – Probe Vehicles on pre-defined route

See details in ET-CM-E2E-1 E2E Correct Charging Rate

Fleet of vehicles drives 10 circuits of the Defined Test Route</td></tr>
<tr><td>Method for Generating Reference Data</td><td colspan="5">For each vehicle the expected charges for each circuit of the defined test route is calculated based on the Toll Sections using the publically available Toll Calculator</td></tr>
<tr><td colspan="6">Test Route / Sub-set of charge Network</td></tr>
<tr><td colspan="6">See network defined in ET-CM-E2E-1 E2E Correct Charging Rate</td></tr>
<tr><td colspan="6">Metric Calculation Details</td></tr>
<tr><td colspan="6">$$UA\ Correct\ Charging\ Rate = \frac{A}{B}$$
Where
A = Number of Users where the Average Relative Charging Error (ARCE) is within the Accepted Charging Error Interval during the invoicing period
B = the total number of Users
And
ARCE = (C/D) - 1
Where
C = Sum of Actual Charges for representative trips for a User
D = Sum of Expected Charge for representative trips for a User
And
Accepted Charging Error Interval Lower bound (CELB) = -1.0%
Accepted Charging Error Interval Upper Bound (CEUB) = + 0.0%</td></tr>
</table>

E.1.4.3 ET-CM-UA-5 UA – Accurate Personalisation of OBUs

Measured Metric:	CM-UA-5 UA – Accurate Personalisation of OBUs				
Metric Definition					
The probability that the personalisation for any set of Users during a time span Δt is correct					
Metric Measurement Data requirements					
Reference Data	Charge Report	Toll Declaration	Billing Details	Payment Claim	User Account Charges
Y					
Environmental Conditions	N/A				
Performance Requirement	100%				
Sample Size	10 OBUs installed in the probe vehicles for the Suitability for Use Assessment See details in ET-CM-E2E-1 E2E Correct Charging Rate				
Details of Method for Generating Charging Input	N/A				
Method for Generating Reference Data	Handheld DSRC interrogator used to check that all vehicle parameters have been correctly programmed for each vehicle in accordance with the Test Specification				
Test Route / Sub-set of charge Network					
Not applicable					
Metric Calculation Details					

$$\textit{UA} - \textit{Accurate Personalisation of OBUs} = \frac{A}{B}$$

Where

A = Number of OBEs where the agreed sub-set of OBE Parameters have been verified as correct by the Toll Charger Compliance Equipment in the selected time period

B = Total number of OBEs checked by the Toll Charger Compliance Equipment in the selected time period

E.1.4.4 ET-CM-BD-9 BD – Inferred Billing Details Rate

Measured Metric:	CM-BD-9 BD – Inferred Billing Details Rate				
Metric Definition					
The ratio of inferred Billing Details in relation to the total number of Billing Details in the measurement period.					
Metric Measurement Data requirements					
Reference Data	Charge Report	Toll Declaration	Billing Details	Payment Claim	User Account Charges
			Y		
Environmental Conditions	No special requirements – performance will be measured for the encountered traffic conditions.				
Performance Requirement	Inferred Billing Details rate for the Probe Vehicle Fleet will be compared with the Inferred Billing Details Rate for ViaToll OBUs for the same test route and test period. Inferred Billing Details rate for VSU shall be less that 5% greater than ViaToll OBU Value				
Sample Size	Number of Billing Details generated from the Probe Vehicles on the defined Test Route				
Details of Method for Generating Charging Input	PVP – Probe Vehicles on pre-defined route See details in ET-CM-E2E-1 E2E Correct Charging Rate Fleet of vehicles drives 10 circuits of the Defined Test Route				
Method for Generating Reference Data	N/A				
Test Route / Sub-set of charge Network					
See network defined in ET-CM-E2E-1 E2E Correct Charging Rate					
Metric Calculation Details					

$$\textit{Inferred Billing Details Rate} = \frac{A}{B}$$

Where

A = Number of Billing Details Generated by the Toll Charger without an associated Toll Declaration in the measurement period

B = Total Number of Billing Details sent by the Toll Charger in the measurement period

E.1.4.5 ET-CM-TD-1 TD - Correct Toll Declaration Generation

Measured Metric:	CM-TD-1 TD - Correct Toll Declaration Generation
Metric Definition	
The probability that a DSRC Toll Declaration is correctly generated.	

