PD CEN ISO/TS 17444-2:2017

BSI Standards Publication

Electronic fee collection - Charging performance

Part 2: Examination Framework

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National foreword

This Published Document is the UK implementation of CEN ISO/TS 17444-2:2017. It is identical to ISO/TS 17444-2:2017. It supersedes PD CEN ISO/TS 17444-2:2013, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/278, Intelligent transport systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Published by BSI Standards Limited 2018

ISBN 978 0 580 97816 6

ICS 35.240.60; 03.220.20

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This Published Document was published under the authority of the Standards Policy and Strategy Committee on 28 February 2018.

Amendments/corrigenda issued since publication

Date	Text affected

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TECHNICAL SPECIFICATION

SPÉCIFICATION TECHNIQUE

TECHNISCHE SPEZIFIKATION

CEN ISO/TS 17444-2

November 2017

ICS 03.220.20; 35.240.60

Supersedes CEN ISO/TS 17444-2:2013

English Version

Electronic fee collection - Charging performance - Part 2: Examination framework (ISO/TS 17444-2:2017)

Perception du télépéage - Performance d'imputation - Partie 2: Cadre d'examen (ISO/TS 17444-2:2017)

Elektronische Gebührenerhebung - Abbuchungsdurchführung - Teil 2: Rahmenbedingungen für Prüfungen (ISO/TS 17444-2:2017)

This Technical Specification (CEN/TS) was approved by CEN on 27 August 2017 for provisional application.

The period of validity of this CEN/TS is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the CEN/TS can be converted into a European Standard.

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European foreword

This document (CEN ISO/TS 17444-2:2017) has been prepared by Technical Committee ISO/TC 204 “Intelligent transport systems” in collaboration with Technical Committee CEN/TC 278 “Intelligent transport systems” the secretariat of which is held by NEN.

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The text of ISO/TS 17444-2:2017 has been approved by CEN as CEN ISO/TS 17444-2:2017 without any modification.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*.

This second edition cancels and replaces the first edition (ISO/TS 17444-2:2013), which has been revised with the following changes:

— editorial and formal corrections, as well as changes, to improve readability;

— updated terminology.

A list of all parts in the ISO/TS 17444 series can be found on the ISO website.

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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 document.

This document 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 document whenever the respective system aspects are subjected to performance measurements, rather than using other definitions and examination methods than the ones specified in this document.

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.

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Toll schemes take on various forms as identified in the ISO 17575 series 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);

— 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, for example, 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 document is designed for measuring the metrics defined in ISO/TS 17444-1. The general aim is to achieve a maximum comparability and reproducibility of the results without restricting the technological choices in system design. Specific Examination Frameworks may be 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, and

— 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 document, 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.

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

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

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

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

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

f) Annex E provides examples of Specific Examination Frameworks which have been developed in accordance with the methodology in 5.2.

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Electronic fee collection — Charging performance —

Part 2: Examination framework

1 Scope

This document 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 document whenever the respective system aspects are subjected to performance measurements, rather than using other definitions and examination methods than the ones specified in this document.

The following aspects are outside the scope of this document.

— This document 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 document does not consider the evaluation of the expected performance of a system based on modelling and measured data from trial at another place.

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

— This document defines measurements only on standardized interfaces. Proprietary interfaces are excluded, because it is not possible to define standardized 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

There are no normative references in this document.

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3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
absolute charging error
difference between the measured charge (toll) value and the actual value as measured by a reference system where a positive error means that the measurement exceeds the actual value

[SOURCE: ISO/TS 17444-1:2017, 3.1]

3.2
accepted charging error interval
interval of the relative charging error that the toll charger considers as acceptable, i.e. as correct charging

[SOURCE: ISO/TS 17444-1:2017, 3.2]

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

[SOURCE: ISO/TS 17444-1:2017, 3.3]

3.4
billing detail
information needed to determine or verify the amount due for the usage of a given service

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 should fulfil formal requirements, including security requirements, agreed between the Toll Service Provider and the Toll Charger.

