PD CEN ISO/TS 37444:2023

BSI Standards Publication

Electronic fee collection — Charging performance framework

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National foreword

This Published Document is the UK implementation of CEN ISO/TS 37444:2023. It is identical to ISO/TS 37444:2023. It supersedes PD CEN/ISO TS 17444-2:2017, which is withdrawn.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 committee manager.

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European foreword

This document (CEN ISO/TS 37444:2023) 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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Full document details: PD CEN ISO/TS 37444:2023

Contents

Page

Foreword ... **v**
Introduction ... **vi**
1 Scope ... **1**
2 Normative references ... **2**
3 Terms and definitions ... **2**
4 Symbols and abbreviated terms ... **6**
5 Examination framework ... **7**
5.1 General ... 7
5.2 Method for defining a specific examination framework ... 7
5.2.1 General ... 7
5.2.2 Selection of metrics to be evaluated ... 8
5.2.3 Definition of environmental conditions and performance requirements ... 9
5.2.4 Determination of required sample sizes ... 9
5.2.5 Selection of methods for generating charging input and reference data ... 9
5.2.6 Determination of test routes and trips ... 9
5.2.7 Definition of measurement time period ... 10
5.2.8 Documentation of the specific examination framework ... 10
5.3 Sources of data ... 10
5.4 Methods of generating charging input ... 13
5.4.1 General ... 13
5.4.2 Predefined routes (identifier: “PVP”) ... 14
5.4.3 Reference system (used in combination with identifiers: “PVR” and “UVR”) ... 15
5.4.4 Simulated OBE/FE (identifier: “SO”) ... 16
5.4.5 Dedicated OBE testing (identifier: “DO”) ... 16
6 Charging performance metrics ... **17**
6.1 General ... 17
6.2 Metric identification ... 20
6.3 Charge report metrics ... 21
6.3.1 General ... 21
6.3.2 Metrics relevant for all schemes ... 21
6.3.3 Metrics only applicable to discrete schemes ... 22
6.3.4 Metrics applicable to continuous schemes ... 23
6.4 Toll declaration metrics ... 24
6.4.1 General ... 24
6.4.2 Metrics relevant for all schemes ... 24
6.4.3 Metrics only applicable to discrete schemes ... 25
6.4.4 Metrics applicable to continuous schemes ... 26
6.5 Billing details metrics ... 27
6.6 Payment claim metrics ... 29
6.7 Exception list metrics ... 30
6.8 User account metrics ... 31
6.9 End-to-end metrics ... 32
6.10 Applicability of metrics scheme types ... 32
6.11 Charging metric selection tables ... 37
6.11.1 General ... 37
6.11.2 Discrete ... 37
6.11.3 Autonomous discrete ... 39
6.11.4 Autonomous continuous ... 41
7 Examination tests ... **43**
7.1 General ... 43
7.2 Technology-independent tests ... 43
7.2.1 General ... 43

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AVA Documents
Document Sharing Hub
Full document details: PD CEN ISO/TS 37444:2023

7.2.2 ET-CM-E2E-1 E2E — Correct charging rate 43
7.2.3 ET-CM-E2E-2 E2E — Overcharging rate 44
7.2.4 ET-CM-E2E-3 E2E — Undercharging rate 45
7.2.5 ET-CM-E2E-4 E2E — Late charging rate 46
7.2.6 ET-CM-UA-1 UA — Correct charging rate 46
7.2.7 ET-CM-UA-2 UA — Overcharging rate 47
7.2.8 ET-CM-UA-3 UA — Undercharging rate 48
7.2.9 ET-CM-UA-4 UA — Accurate application of payments and refunds 49
7.2.10 ET-CM-UA-5 UA — Accurate personalization of OBEs 49
7.2.11 ET-CM-EL-1 EL — Correct exception list generation rate 50
7.2.12 ET-CM-EL-2 EL — Incorrect exception list generation rate 50
7.2.13 ET-CM-PC-1 PC — Correct charging rate 51
7.2.14 ET-CM-PC-2 PC — Overcharging Rate 52
7.2.15 ET-CM-PC-3 PC — Undercharging rate 53
7.2.16 ET-CM-PC-4 PC — Latency — TC 53
7.2.17 ET-CM-PC-5 PC — Late payment claims rate 54
7.2.18 ET-CM-PC-6 PC — Rejected payment claim rate 55
7.2.19 ET-CM-BD-1 BD — Correct charging rate 55
7.2.20 ET-CM-BD-2 BD — Overcharging rate 56
7.2.21 ET-CM-BD-3 BD — Undercharging rate 57
7.2.22 ET-CM-BD-4 BD — Incorrect charging rate 57
7.2.23 ET-CM-BD-5 BD — Latency — TC 58
7.2.24 ET-CM-BD-6 BD — Late billing details rate 59
7.2.25 ET-CM-BD-7 BD — Rejected billing details rate 59
7.2.26 ET-CM-BD-8 BD — Incorrectly rejected billing details rate 60
7.2.27 ET-CM-BD-9 BD — Inferred billing details rate 60
7.2.28 ET-CM-CR-1 CR— Usage evidence availability 61
7.2.29 ET-CM-CR-2 CR— Usage evidence integrity 61
7.2.30 ET-CM-CR-3 CR- Usage evidence time-to-first-fix 62
7.3 Technology-dependent tests 63
7.3.1 Autonomous discrete specific examination tests 63
7.3.2 Discrete — Optional toll declaration metrics 73
7.3.3 Autonomous continuous specific examination tests 76

Annex A (informative) **Examination test documentation template** **86**

Annex B (informative) **Examination framework considerations** **87**

Annex C (informative) **Statistical considerations** **90**

Annex D (informative) **Methods for reducing sample sizes during the evaluation phase** **95**

Annex E (informative) **Examples of specific examination frameworks** **99**

Annex F (informative) **Defining performance requirements** **110**

Bibliography **118**

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Documents
Document Sharing Hub
Full document details: PD CEN ISO/TS 37444:2023

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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This document was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems,* in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 278, *Intelligent transport systems,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition cancels and replaces the second editions ISO/TS 17444-1:2017 and ISO/TS 17444-2:2017, which have been technically revised.

The main changes are as follows:

— the resulting document has been renumbered as ISO/TS 37444;

— various editorial changes have been made to improve the readability of the text;

— a technology-neutral definition of metrics and examination tests has been applied, which also includes support for tolling systems based on automatic number plate recognition (ANPR) technology;

— terminology and references to other documents have been updated.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

0.1 General

Electronic tolling systems are complex distributed systems involving critical technology such as dedicated short-range communication (DSRC), camera-based technology (e.g. automatic number plate recognition, ANPR) and global navigation satellite systems (GNSS). These technologies are all subject to a certain behaviour that can affect the computation of the charges. Thus, to protect the interests of the different stakeholders involved, particularly toll service users (SUs) and toll chargers (TCs), it is essential to define metrics that measure the performance of the system in terms of computation of charges, and that ensure that the potential resulting errors are acceptable. These metrics will be a useful tool for establishing requirements for the systems and for examining the system capabilities during acceptance and throughout the operational life of the system.

In addition, to ensure the interoperability of different systems, it is necessary to agree on common metrics for use and on the actual values that define the required acceptable performances. However, these points are not covered in this document.