Metric Measurement Data requirements					
Reference Data	Charge Report	Toll Declaration	Billing Details	Payment Claim	User Account Charges
Y		Y			

Environmental Conditions	No special requirements – performance will be measured for the encountered traffic conditions.
Performance Requirement	99.0%
Sample Size	Number of Toll Declarations generated by Test fleet on defined test route
Details of Method for Generating Charging Input	PVP – Probe Vehicles on pre-defined route See details in ET-CM-E2E-1 E2E Correct Charging Rate Fleet of vehicles drives 10 circuits of the Defined Test Route
Method for Generating Reference Data	The RSI Event Generator will be used to simulate the Vehicle Fleet driving the defined test routes to determine the number of Charge Relevant Events

Test Route / Sub-set of charge Network

See network defined in ET-CM-E2E-1 E2E Correct Charging Rate

Metric Calculation Details

$$\textit{TD Correct Toll Declaration Generation} = \frac{A}{B}$$

Where

A = Number of correctly generated Toll Declarations, i.e. number of Toll Declarations generated during the measurement period by the TC Front End which are consistent with the respective total number of Chargeable Events resulting from the Reference Data correctly assigned to Toll Declarations in the measurement period. Consistency requires correct representation of all Chargeable Events.

B = Total number of Toll Declarations, i.e. number of Toll Declarations generated by the TC Front End in the measurement period.

E.1.4.6 ET-CM-TD-4 TD - TSP Event Detection

Measured Metric:	CM-TD-4 TD - TSP Event Detection				
Metric Definition					
The probability that for any predefined Charge-Relevant Event that takes place the TC properly detects it.					
Metric Measurement Data requirements					
Reference Data	Charge Report	Toll Declaration	Billing Details	Payment Claim	User Account Charges
Y		Y			
Environmental Conditions	No special requirements – performance will be measured for the encountered traffic conditions.				
Performance Requirement	99.0%				
Sample Size	Number of Toll Declarations generated by Test fleet on defined test route				
Details of Method for Generating Charging Input	PVP – Probe Vehicles on pre-defined route See details in ET-CM-E2E-1 E2E Correct Charging Rate Fleet of vehicles drives 10 circuits of the Defined Test Route				
Method for Generating Reference Data	The RSI Event Generator will be used to simulate the Vehicle Fleet driving the defined test routes to determine the number of Charge Relevant Events				
Test Route / Sub-set of charge Network					
See network defined in ET-CM-E2E-1 E2E Correct Charging Rate					
Metric Calculation Details					

$$\textit{TD Event Detection} = \frac{A}{B}$$

Where

A = Number of correct Toll Declarations, i.e. the number of Toll Declarations containing the DSRC Charge-Relevant Events expected based on the Reference Data during the measurement period.

B = Total number of Toll Declarations generated by the TC in the measurement period

E.2 Examination Framework for Autonomous Discrete: Operational Performance

E.2.1 Introduction

The Section describes an example of an Examination Framework for a discrete system (discrete road links charging, see Table 1 of part 1 of this standard) focusing on:

— billing Details in the monitoring phase;

— an End-to-End view in the monitoring phase.

At the outset there is a brief description of the toll scheme and the road topology to which the proposed metrics are applied in order to facilitate the understanding of the following information.

The description of the Examination Framework will be according to the steps identified in Clause 5.2.

E.2.2 Brief System Description

The example scheme is described along some of the publically known lines of the German Heavy good vehicle charge, though it is not entirely identical.

Service users are to be charged for a defined road network with defined sections, mainly primary roads.

In this context the key functions that affect the charging performances are:

— Function for recognizing sections used by Service Users, based on GNSS (GPS) as well as tariff and map-data in the OBE.

As such errors in the charging computation (to which the Examination Framework could pay special attention) can be derived from:

— Errors in the chain positioning – charging-object detection – association with a tariff.

— Errors in the communication chain OBE – proxy – Toll Service Provider – Toll Charger.