[SOURCE: ISO 12855:2015, 3.1]

3.5
charge object detection
functionality of the system responsible for detecting chargeable events associated with a *charge object* (3.6)

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 17444-1:2017, 3.5]

3.6
charge object
geographic or road related object for the use of which a charge is applied

[SOURCE: ISO 17575-1:2016, 3.6]

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3.8
charge parameter change
event occurring within a tolling system, that is relevant for charge calculation, such as change of vehicle category, but not for the detection of a *charge object* (3.6) itself

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

[SOURCE: ISO/TS 17444-1:2017, 3.7]

3.9
charge report
information containing road usage and related information originated at the Front End

[SOURCE: ISO 17575-1:2016, 3.6]

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

3.10
discrete toll scheme
toll scheme where the charge is calculated based on distinct events associated with the identification of *charge objects* (3.6) 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 17444-1:2017, 3.11]

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 17444-1:2017, 3.10]

3.13
evaluation
systematic process of determining how individuals, procedures, systems or programs have met formally agreed objectives and requirements

[SOURCE: ISO 10795:2011, 1.90]

3.14
Front End
part of a tolling system consisting of an OBE and possibly a proxy where road tolling information and usage data are collected and processed for delivery to the Back End

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

[SOURCE: ISO/TS 19299:2015, 3.17]

3.15
false positive event
event that was erroneously detected but did not take place

[SOURCE: ISO/TS 17444-1:2017, 3.13]

3.16
missed recognition event
usage of a *charge object* (3.6) that is not recorded by the system

[SOURCE: ISO/TS 17444-1:2017, 3.16]

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3.17
monitoring
collection and assessment of status data for a process or a system

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

[SOURCE: ISO/TS 17444-1:2017, 3.16]

3.18
overcharging
situation when the calculated charge is above the *accepted charging error interval* (3.2)

[SOURCE: ISO/TS 17444-1:2017, 3.17]

3.19
payment claim
recurring statement referring to concluded *billing details* (3.4) made available to the payer by the payee indicating and justifying 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 refers to 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 should fulfil formal requirements, including security requirements, agreed between the Toll Service Provider and the Toll Charger.

[SOURCE: ISO 12855:2015, 3.10]

3.20
charging performance metrics
specific calculations used to describe the charging performance of a system

Note 1 to entry: These calculations are technology and schema-independent.

[SOURCE: ISO/TS 17444-1:2017, 3.8]

3.21
population
totality of items under consideration

[SOURCE: ISO 3534-1:2006]

3.22
relative charging error
ratio between the *absolute charging error* (3.1) and the reference value

[SOURCE: ISO/TS 17444-1:2017, 3.19]

3.23
representative trips
trips that are of a distance larger than a defined threshold and so should 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 should be considered.

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

[SOURCE: ISO/TS 17444-1:2017, 3.20]

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3.24
sample
subset of a population made up of one or more of its individual parts

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

3.25
toll service user
customer of a toll service provider, i.e. one liable for toll, owner of the vehicle, fleet operator or driver depending on the context

[SOURCE: ISO 17444:2017, 3.23]

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 charge object detections have been correctly identified and for continuous schemes that the Charge determined is within the Accepted Charging Error Interval.

[SOURCE: ISO/TS 17444-1:2017, 3.21]

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 17573:2015, 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, 3.23, modified]

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 should fulfil formal requirements, including security requirements, agreed between the Toll Service Provider and the Toll Charger.

[SOURCE: ISO/TS 19299:2015, 3.44]

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3.31
trip
part of space-time trajectory of a particular vehicle within a toll domain

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 17444-1:2017, 3.27]

3.32
undercharging
situation where the calculated charge is below the *accepted charging error interval* (3.2)

[SOURCE: ISO/TS 17444-1:2017, 3.28]

3.33
user account
centrally or on-board stored transport related service rights of the user in his relationship to a service provider

[SOURCE: ISO/TS 17444-1:2017, 3.291]

3.34
user complaint
complaints from users related to a specific service provision

[SOURCE: ISO/TS 17444-1:2017, 3.30]

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
DO	Dedicated OBE Testing
DSRC	Dedicated Short Range Communications (ISO 14906)
DTD	Discrete Toll Declaration
E2E	End to End (ISO/TS 17444-1)
EETS	European Electronic Toll Service (ISO 17573)

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EFC	Electronic Fee Collection (ISO 17573)
ESA	Enforcement System ANPR
ESD	Enforcement System DSRC
FE	Front End (ISO 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
TC	Toll Charger (ISO 17573)
TC-BO	Toll Charger back office
TD	Toll Declaration
TSP	Toll Service Provider (ISO 17573)
TSP-BO	Toll Service Provider back office
UA	User Account

5 Examination Framework

5.1 General

A toolbox of Examination Tests for the following scheme types are listed in 6.1 to 6.4:

a) DSRC Discrete (6.1 and optionally, 6.2);

b) Autonomous Discrete (6.3);

c) Autonomous Continuous (6.4).