Instead, this document is defined as a toolbox standard of examination tests, with a method for defining and documenting a specific examination framework 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. Conformance to this document means 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.

0.2 Charging performance metrics

This document also defines a set of charging performance metrics with definitions, principles and formulae, which together make up a reference framework for the establishment of requirements for electronic fee collection (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 can differ between 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 (FE) interface and the interoperability interfaces between toll service providers (TSPs) and TCs, as well as information on the end-to-end level.

Metrics for the following information exchanges are defined:

— charge reports (including usage evidence);

— toll declarations;

— billing details and associated event data;

— payment claims on the level of user accounts;

— exception lists;

— 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 TSPs, TCs and SUs. They can be used to define requirements (e.g. for requests for proposals) and for performance assessments.

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Toll schemes take on various forms as identified in ISO 17573-1 and ISO 12855. 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);

— charging based on a continuous measurement (duration or distance).

The following are examples of discrete (event-based) toll schemes.

— Single object charging: a road section, bypass, bridge, tunnel, mountain pass or even a ferry, charged per passage.

EXAMPLE 1 Most tolled bridges belong to this category.

— Closed road charging: a fixed amount is charged for a certain combination of entry and exit on a motorway or other closed road network.

EXAMPLE 2 Many of the motorways in Southern Europe belong to this category.

— Discrete road links charging: determined by use of specified road links, whether or not they are used in their entirety.

EXAMPLE 3 Heavy goods vehicle (HGV) charge in Germany.

— Charging for cordon crossing: triggered by passing in or out through a cordon that encircles a city core, for example.

EXAMPLE 4 Congestion and infrastructure charging schemes in Stockholm and Gothenburg (Sweden).

The following are examples of continuous toll schemes.

— Charging based on direct distance measurement: defined as an amount per km driven.

EXAMPLE 5 HGV charge in Switzerland and US basic vehicle miles-travelled toll systems concepts.

— Charging based on direct distance measurement in different tariff zones or road types: defined as an amount per km driven, with different tariffs applying in different zones or on different road types. This is a widely discussed approach, also known as time-distance-place charging, and is under consideration in European countries.

EXAMPLE 6 OReGO, the pilot programme in Oregon, North America.

— Time in use charge: determined by the accumulated time a vehicle has been in operation, or alternatively, by the time the vehicle has been present inside a predefined zone.

In all of these toll schemes, tolls can additionally vary as a function of vehicle class characteristics (such as trailer presence, number of axles, taxation class and 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 weekends.

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

The identification of different types of schemes as proposed in the ISO 17575 series and their grouping in the mentioned two classes is described in Table 1. Table 1 also identifies the examples mentioned above.

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Table 1 — Toll scheme designs grouped according to scheme categories

Examples	Scheme type	ISO 17575 series category
Single object charging	Discrete	Sectioned roads pricing
Closed road charging	Discrete	Sectioned roads pricing
Discrete road links charging	Discrete	Sectioned roads pricing
Charging for cordon crossing	Discrete	Cordon pricing
Time in use charge	Continuous	Area pricing — time
Cumulative distance charge	Continuous	Area pricing — distance
Charging for cumulative distance in different zones (or by road type)	Continuous	Area pricing — distance

0.3 Examination framework

The examination framework that is defined in this document is designed for measuring the metrics defined in Clause 6. 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 can be defined for the evaluation and monitoring phases of a project due to the differences in the availability of equipped vehicles.

a) **Evaluation phase**

The evaluation 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.

b) **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 service level agreements (SLAs) between contractual partners (supplier, TC, TSP, 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.

0.4 Reader's guide

To understand the content of this document, the reader should be aware of the methodology and assumptions used to develop the examination framework; 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 provides definitions of charging metrics and their applicability to the scheme types described above.

e) Clause 7 contains the toolbox of examination tests for the evaluation of charging performance for the identified scheme types.

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f) Annex A contains an example template for the documentation of examination tests and their results.

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

h) 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 framework

1 Scope

This document defines the charging performance metrics to be used during the evaluation or on-going monitoring of an electronic fee collection (EFC) system and the examination framework for the measurement of these metrics.

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.

The following scheme types are within the scope of this document:

a) discrete schemes;

b) continuous schemes (autonomous type of systems).

This document defines measurements only on standardized interfaces.

This document defines metrics for the charging performance of EFC systems in terms of the level of errors associated with charging computation.

This document describes a set of metrics with definitions, principles and formulations, which together make up a reference framework for the establishment of requirements for EFC systems and the subsequent examination of charging performance.

This document defines metrics for the following information exchanges:

— charge reports (including usage evidence);

— toll declarations;

— exception lists;

— billing details and associated event data;

— payment claims on the level of service user accounts;

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

These metrics 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 following aspects are outside the scope of this document.

— Definition of specific numeric performance bounds, or average or worst-case error bounds in percentage or monetary units.

— Specification of a common reference system which would be required for comparison of performance between systems.

— Measurements on proprietary interfaces.

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NOTE It is not possible to define standardized metrics on such system properties. Neither is it possible to define metrics for parts of the charging processing chain which are considered to be the internal matter of an interoperability partner, such as:

— equipment performance, e.g. for on-board equipment (OBE), roadside equipment (RSE) or data centres such as signal range, optical resolution or computing system availability;

— position performance metrics: the quality of data generated by position sensors is considered as an internal aspect of the GNSS front end. It is masked by correction algorithms, filtering, inferring of data and the robustness of the charge object recognition algorithms.

— The evaluation of the expected performance of a system based on modelling and measured data from a trial at another place.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12855:2022, *Electronic fee collection — Information exchange between service provision and toll charging*

3 Terms and definitions

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

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

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

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

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 17573-2:2020, 3.1]

3.2
accepted charging error interval
interval of the *relative charging error* (3.22) that the *toll charger* (3.27) considers as acceptable, i.e. as correct charging

[SOURCE: ISO/TS 17573-2:2020, 3.3]

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 17573-2:2020, 3.21]

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

[SOURCE: ISO/TS 17573-2:2020, 3.25]

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3.5
charge object
geographic or road-related object for the use of which a charge is applied

[SOURCE: ISO/TS 17573-2:2020, 3.31]

3.6
charge object detection
event marking the usage of a *charge object* (3.5)

[SOURCE: ISO/TS 17573-2:2020, 3.32]

3.7
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* (3.5) itself

[SOURCE: ISO/TS 17573-2:2020, 3.34]

3.8
charge report
information containing road usage and related information originated at the *front end* (3.15)

[SOURCE: ISO/TS 17573-2:2020, 3.35]

3.9
charging performance metrics
specific calculations used to describe the charging performance of a system

[SOURCE: ISO/TS 17573-2:2020, 3.37]

3.10
continuous toll scheme
toll scheme where the charge is calculated based on the accumulation of continuously measured parameter(s)

[SOURCE: ISO/TS 17573-2:2020, 3.50, modified — EXAMPLE removed.]

3.11
data analysis
parameter estimation and inference based on *samples* (3.24)

3.12
discrete toll scheme
toll scheme where the charge is calculated based on distinct events associated with the identification of *charge objects* (3.5) such as crossing a cordon, passing a bridge and being present in an area

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

[SOURCE: ISO/TS 17573-2:2020, 3.62, modified — Note 1 to entry added.]