E.2.3 Selection of Metrics to be Evaluated

The following Charging metrics have been selected to be evaluated during the Examination Framework:

Table E.3 — Autonomous Discrete - Metric Selection Table

		Evaluation		Monitoring	
Metric ID	**Examination Test**	**CI Method**	**Target Value**	**CI Method**	**Target Value**
CM-BD-1 Correct Charging Rate	cl. 6.1.17			Y	>99.0%
CM-E2E-2 Overcharging Rate	cl. 6.1.3			Y	$<10^{-5}$

E.2.4 Documented Examination Tests

E.2.4.1 ET-CM-BD-1 Correct Charging Rate

Measured Metric:	CM-BD-1 Correct Charging Rate				
Metric Definition					
The probability, that for any given Billing Detail, the Average Relative Charging Error is above the Accepted Charging Error Interval. The probability that for any predefined Chargeable Event that is recorded the corresponding Toll Declaration is correctly generated. "Predefined" may be defined by random measurements of determined Charge Events.					
Metric Measurement Data requirements					
Reference Data	Charge Report	Toll Declaration	Billing Details	Payment Claim	User Account Charges
Y			Y		
Environmental Conditions	Environment conditions are not defined explicitly, but varying conditions are included indirectly through the random influences during the predefined number of checks over one year.				
Performance Requirement	The correct charging rate shall be greater than 99%, where the *confidence interval* is the one determined by the sample size of 50.000 (i.e. < 0,2%-points).				
Sample Size	The sample size is predefined to be 50.000 (sections per year) for UVR. The sampling has to cover most of the service road network sections: at least 95% of the sections have to be sampled at least once per year by PVP, see below.				
Details of Method for Generating Charging Input	PVP is used for one part of CM-BD-1. Here, probe vehicles (enforcement vehicles equipped with OBE) with known and predefined trips are used. These enforcement vehicles are also equipped with a commercial GPS-reference system for documentation purposes. Routes are planned to cover all times of the year and the day, as well as most of the road network. The probe vehicles have to have a “truck-like driving behaviour” (e.g. no stops or road turns which are not possible or legal for a truck). Special circumstances are documented. The second part of CM-BD-1 is generated by spot checks (UVR) generated by those enforcement vehicles during the predefined trips described above. The spot checks are performed during the same trips as in PVP, and the same GPS-reference systems are used for documentation purposes. The numbers of licence plates of the checked toll liable vehicles and special circumstances are documented. Only vehicles are included for which the users are compliant (i.e. OBE status is “green”). A document that lists all the prerequisites and conditions as well as the documentation needs is used. Both inputs from PVP and UVR are used and calculated separately to give a value for CM-BD-1 (PVP) and CM-BD-1 (UVR). The weighted average (weighting factors 30% for PVP and 70% for UVR) of these two				

	values results in the total CM-BD-1 value, which is to be compared to the performance requirement. NOTE: here, PVP is intended to cover (mainly) charging errors resulting from (general) modelling errors, whereas UVR is intended to cover (mainly) charging errors resulting from technical errors from individual OBE as well as user data errors (mismatch of licence number plate, etc.). In both PVP and UVR all kinds of errors are counted, nonetheless.
Method for Generating Reference Data	For each vehicle the expected charges for each circuit of the defined test route is calculated based on the Toll Sections using the publically available Toll Calculator
Test Route / Sub-set of charge Network Not applicable	
Insert map and text description of route Not applicable	
Metric Calculation Details	

$$\boldsymbol{BD\ Correct\ Charging\ Rate} = a * \frac{\boldsymbol{A}1}{\boldsymbol{B}1} + b * \frac{\boldsymbol{A}2}{\boldsymbol{B}2} \qquad with\, a = 0.3\, and\, b = 0.7$$

Where

A1, A2 = Number of Chargeable Events associated to Billing Details from PVP and UVR, respectively, i.e. total number of Chargeable Events resulting from the Reference Data correctly assigned to Billing Details in the measurement period.

B1, B2 = Total number of Chargeable Events from PVP and UVR, respectively, i.e. total number of Chargeable Events resulting from the Reference Data in the measurement period.

NOTE 1: The “BD Correct Charging Rate” can here be seen as a “Overall BD Correct Charging Rate”, comprising the sum of two weighted “DB Correct Charging Rate”(s) measured by the two different methods PVP und UVR.

NOTE 2: Each missing charge event in the Billing Detail is seen as outside the accepted charging Error Interval.