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

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Each of these subclauses contains the specific examination tests for the applicable Charging Metrics identified in ISO/TS 17444-1:2017:

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

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

— 5.4 provides the definitions of the methods of generating Charging Input referenced in the Examination Tests defined in 5.5;

— 5.5 defines the applicability of the defined Charging Metrics for the Roles of Toll Charger and Toll Service Provider for the three identified scheme types;

— 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

5.2.1 General

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 5.2.2 to 5.2.7.

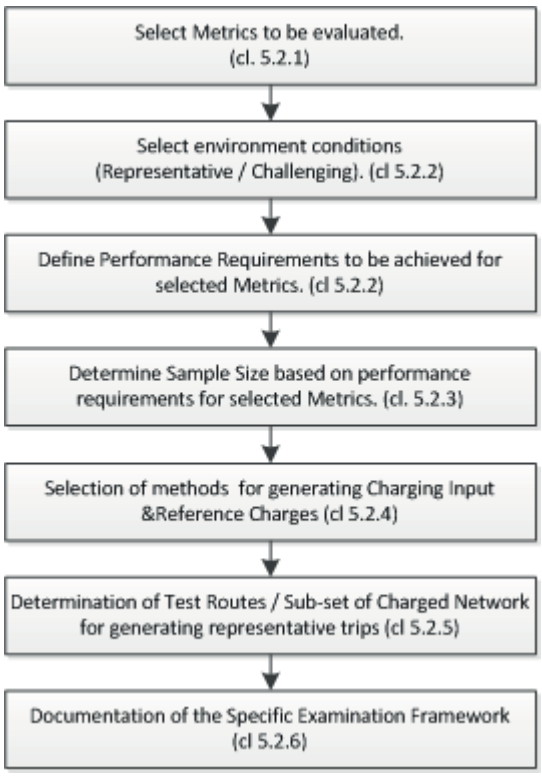

Figure 1 — Method for defining a Specific Examination Framework

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5.2.2 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 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

5.2.3 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 5.2.2.

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 nonlinear 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 is still necessary to perform the step described in 5.2.3. 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.

5.2.4 Determination of Required Sample Sizes

Based on the performance requirements set for each metric selected in 5.2.3, 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.

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5.2.5 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 (see 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 5.3.

5.2.6 Determination of Test Routes/Subset 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 5.2.3, particular care is 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 subset of the charged network. Additionally, it might be necessary to prepare the OBE for the test, e.g. generating geo-data defining the subset of the charged network and loading those data into the Front End.

5.2.7 Documentation of the Specific Examination Framework

By following the process defined in 5.2.2 to 5.2.6, 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).

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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 analysing 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 Table 1.

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 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?