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

[SOURCE: ISO/TS 17573-2:2020, 3.75]

3.14
false positive
event that was erroneously detected, but did not take place

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3.15
front end
part of an EFC system which consists of on-board equipment (OBE) and possibly of a proxy where road tolling information and usage data are collected and processed for delivery to the back end

[SOURCE: ISO/TS 17573-2:2020, 3.85]

3.16
interval estimation
calculation of lower and upper bounds for unknown parameters, assuring a predefined coverage probability of the true value

3.17
missed recognition
usage of a *charge object* (3.5) that is not recorded by the system

3.18
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 17573-2:2020, 3.120, modified — Note 1 to entry added.]

3.19
overcharging
situation where the calculated charge is above the *accepted charging error interval* (3.2)

[SOURCE: ISO/TS 17573-2:2020, 3.130]

3.20
payment claim
statement made available to the payer by the payee to justify the amount due

Note 1 to entry: The statement can include the concluded *billing detail* (3.4).

[SOURCE: ISO/TS 17573-2:2020, 3.133]

3.21
population
totality of items under consideration

[SOURCE: ISO/TS 17573-2:2020, 3.142]

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

[SOURCE: ISO/TS 17573-2:2020, 3.154]

3.23
representative trip
trip (3.31) that is of a distance larger than a defined threshold and so is to be considered by the related metrics

3.24
sample
subset of a *population* (3.21) made up of one or more of its individual parts

[SOURCE: ISO/TS 17573-2:2020, 3.164]

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3.25
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* (3.13) and/or *monitoring* (3.18)

3.26
successful charging
situation where the user has been correctly charged according to the rules of the system

[SOURCE: ISO/TS 17573-2:2020, 3.177]

3.27
toll charger
entity which levies toll for the use of vehicles in a toll domain

[SOURCE: ISO/TS 17573-2:2020, 3.194]

3.28
toll declaration
statement to declare the usage of a given toll service to a *toll charger* (3.27)

[SOURCE: ISO/TS 17573-2:2020, 1.199]

3.29
toll service provider
entity providing toll services in one or more toll domains

[SOURCE: ISO/TS 17573-2:2020, 3.206]

3.30
toll service user
customer of a *toll service provider* (3.29), i.e. one liable for toll, owner of the vehicle, fleet operator or driver depending on the context

[SOURCE: ISO/TS 17573-2:2020, 3.207]

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

[SOURCE: ISO/TS 17573-2:2020, 3.220]

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

[SOURCE: ISO/TS 17573-2:2020, 3.225]

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

[SOURCE: ISO/TS 17573-2:2020, 3.228]

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

[SOURCE: ISO/TS 17573-2:2020, 3.229]

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4 Symbols and abbreviated terms

ANPR	automatic number plate recognition
ARCE	average relative charging error
BD	billing details
CCA	compliance checking detections using ANPR systems
CCD	compliance checking detections using DSRC systems
CCR	continuous charge report
CCTV	closed-circuit television
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
DTD	discrete toll declaration
E2E	end-to-end
EETS	European electronic toll service
EFC	electronic fee collection
FE	front end
GBPT	GNSS-based positioning terminals
GNSS	global navigation satellite system
GPP	GNSS path post processing
IS	independent reference system
ITS	intelligent transport systems
KPI	key performance indicator
LPN	licence plate number
MBDD	maximum billing details delay
MPCD	maximum payment claim delay

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MTDD	maximum toll declaration delay
MUSD	maximum user statement delay
OBE	on-board equipment
PC	payment claim
PV	probe vehicle
RCE	relative charging error
REE	relative evidence error
RSE	roadside equipment
SLA	service level agreement
SO	simulated OBE/FE
SU	service user
TC	toll charger
TC-BE	toll charger back end
TD	toll declaration
TSP	toll service provider
TSP-BE	toll service provider back end
TSP-FE	toll service provider front end
UA	user account
UVR	service user vehicle

5 Examination framework

5.1 General

This clause:

— defines the process that should be followed to define a specific examination framework for a particular purpose (5.2);

— provides a definition of the sources of data that can be used by the examination tests to calculate the charging metrics (5.3);

— provides the definitions of the methods of generating charging input referenced in the examination tests defined in Clause 7 (5.4).

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 TSP and/or TC in a particular toll scheme. Further details are provided in 5.2.2 to 5.2.8.

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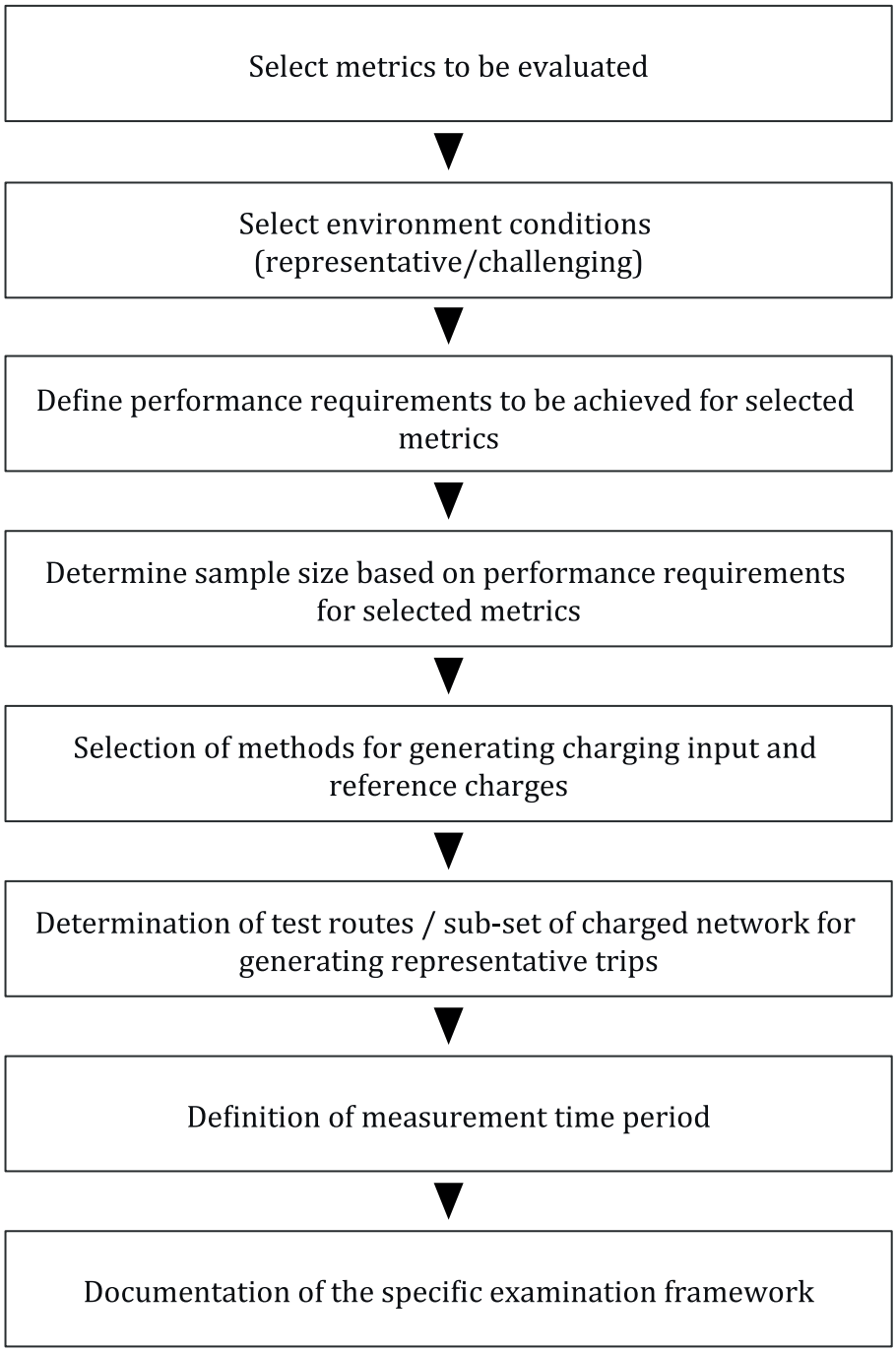