E.2.4.2 ET-CM-E2E-2 Overcharging Rate

Measured Metric:	CM-E2E-2 Overcharging Rate				
Metric Definition					
The probability that for any set of *representative trips* travelled by a set of Users during a time span of one year the Average Relative Charging Error is above the Accepted Charging Error Interval.					
Metric Measurement Data requirements					
Reference Data	Charge Report	Toll Declaration	Billing Details	Payment Claim	User Account Charges
Y				Y	Y
Environmental Conditions	Environment conditions are not defined explicitly, but varying conditions are included indirectly through the random influences during the time interval considered (one year).				
Performance Requirement	For the vehicles not using the infrastructure, the probability that a charging event (false positive) is the basis for user account charges shall be smaller than 10^{-5}.				
Sample Size	Number of charging events which are charged to user accounts per year.				
Details of Method for Generating Charging Input	UVR: Charging input from customers who complain about false positives.				
Method for Generating Reference Data	“Independent reference system”: number of rightful user complaints owing to false positives. User complaints about false positives are checked independently. If a complaint is acknowledged as legitimate, the corresponding charging event is counted.				
Test Route / Sub-set of charge Network					
Not applicable					
Metric Calculation Details					
$E2E\ \textit{Overcharging rate} = \frac{A}{B}$ Where A = Number of Charge Events associated with User Account Charges which are identified as false positives via customer complaints per 12 months. B = Total number of Charge Events associated with all User Account Charges during the same 12 months as above. NOTE: “trips” are here defined as individual Charge Events. Each false positive is per definition outside the Accepted Charging Error Interval bound.					

E.3 Examination Framework for Autonomous Continuous: Front-end Evaluation

E.3.1 Introduction

This clause describes an example of Examination Framework for continuous systems focusing in the front-end related metrics (charge reports) and in the Evaluation phase. Some of the ideas presented are in any case also valid for the monitoring phase.

The description will start with a brief description of the toll scheme and the road topology to which the proposed metrics are applied in order to facilitate the understanding of the described information.

Description of the Examination Framework will be according to the different steps identified in Clause 5.2.

E.3.2 Brief System Description

The proposed scheme takes as reference the key charging principles outlined in the ABvM system that was planned to be implemented in the Netherlands although largely simplified for the sake of the clarity.

Vehicles are to be charged in all the road network of the country at a fixed standard tariff per km (tariff A)

A predefined highway will be charged at a different (higher) tariff per km (tariff B). This tariff being higher than the standard tariff is an arbitrary choice necessary for the detection of overcharging.

Distance driven within a city (defined by a certain contour) will be also charged at a different (higher) tariff per km (tariff B).

In this context the key functions that affect the charging performances are:

- function for counting distance driven;
- function to detect geo-objects including:
  - country borders;
  - highway;
  - city contour.

As such errors in the charging computation (to which the Examination Framework could pay special attention) can be derived from:

- errors in counting distance;
- errors in the geo-object detection including both:
  - wrong detection;
  - delays in the detection process that can imply that distance travelled inside/outside a geo-object can be charged at a wrong tariff.

E.3.3 Selection of Metrics to be Evaluated

The selected metrics to be evaluated are:

Table E.4 — Autonomous Continuous - Metric Selection Table

		Evaluation		Monitoring	
Metric ID	**Examination Test (cl.)**	**CI Method**	**Target Value**	**CI Method**	**Target Value**
CM-CR-5 CR – TSP Front End False Positive	cl.6.4.14	PVP	$< 10^{-5}$		
CM-CCR-1 CCR - Correct Charging Rate	cl.6.4.15	PVP	> 99%		
CM-CCR-2 CCR - Overcharging Rate	cl.6.4.16	PVP	< 0.1%		