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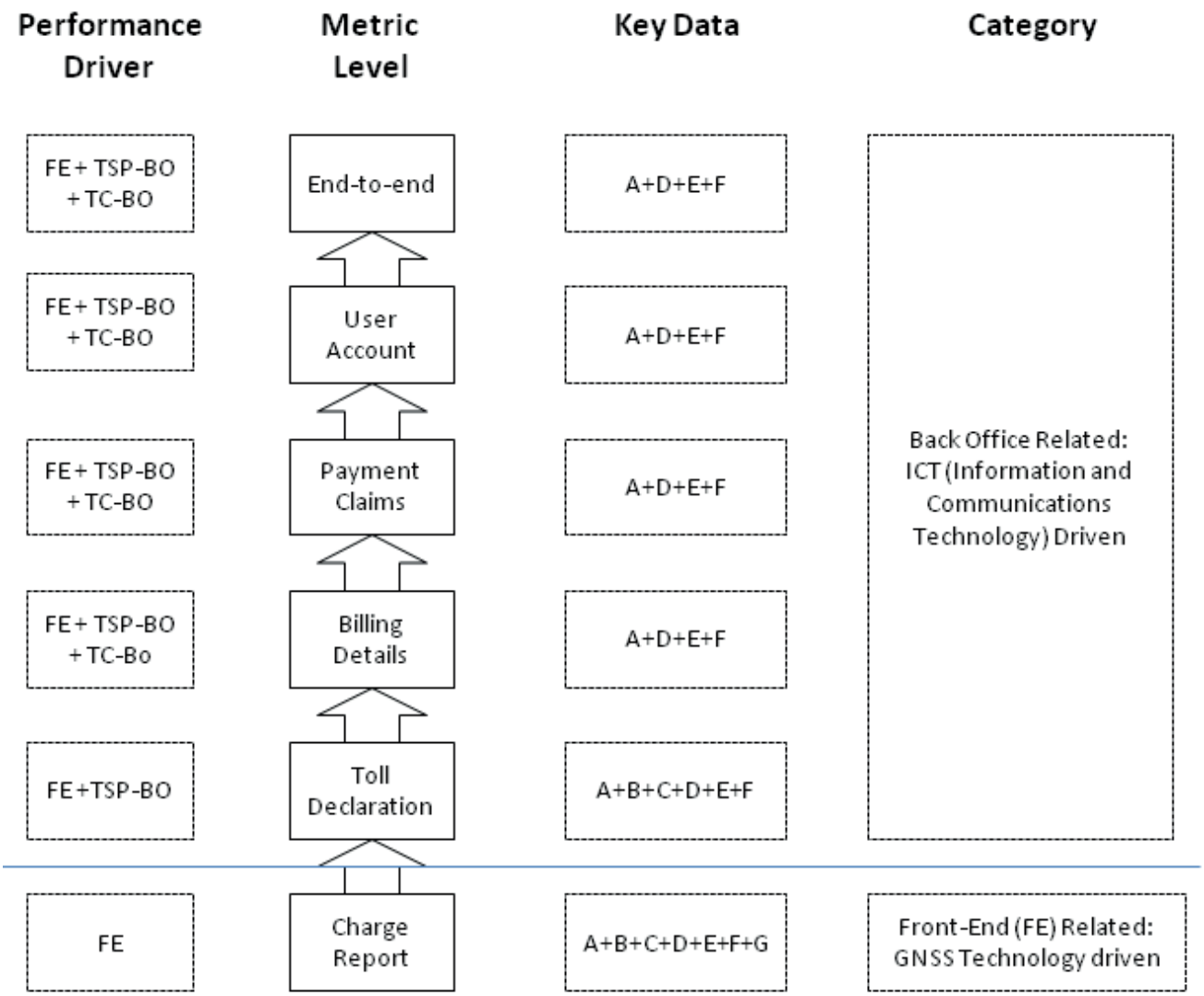

NOTE Key Data refers to an identifier from Table 1.

Figure 2 — Applicability of different sources of data to different charging metrics for autonomous systems, both discrete and continuous