Figure 1 — Method for defining a specific examination framework

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 TSP and/or TC using the applicable tables in 6.11.

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5.2.3 Definition of environmental conditions and performance requirements

The entity responsible for the definition of the specific examination framework shall determine the environmental conditions (representative or 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 fully 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.

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.

NOTE 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 on 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.

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 and trips

For each selected examination test in the specific examination framework that requires the generation of specific charging input, 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 the charged network are chosen to meet the required test environment conditions.

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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 are expected to drive as much as possible on the subset of the charged network. Additionally, it can 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 (FE).

NOTE 3 Such an approach can be mainly suitable for the evaluation phase due to the use of the dedicated probe vehicles following the predefined path.

5.2.7 Definition of measurement time period

For each selected examination test, or a set of tests in the specific examination framework, a relevant measurement time period shall be determined by the responsible entity. The extent of this period shall reflect all the relevant aspects of the tests for which the periods are to be defined, i.e.:

— different phases (evaluation/monitoring);

— environments;

— required measurement data size.

5.2.8 Documentation of the specific examination framework

By following the process defined in 5.2.2 to 5.2.7, 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 natures, depending on:

— the different phases (evaluation/monitoring);

— the type of system (discrete/continuous);

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

The definition of metrics generally involves the comparison of measured system values to expected values. Therefore, 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 the most complex task as it requires either an independent system that has to provide expected values, or a concise statistical analysis applied to a sufficiently large data set, or in most cases both (see Annex C).

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

— outputs from FE (charge reports);

— outputs from TSP back end (TSP-BE) (toll declarations and user account);

— outputs from TC back end (TC-BE) (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 being compared to the reference system. These references can be obtained by any of the means described in the following items.

b) The operational enforcement system.

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c) Independent detection systems (e.g. roadside 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 FEs (to feed the BE) that allow the analysis of the capabilities of the back-office system, using the known (simulated) data generated by those OBEs as a reference.

e) Reference systems installed in vehicles (e.g. highly accurate positioning system based on GNSS + 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 approach can be used to find the detailed trajectory (and hence the charge due) of these probe vehicles:

   1) known routes: the reference data is known through the specification of these routes. This is only applicable to discrete systems since continuous systems require a detailed knowledge of the actual trajectory followed;

   2) use of reference systems as described in item e).

g) Data from OBE testing based on the use of GNSS signal simulators or DSRC simulators, for example.

NOTE Data inputs directly linked to the use of OBE are applicable to the toll schemes based on technologies requiring the use of OBE.

The potential use of these data for the different cases considered is summarized in Table 2 (valid for both discrete and continuous systems).

Table 2 — Identification of where different sources of data can be used

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 OBE 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 the metrics defined in each level, taking into consideration the following points:

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

— what key data (identifier from Table 2) are required for the metrics' computation?

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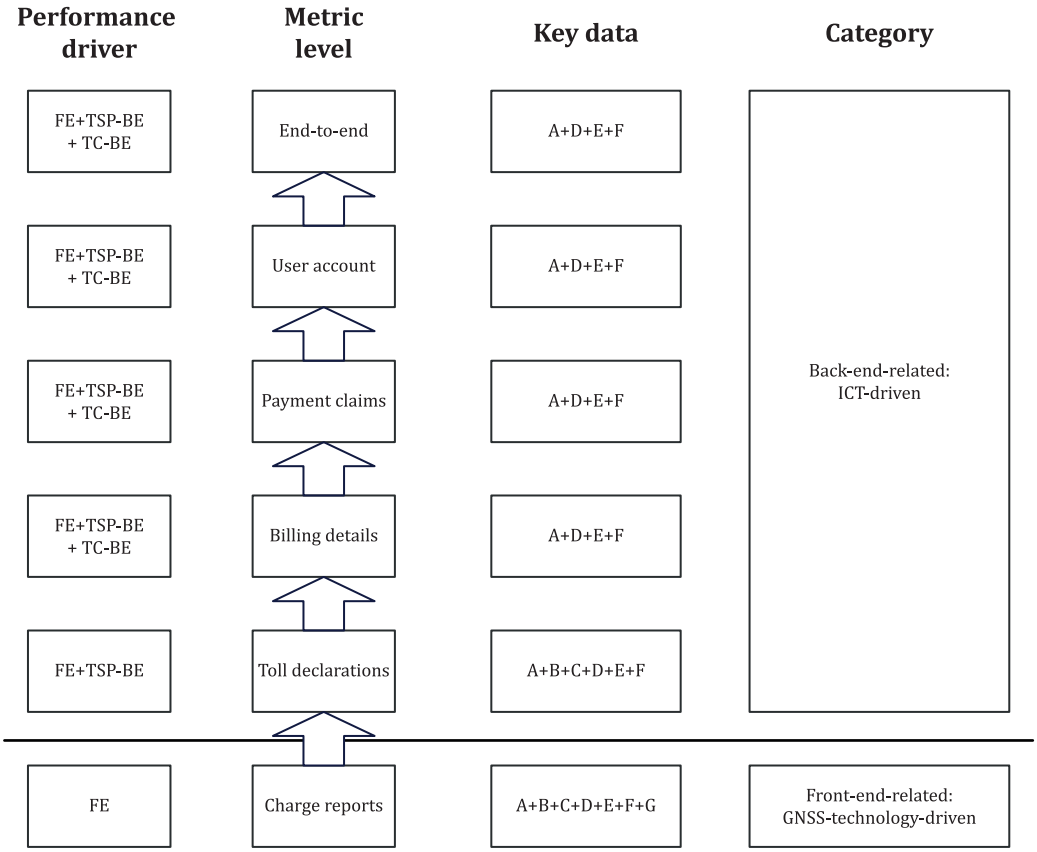

NOTE Key data refers to an identifier from Table 2.