E.3.4 Documented Examination Tests

E.3.4.1 ET-CM-CR-5 CR – TSP Front End False Positive

<table>
<tr><td colspan="2">Measured Metric:</td><td colspan="4">CM-CR-5 CR – TSP Front End False Positive</td></tr>
<tr><td colspan="6">Metric Definition</td></tr>
<tr><td colspan="6">For the vehicles not using the infrastructure, it is the probability that for any predefined Chargeable Event the front-end improperly detects it.</td></tr>
<tr><td colspan="6">Metric Measurement Data requirements</td></tr>
<tr><td>Reference Data</td><td>Charge Report</td><td>Toll Declaration</td><td>Billing Details</td><td>Payment Claim</td><td>User Account Charges</td></tr>
<tr><td>Y</td><td>Y</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Environmental Conditions</td><td colspan="4">Representative environment conditions will be defined to cover:
• Different times in a day to be representative of GNSS constellation geometry variations
• Different traffic conditions to consider different speeds and different neighbour vehicles/trucks
• Different route largely covering different parts of the country
Demanding environment conditions will be defined to cover:
• Foreseeable interferences
• Worst tropospheric/ionospheric conditions (as far as feasible during the planned testing period)
• Urban canyons/tunnels
• Dense foliage areas
• Routes that are in the surroundings of the city/highway subject to higher tariffs
Since the full combinations of cases will require a huge amount of testing time it is proposed to combine different conditions resulting in different “cases” covering for instance
• Simple/demanding routes
• Nominal environment / demanding environment / worst environment.</td></tr>
<tr><td colspan="2">Performance Requirement</td><td colspan="4">For the vehicles not using the infrastructure, the probability that for any predefined Chargeable Event the front-end improperly detects it (false positive) shall be smaller than 10⁻⁵.</td></tr>
<tr><td colspan="2">Sample Size</td><td colspan="4">A measurement campaign to demonstrate with a satisfactory level of confidence the false positive probability of 10-5 requires an amount of data (trips in the proximity of geo-objects of special tariff) that is</td></tr>
</table>

	economically not affordable and for which alternative methods are required. Generation of additional (not real) geo-objects can alleviate the total number of trips to be performed, Although the full demonstration can be complex an statistical rule can be established that, given the number of samples that are affordable, a number of allowed false positives (that can be even 1 or 0) are necessary to accept that the requirement can be potentially fulfilled. I.e. false positives above the allowed number would imply that requirement is not fulfilled.
Details of Method for Generating Charging Input	PVP – Probe Vehicles on pre-defined route equipped with Positioning Reference system. PVR can be also used but extra cost is not justified unless there are doubts related to the capability/commitment of the driver to follow those predefined routes. Predefined routes will be designed to be in the proximity (as close as feasible, but never inside) any area/segment subject to special tariffs In order to have significant results with a reasonably limited amount of predefined routes, artificial geo-objects can be defined as highlighted above.
Method for Generating Reference Data	Because predefined routes are always outside the areas/segments that can provoke a false positive, reference data is zero detections. I.e. every detection of any zone will be a false positive..
Test Route / Sub-set of charge Network	
Test routes have to be defined to cope with the selected environment conditions Routes have to consider: • Different duration/distance. • Different staring conditions (e.g. starting in a garage or an open environment) • Different routes in the proximity of the areas/segments subject to higher tariffs • Different areas (urban, road, highway) For metric CM-CR-5 routes should be principally outside of the charged network but place in close proximity to areas of the Charge Network.	
Metric Calculation Details	

$$\textit{CR Front End False Positive} = \frac{A}{B}$$

Where

A = Number of False Positives identified in all Charge Reports which are generated during the measurement period

B = Total Number of passes of vehicles in the proximity (but outside) the charging objects in the measurement period