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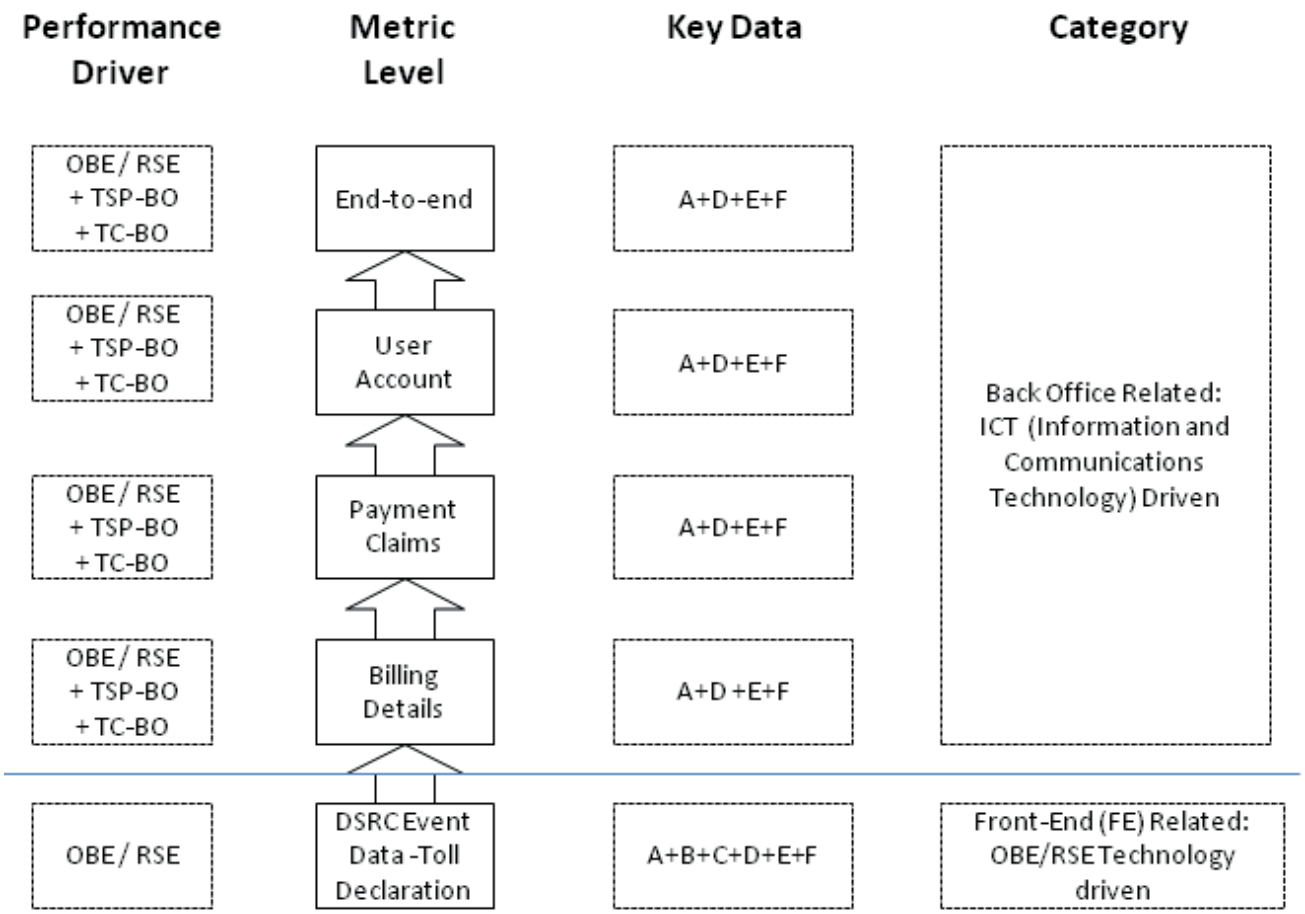

NOTE Key Data refers to an identifier from Table 1.

Figure 3 — Applicability of different sources of data to different charging metrics for DSRC-based systems

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

5.4.1 General

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 versus number of different toll objects examined;

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— cost vs. benefit;

— statistics.

Table 2 gives an overview of 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 for generating Charging Input

Name	Description	Source of data (5.3)	Identifier for later reference	Subclause
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)	5.4.2 and 5.4.3
Service User vehicles (UVR)	Service Users vehicles in relation to a reference system	A, B, C, E	UVR	5.4.3
Compliance 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)	5.4.3.2
Simulated OBE/FE	Simulators used to generate charge object detections	A, D	SO	5.4.3
Dedicated OBE Testing	White box OBE testing	G	DO	5.4.5

Table 3 — Overview of methods for 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 5.4.3	PVR	UVR

5.4.2 Predefined routes (identifier: "PVP")

Testing charging performance using 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 organization 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

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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.

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

5.4.3.1 General

A reference system is defined as a setup where a reliable reference is generated with regard to the toll due of vehicles in question. The vehicles can either be ones under the control of the organization 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 can 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 subclauses, methods for establishing a reliable reference are described.

5.4.3.2 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 subset 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.

5.4.3.3 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 either be a commercial positioning system or a high-accuracy positioning system. For

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UVR, Service User vehicles have to be acquired and consented, depending on data protection laws and special contracts 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 predefined routes or at random, in such a way that is typical for tolled vehicles. The data generated by these vehicles will be reported to a 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 (KPIs) for the system. The accuracy of continuous charging (time, distance) can be assessed between discrete charging events.

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

It is possible to compare events from an independent system against the 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.

A second toll charging system is especially relevant for tests of new (discrete) interoperable toll systems or the 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.

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

GNSS path post processing is defined as a setup where a reference is generated by route analysis of the vehicle in question. The vehicles can either be ones under the control of the organization 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 can be obtained from the EFC OBE itself.