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

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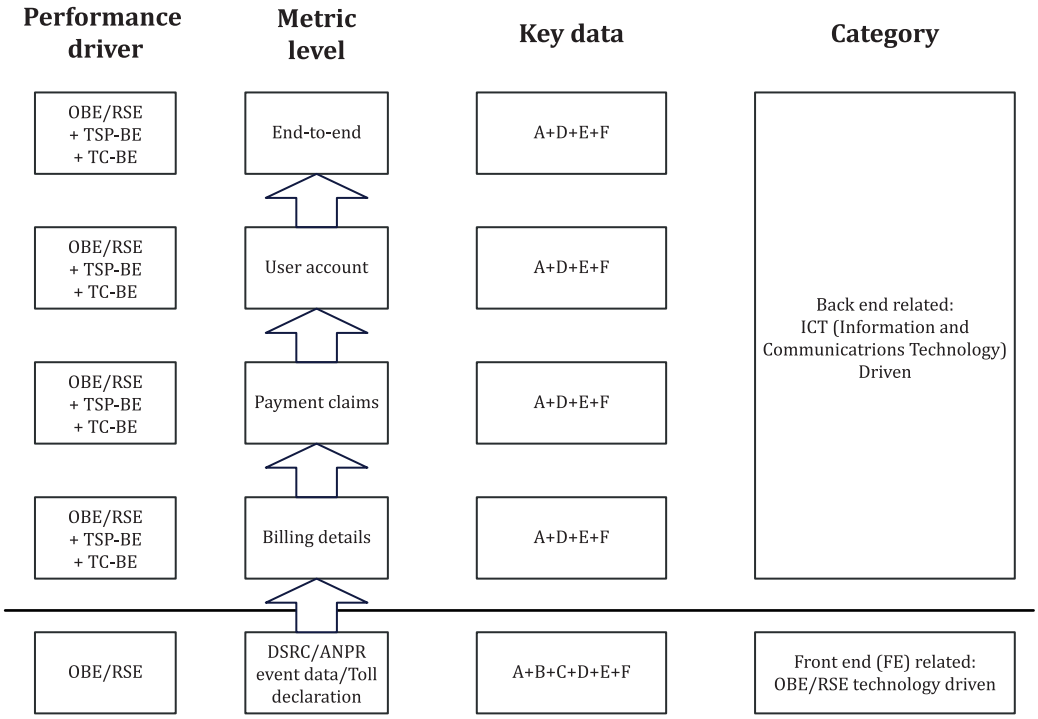

NOTE Key data refers to an identifier from Table 2.

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 derived that the two groups of metrics require very different data and methodologies.

— 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 can include 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 either one method or a combination of methods for generating charging input shall take into account the advantages and disadvantages of the respective examination methods. Particular attention shall be paid to:

— the number of OBE under test (and what kind of variation of OBE is necessary);

— the number of toll objects versus the number of different toll objects examined;

— cost vs. benefit;

— statistical significance.

Table 3 gives an overview of the methods of generating charging input within the toll scheme. In Table 4, a subset of those methods are ordered according to whether the vehicle generating the input is an SU vehicle (UVR), the driver of which is not even necessarily aware that they are participating

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in performance measurements, or a rather perhaps a dedicated probe vehicle (PV). The meaning of "predefined routes" and "reference system" are described in the following clauses.

Table 3 — 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
SU vehicles (UVR)	SUs vehicles in relation to a reference system	A, B, C, E	UVR	5.4.3
Compliance checking (CC)	Controlled/dedicated vehicles or SU 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 4 — Overview of methods for generating charging input by vehicles using the toll scheme

	Type of vehicle used to generate data	
	Probe vehicle	SU 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 OBE (if applicable), RSE, 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. They 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 of sufficient length and the vehicle may drive repeatedly a number of times to ensure that the test results are statistically significant. This can potentially require statistically significant time (e.g. a period of weeks or months).

NOTE If performances of the OBE of autonomous systems are to be compared (the proposed method is not valid for continuous measurements), all of the OBE can be installed in one single test vehicle. Variations caused by external conditions and driving patterns are thereby reduced (the OBE could also be fitted in several different vehicles for testing). However, when comparing the performance of DSRC OBE in a "real" environment, ideally only one OBE will be installed per test vehicle.

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

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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 under the control of the organization responsible for the performance measurements (PVR) or vehicles of SUs (UVR).

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

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 is generated.

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. This 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 SU vehicle.

CCD and CCA will not have a detection accuracy of 100 %, so the reference of passing SUs 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 abovementioned way makes it possible to continuously monitor the toll scheme performance in real-time. It also provides a low-cost option in terms of personnel required.

5.4.3.3 Reference system: Positioning reference system (identifier: “PR”)

Vehicles (either probe vehicles or SU vehicles) shall be equipped with a positioning reference system. This can either be a commercially-available positioning system or a high-accuracy positioning system. For UVR, SU vehicles shall be acquired and consent provided, taking into consideration data protection laws and special contracts signed. An incentive scheme can be necessary.

EXAMPLE The vehicles could be equipped with high-performance GNSS receiver terminals, such as differential or kinematic GNSS for positioning, supplemented by an inertial measurement unit (IMU). This would achieve high accurate measurement of distance. FEs under evaluation will be installed by a TSP (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 all of the computations and interfaces to the billing information, in order 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.

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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 the manual analysis of passing traffic, use of a second toll charging system (which can 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 passing traffic or the recording of charges liable with a second system. The reliability of the independent reference system has to be established, along with 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 it can potentially 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 from route analysis of the vehicle in question. The vehicles can either be under the control of the organization responsible for the performance measurements (PVR) or vehicles of SUs (UVR).

The method is based on the analysis of GNSS-based vehicle tracks, which allow positioning and tracking of a single or multiple vehicles, mapping their location onto charging objects along with the routes travelled and their detailed historical analysis. The mapping of GNSS tracks onto charge objects is 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 can be used to generate simulated charge object detections from the FE of the TSP (charge reports) or TC (ANPR / DSRC transaction reports). This method can be used in one of two ways:

a) evaluation of charge report generation for a given GNSS path;

b) generation of reference charging input for the evaluation of metrics for toll declaration, payment claims, user account and end-to-end.

NOTE 1 In order to also cover toll schemes using an ANPR technology, for the purpose of vehicle identification, the licence plate number (LPN) serves as an identification element similar to an OBE.

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

NOTE 2 An example of the possible application of such a method could be the suitability for use tests in European electronic toll service (EETS).

5.4.5 Dedicated OBE testing (identifier: “DO”)

While “black box testing” (i.e. testing based only on the information available in the “public” interfaces) is intended as the main mechanism for the definition of the examination tests described in Clause 7, 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 are analysed. This sort of analysis is potentially technology-dependent and, therefore,

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can require knowledge of the OBE design. As such, they cannot be defined *a priori* and therefore, they require a special procedure to be agreed between the TSP and the OBE supplier.

Dedicated OBE testing can involve the use of GNSS signal simulators (if no other position technology is integrated within the OBE) to simulate demanding environment conditions, as well as to provide positional data input for the OBE under test.

A more detailed description of alternative methods to the one described in Clause 7, including dedicated OBE testing, is 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 this are widely used and expected to gain even more importance in the future. If used with care, dedicated OBE testing could provide valuable insight which would be hard to obtain otherwise. In evaluating the results, the nonlinear system behaviour shall be taken into account (e.g. barely or not quite receiving the signal of the fourth GNSS satellite, resulting in good or no position data).

6 Charging performance metrics

6.1 General

Charging performance metrics can be applied at different levels of the processing chain, from the lowest level where the basic charging information is measured, to the final computation of charging information to be provided to TCs and SUs.