E.3.4.2 ET-CM-CCR-1 CCR - Correct Charging Rate

<table>
<tr><td colspan="2">Measured Metric:</td><td colspan="4">CM-CCR-1 CCR - Correct Charging Rate</td></tr>
<tr><td colspan="6">Metric Definition</td></tr>
<tr><td colspan="6">The probability that for any set of representative trips travelled by a vehicle and during a certain period of time, the Average Relative Charging Error is within the Accepted Charging Error Interval</td></tr>
<tr><td colspan="6">Metric Measurement Data requirements</td></tr>
<tr><td>Reference Data</td><td>Charge Report</td><td>Toll Declaration</td><td>Billing Details</td><td>Payment Claim</td><td>User Account Charges</td></tr>
<tr><td>Y</td><td>Y</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Environmental Conditions</td><td colspan="4">See ET-CM-CR-5 CR – TSP Front End False Positive</td></tr>
<tr><td colspan="2">Performance Requirement</td><td colspan="4">Correct charging rate shall be greater than 99%, where the Accepted Charging Error Interval is between -1% and 0.3%.</td></tr>
<tr><td colspan="2">Sample Size</td><td colspan="4">A sample has to be defined as a set of representative trips travelled by a vehicle during a certain period of time.
Number of samples to produce statistically significant values has to be in the order of magnitude of 1.000.
Note 1: In order to have more observability of the process (i.e. the resulting metric to be closer to the reality) set of representative trips do not need to be fully independent. I.e. different sets can share the same trips. For instance if the considered period is one month, one can consider periods of 30 days starting each day instead of considering a set each month.
Note 2: These tests and the one associated to “E.3.4.3 ET-CM-CCR-2 CCR - Overcharging Rate” should be performed in parallel in such a way that same input data can be used to assess both performances.</td></tr>
<tr><td colspan="2">Details of Method for Generating Charging Input</td><td colspan="4">PVP – Probe Vehicles on pre-defined route equipped with Positioning Reference system</td></tr>
<tr><td colspan="2">Method for Generating Reference Data</td><td colspan="4">The data from the Positioning Reference System will be used in combination with the GNSS path post processing method to establish the reference data.</td></tr>
<tr><td colspan="6">Test Route / Sub-set of charge Network</td></tr>
<tr><td colspan="6">Test routes have to be defined to cope with the selected environment
Routes have to consider:
• Different duration/distance.
• Different staring conditions (e.g. starting in a garage or an open environment)
• Different routes in the proximity of the areas/segments subject to higher tariffs
• Different areas (urban, road, highway)
For metric CM-CCR-1, routes have to cover all types of foreseeable routes and should have routes which are in the proximity but outside the higher tariffs areas/segments.</td></tr>
<tr><td colspan="6">Metric Calculation Details</td></tr>
<tr><td colspan="6">$$\textit{CR}\ \ \textit{Correct Charge Report Generation Rate} = \frac{A}{B}$$</td></tr>
</table>

Where

A = Number of sets of representative trips travelled by a vehicle during a certain period of time whose Average Relative Charging Error is within the Accepted Charging Error Interval.

B = Overall number of sets of representative trips analysed

Note: In order to have more observability of the process (i.e. the resulting metric to be closer to the reality) set of representative trips do not need to be fully independent. I.e. different sets can share the same trips. For instance if the considered period is one month, one can consider periods of 30 days starting each day instead of considering a set each month.

E.3.4.3 ET-CM-CCR-2 CCR - Overcharging Rate

Measured Metric:	CM-CCR-2 CCR - Overcharging Rate

Metric Definition
The probability that for any single predefined *representative trip*, the Relative Charging Error is above the upper bound of the Accepted Charging Error Interval.

Metric Measurement Data requirements					
Reference Data	Charge Report	Toll Declaration	Billing Details	Payment Claim	User Account Charges
Y	Y				

Environmental Conditions	See ET-CM-CR-5 CR – TSP Front End False Positive
Performance Requirement	Overcharging rate shall be smaller than 0.1%, where the upper limit of the Accepted Charging Error Interval is 0.3%.
Sample Size	A sample is defined in this case as a single representative trip. Number of samples to produce statistically significant values has to be in the order of magnitude of 10.000. Because this number is possibly not affordable other types of tests as the use of worst cases need to be implemented for which some relaxed metric could be acceptable. Note 1: These tests and the one associated to "E.3.4.2 ET-CM-CCR-1 CCR - Correct Charging Rate" should be performed in parallel in such a way that same input data can be used to assess both performances.
Details of Method for Generating Charging Input	PVP – Probe Vehicles on pre-defined route equipped with Positioning Reference system
Method for Generating Reference Data	The data from the Positioning Reference System will be used in combination with the GNSS path post processing method to establish the reference data.

Test Route / Sub-set of charge Network
Test routes have to be defined to cope with the selected environment conditions. Routes have to consider: • Different duration/distance. • Different staring conditions (e.g. starting in a garage or an open environment) • Different routes in the proximity of the areas/segments subject to higher tariffs • Different areas (urban, road, highway) For metric CM-CCR-2, routes have to cover all types of foreseeable routes and should involve routes with frequent entry/exit to higher tariff areas / segments.

Metric Calculation Details

$$CR\ \ Overcharging\ Rate = \frac{A}{B}$$

Where

A = Number of representative trips travelled by a vehicle during a certain period of time whose Relative Charging Error is above the Accepted Charging Error Interval.

B = Overall number of representative trips analysed

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