5.4.4 Simulated OBE/FE (identifier: "SO")

Simulators/Emulators that can be used to generate simulated charge object detections from the Front-End of the Toll Service Provider (Charge Reports) or Toll Charger (DSRC Transaction Reports). This method can be used in 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.

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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.

5.4.5 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 hybridized 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 pieces of information are 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;

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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 (see 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 (see 5.4), entries of PVR and UVR imply the use of one or more of the Reference Identifiers: CCD, CCA, PR, IS, GPP.

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

	Metric ID	Metric name	Scheme type			Key data requirements	Evaluation	Monitoring
			DD	AD	AC		Charging Input Method Options	Charging Input Method Options
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 Rate	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

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Table 4 *(continued)*

	Metric ID	Metric name	Scheme type			Key data requirements	Evaluation	Monitoring
			DD	AD	AC		Charging Input Method Options	Charging Input Method Options
Toll Declaration	CM-TD-1	TD — Correct Toll Declaration Generation Rate	O	Y	Y	RD, TD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-TD-2	TD — Incorrect Toll Declaration Generation Rate	O	Y	Y	RD, TD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-TD-3	TD — Late Toll Declarations Rate	O	Y	Y	RD, TD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-TD-4	TD — TSP Charge Parameter Change Rate	O	Y	Y	RD, TD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-TD-5	TD — TSP False Positive Rate	O	Y	Y	RD, TD	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-DTD-1	DTD — Correct Charging Rate (charge object detections)		Y		RD, TD	PVP,PVR,UVR,IS,SO,-DO	PVP,PVR,U-VR,IS,SO,DO
	CM-DTD-2	DTD — Incorrect Charge Event recognition		Y		RD, TD	PVP,PVR,UVR,IS,SO,-DO	PVP,PVR,U-VR,IS,SO,DO
	CM-DTD-3	DTD — Missed Charge Object Detection Rate		Y		RD, TD	PVP,PVR,UVR,IS,SO,-DO	PVP,PVR,U-VR,IS,SO,DO
	CM-DTD-4	DTD Overcharging Rate		Y		RD, TD	PVP,PVR,UVR,IS,SO,-DO	PVP,PVR,U-VR,IS,SO,DO
	CM-CTD-1	CTD Correct Charging Rate			Y	RD, TD	PVP,PVR,UVR,IS,SO,-DO	PVP,PVR,U-VR,IS,SO,DO
	CM-CTD-2	CTD Overcharging Rate			Y	RD, TD	PVP,PVR,UVR,IS,SO,-DO	PVP,PVR,U-VR,IS,SO,DO
	CM-CTD-3	CTD Accuracy of Distance/Time Measurement			Y	RD, TD	PVP,PVR,UVR,IS,SO,-DO	PVP,PVR,U-VR,IS,SO,DO

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Table 4 *(continued)*

	Metric ID	Metric name	Scheme type			Key data requirements	Evaluation	Monitoring
			DD	AD	AC		Charging Input Method Options	Charging Input Method Options
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 Rate		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 Charge Parameter Change Rate		Y	Y	RD, CR	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-CR-5	CR — TSP Front End False Positive Rate		Y	Y	RD, CR	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-DCR-1	DCR — Correct Charging Rate (charge object detections)		Y		RD, CR	PVP,PVR,UVR,IS,SO,-DO	PVP,PVR,U-VR,IS,SO,DO
	CM-DCR-2	DCR — Incorrect Charge Event recognition		Y		RD, CR	PVP,PVR,UVR,IS,SO,-DO	PVP,PVR,U-VR,IS,SO,DO
	CM-DCR-3	DCR — Missed Charge Object Detection Rate		Y		RD, CR	PVP,PVR,UVR,IS,SO,-DO	PVP,PVR,U-VR,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,U-VR,IS,SO,DO
	CM-CCR-1	CCR — Correct Charging Rate			Y	RD, CR	PVP,PVR,UVR,IS,SO,-DO	PVP,PVR,U-VR,IS,SO,DO
	CM-CCR-2	CCR — Overcharging Rate			Y	RD, CR	PVP,PVR,UVR,IS,SO,-DO	PVP,PVR,U-VR,IS,SO,DO
	CM-CCR-3	CCR — Accuracy of Distance/Time Measurement			Y	RD, CR	PVP,PVR,UVR,IS,SO,-DO	PVP,PVR,U-VR,IS,SO,DO

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