Metrics are also defined for information transmitted through standardized interfaces, including those defined at an overall toll scheme level. Such metrics are called end-to-end metrics.

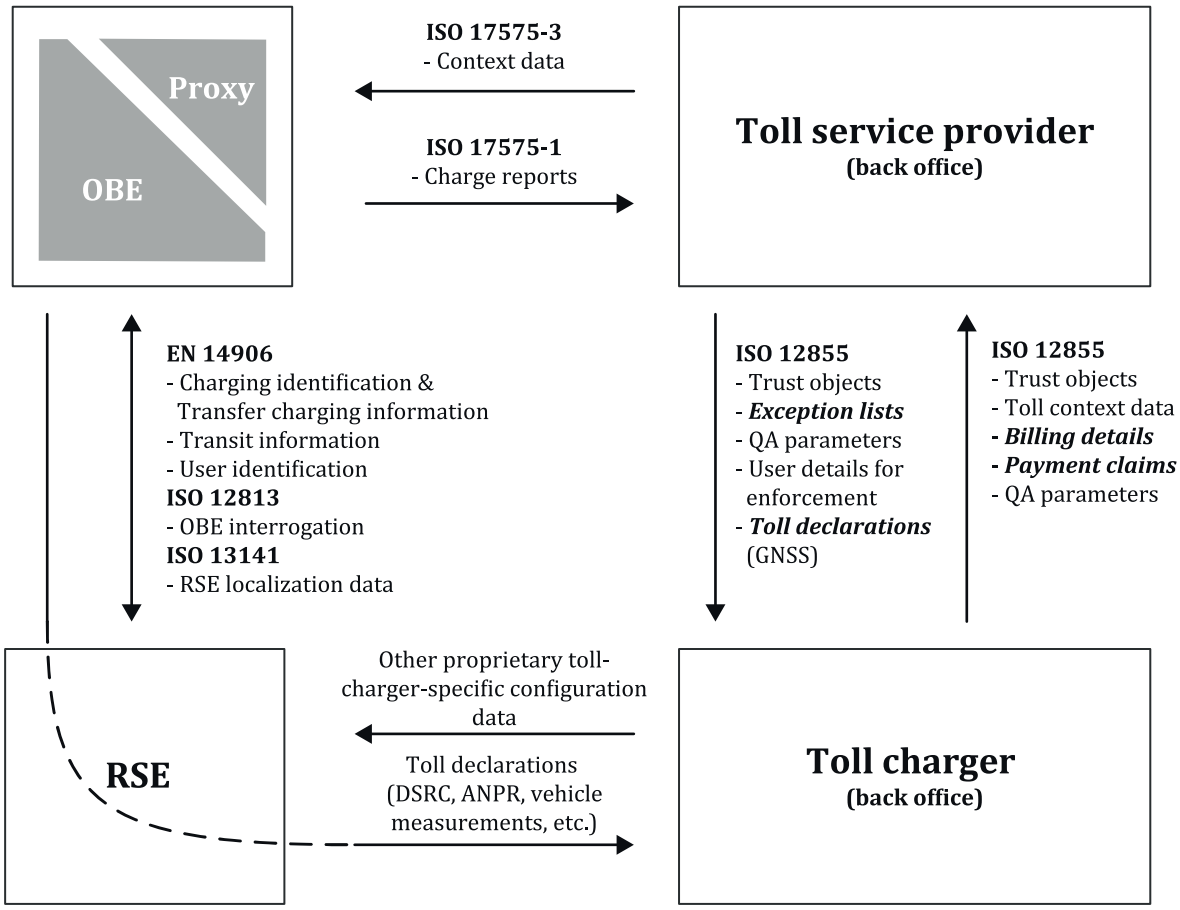

Figure 4 — EFC architecture and interfaces

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In accordance with ISO 17573-1 and ISO 17573-3:—[1)], and with the associated interface documents ISO 12855 and ISO 14906, metrics shall be based on the following charging information exchanges in correspondence with the interfaces indicated in Figure 4:

— charge reports as transmitted from the FE to the TSP-BE and finally included in charge reports provided to the TC (ISO 12855);

— charging identification and transfer of charging information as exchanged between the OBE and the RSE for DSRC systems (ISO 14906);

— toll declarations as transmitted from the TSP to the TC for autonomous systems (ISO 12855:2022, 5.2.7);

— billing details as transmitted from the TC to the TSP (ISO 12855:2022, 5.2.8);

— payment claims transmitted from the TC to the TSP (ISO 12855:2022, 5.2.9).

Payment claims form the basis for toll statements/invoices as transmitted in the interface between TSP and the SU (user account).

Charging metrics defined at the level of charge reports and toll declarations focus on the ability of the TSP front end (TSP-FE) and associated TSP back end (TSP-BE) functions to correctly detect and report charging events. Charging metrics defined at the level of billing details and payment claims focus on the TC's ability to correctly determine the charges incurred by SUs based on the toll declarations received. Charging metrics defined at the level of usage statements/invoices cover the overall charging performance for an individual SU, which include other capabilities of the complete system (communications reliability, infrastructure availability, etc.).

In addition to the metrics that can be defined at the level of interfaces, it is often common practice to define metrics which measure the overall charging performance in a toll scheme, in particular for procurements of toll schemes where the roles of TC and TSP are provided by a single entity; these are defined as end-to-end metrics in this document. In toll schemes where the roles of TC and TSP are performed by different entities then the end-to-end metrics measure the combined performance of the TC and TSP.

For the purposes of this document, charging performance metrics are defined for the seven levels below and are independently presented in this clause.

— Charge report metrics (6.3).

— Toll declaration metrics (6.4).

— Billing details metrics (6.5).

— Payment claim metrics (6.6).

— Exception list metrics (6.7).

— User account metrics (6.8).

— End-to-end metrics (6.9).

The charging metrics defined in each subclause are not intended to be mutually exclusive and the decision as to which charging metrics to use is out of the scope of this document.

The remainder of this clause covers the following:

— the applicability of the defined charging metrics for the roles of TC and TSP for the three identified scheme types (6.10);

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— the provision of tables for the selection of charging metrics and associated examination tests for the roles of TC and TSP for each identified scheme type (6.11).

Figure 5 shows the hierarchy of charging metrics as listed above and illustrates how the discrete and continuous nature of toll schemes have an impact on the metrics that can be defined for a particular scheme under consideration.

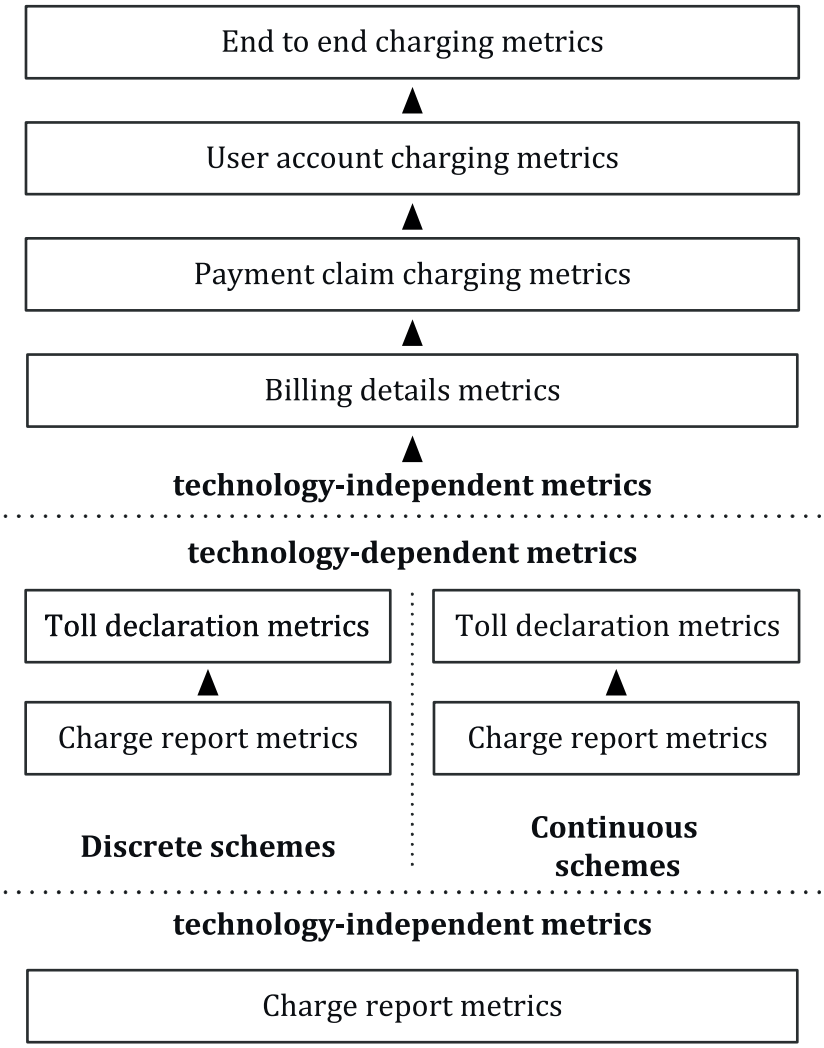

Figure 5 — Charging metrics hierarchy

For the purposes of this document, it is assumed that metrics defined at a level of billing details or higher are independent of whether the toll scheme is continuous or discrete and it is only metrics that are defined at the toll declaration or charge report level that are dependent on the scheme type.

Figure 6 presents five different examples for defining options for measuring charging metrics in a particular toll scheme.

a) Measurement of charging performance at each information interface independently from each other (with reference to the outcome of the previous stage). This is applicable for both discrete and autonomous systems.

b) Measurement of charging performance at each information interface between TSP and TC. This is most applicable to autonomous systems.

c) Measurement of charging performance of the TC at the billing detail and payment claim levels, independently from the performance of the TSP for allocating charges to user accounts. This is only

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recommended for scenarios where the TC is responsible for the usage evidence (e.g. tolling systems using DSRC or ANPR technology to obtain the usage evidence). Otherwise, the performance cannot be attributed to a single responsible entity.

d) Measurement of charging performance of the TC at the payment claim level, independently from the performance of the TSP for allocating charges to user accounts. This is only recommended for scenarios where the TC is responsible for the usage evidence (e.g. tolling systems using DSRC or ANPR technology to obtain the usage evidence) and where there is no aggregation of billing details within payment claims.

e) Measurement of end-to-end charging performance of the whole toll scheme. This measurement represents the SU's perception. It can further be recommended if all charging functions are performed by the same monolithic entity.

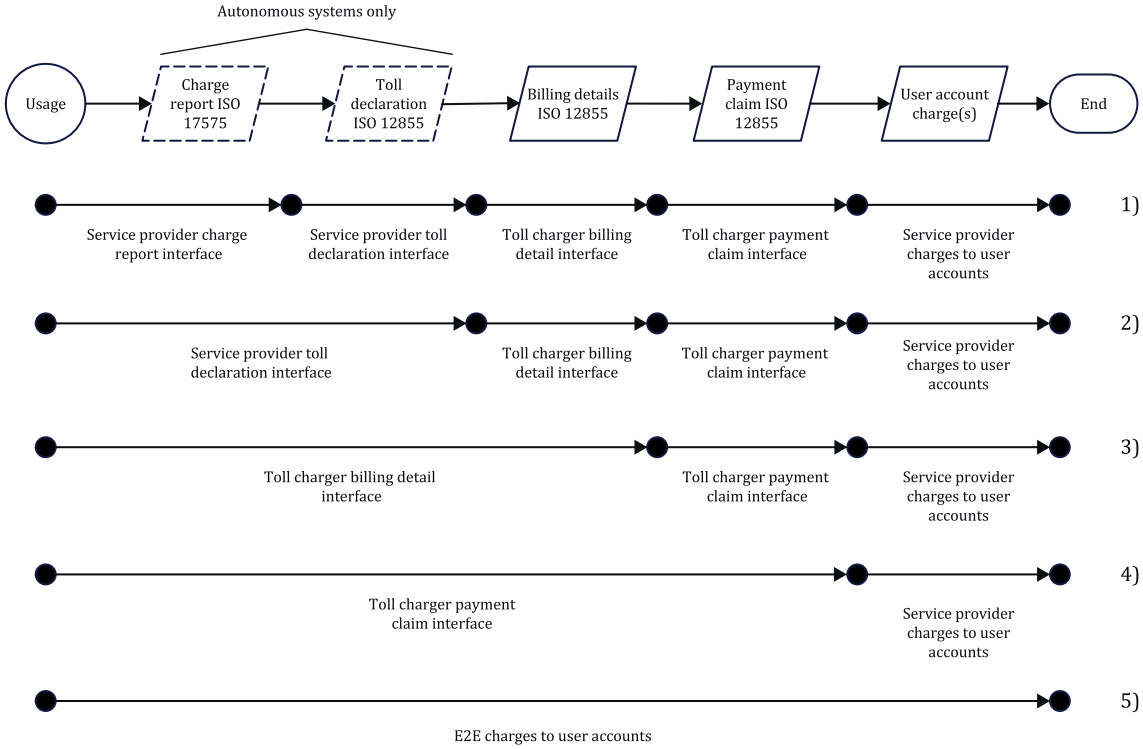

Figure 6 — Charging metrics mapping to toll scheme implementations

The reference value for the measurement is an important issue. Each black filled circle represents the reference value for performance evaluation for the next stage (to the right).

The actual presence of a vehicle cannot be taken as a reference for performance measurement because it is "unknown". For every performance metric which involves comparison to the "real world", a tangible reference ("usage evidence") needs to be defined. This is the record generated to monitor the performance (CCTV, loop detection, manual auditor log file, enforcement record, etc.).

6.2 Metric identification

The metric's unique identifiers are defined in the following manner: CM-xxx-aa

where:

a) CM signifies "charging metrics";

NOTE This is to allow distinctions in case of expansion to other performance metrics.

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b) xxx identifies the level of the metric:

1) "DTD", signifies "Toll declaration/Charge report" for discrete systems,

2) "CTD", signifies "Toll declaration/Charge report" for continuous systems,

3) "DCR", signifies "Charge report" for discrete systems,

4) "CCR", signifies "Charge report" for continuous systems;

c) aa identifies the unique number within the level.

6.3 Charge report metrics

6.3.1 General

Charging metrics, defined at the level of charge reports generated by the FE, assess charging performance at the level of the contents of individual charge reports for autonomous systems.

NOTE 1 These metrics are used to measure the ability of the TC to correctly detect charging events in autonomous systems.

Charge report metrics may be used to evaluate whole charging events as detected by the FE (e.g. predefined charge objects and road sections), or the raw usage data as defined in ISO 12855 (see usage evidence in Figure 6), e.g. GNSS positioning data.

NOTE 2 Although the scope of charge report metrics for usage evidence is at the level of the technology-specific sensors, the definition provided within this document reflects an overall principle rather than specific sensors' data measurements. As such, it is considered as technology-independent.

NOTE 3 Further usage evidence metrics for assessment of GNSS-based positioning data are defined in EN 16803-1.

NOTE 4 For examples of examination and assessment tests for raw usage data in autonomous systems, see EN 16803-2.

6.3.2 Metrics relevant for all schemes

Table 5 provides details of the metrics that have been defined for charge reports that are common for both discrete and continuous charging schemes.

Table 5 — Common charge report metrics

Metric ID	Metric name	Description	Definition
CM-CR-1	CR — Correct charge report generation	Metric that measures the correctness of the generation of charge reports.	This metric defines the probability that a charge report is correctly generated.
CM-CR-2	CR — Incorrect charge report generation rate	Metric that measures the incorrectness of the generation of charge reports.	This metric defines the probability that a charge report is incorrectly generated.
CM-CR-3	CR — Charge report latency	Metric that measures the average latency in generation of charge reports.	The average time it takes between a charge object detection and the time the charge report is created/received by the TSP.

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Table 5 *(continued)*

Metric ID	Metric name	Description	Definition
CM-CR-4	CR — TSP-FE charge parameter change rate	Metric that measures the ability of FEs to correctly detect charge parameter change.	This metric defines the probability that the FE properly detects any defined charge-relevant event that takes place.
CM-CR-5	CR — TSP-FE false positive rate	Metric that measures the ability of TSP-FEs to avoid false positives.	For vehicles not using the infrastructure subject to a charge, this metric defines the probability that for any predefined charge object detection the FE improperly detects it.
CM-CR-6	CR— Usage evidence availability	Metric that measures the relative amount of time for which an input sensor provides usage evidence.	This metric measures the relative amount of time that an input sensor delivers raw usage data for detection of individual charging events.
CM-CR-7	CR— Usage evidence integrity	Metric that measures the quality of the generated usage evidence.	This metric measures the quality of the raw usage data provided by the input sensors.
CM-CR-8	CR — Usage evidence time-to-first-fix	Metric that measures the average time taken for an input sensor to be ready to start sending relevant usage evidence.	This metric defines the average time taken for an input sensor to be ready to start sending relevant usage evidence used for charging event detection.

6.3.3 Metrics only applicable to discrete schemes

Table 6 provides details of the metrics that have been defined as charge report metrics for discrete schemes.

Table 6 — Discrete scheme charge report metrics

Metric ID	Metric name	Description	Definition
CM-DCR-1	DCR — Correct charging rate (Correct charge object detection recognition)	Metric that measures the correct recognition of charge object detections.	This metric defines the probability that for any predefined charge object detection that takes place, the corresponding entry in the respective charge report is correctly generated. “Predefined” may be defined by random measurements of determined charge object detections.

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Table 6 *(continued)*

Metric ID	Metric name	Description	Definition
CM-DCR-2	DCR — Incorrect charge object detection	Metric that measures the incorrect (charging data) recognition of charge object detections. Charging event is correctly generated, but entry contains incorrect data.	This metric defines the probability that for any predefined charge object detection that takes place, an entry in the respective charge report is incorrectly generated. “Predefined” may be defined by random measurements of determined charge object detections.
CM-DCR-3	DCR — Missed charge object detection	Metric that measures the missed recognition of charge object detections.	This metric defines the probability that for any predefined charge object detection, an entry in the respective charge report is not generated.
CM-DCR-4	DCR — Overcharging rate (Incorrect false positive charge object detection)	Metric that measures the incorrect (false positives) recognition of charge object detections.	For vehicles not using the infrastructure, this metric defines the probability that for any predefined charge object detection, an additional entry in the respective charge report is generated (“False positive”).

6.3.4 Metrics applicable to continuous schemes

Table 7 provides details of the metrics that have been defined as charge report metrics for continuous schemes.

Table 7 — Continuous scheme charge report metrics

Metric ID	Metric name	Description	Definition
CM-CCR-1	CCR — Correct charging rate	Metric that measures the level of "Acceptable charging" from the perspective of TCs in continuous systems.	This metric defines 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 (ARCE) is within the accepted charging error interval. It measures the probability that the relative error in the charge computation is within acceptable limits to protect the interest of both the TC and the SU.

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Table 7 *(continued)*

Metric ID	Metric name	Description	Definition
CM-CCR-2	CCR — Overcharging rate	Metric that measures the level of unacceptable overcharging at the SU level in continuous systems.	This metric defines the probability that for any single predefined representative trip, the relative charging error (RCE) is above the upper bound of the accepted charging error interval. It measures the probability that the relative error in the charge computation is larger than an acceptable limit. Protecting the interest of the SU (i.e. avoiding excessive overcharging) requires this probability to be below a very small value.
CM-CCR-3	CCR — Accuracy of distance/time measurement	Metric that measures the accuracy of distance/time measurement by FEs.	The 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 Toll declaration metrics

6.4.1 General

Charging metrics defined at the level of toll declarations generated by the TSP assess the charging performance at the level of the contents of individual toll declarations and are only applicable for autonomous systems.

Due to the substantial difference between discrete and continuous systems as far as the natures of the potential charging errors are concerned, different metrics are defined for different types of systems. Thus, the following groups of metrics are identified:

— metrics that are applicable to all schemes including both continuous and discrete ones;

— metrics that are only applicable to discrete systems;

— metrics that are applicable to continuous systems that, as mentioned in the introduction, can also include some discrete behaviour (e.g. price per km, depending on the type of road).

The following subclauses identify metrics for each of these three defined groups.

6.4.2 Metrics relevant for all schemes

Table 8 provides details of the metrics that have been defined for toll declaration that are common for both discrete and continuous charging schemes.

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Table 8 — Common toll declaration metrics

Metric ID	Metric name	Description	Definition
CM-TD-1	TD — Correct toll declaration generation rate	Metric that measures the correctness of the generation of toll declarations.	This metric defines the probability that a toll declaration is correctly generated.
CM-TD-2	TD — Incorrect toll declaration generation rate	Metric that measures the incorrectness of the generation of toll declarations.	This metric defines the probability that a toll declaration is incorrectly generated.
CM-TD-3	TD — Late toll declaration rate	Metric that measures the overall level of late toll declarations within a charging scheme, i.e. the proportion of toll declarations that are received later than the defined period for the delay between charge object detections and toll declarations to be received in a charging scheme.	This metric defines the proportion of toll declarations received by the TC in a defined period where the time between the charge object detection and the receipt of the associated toll declaration is greater than the defined period for the charging scheme.
CM-TD-4	TD — TSP Charge parameter change rate	Metric that measures the ability of a TSP to correctly detect charge parameter change to avoid undercharging.	This metric defines the probability that for any predefined charge-relevant event that takes place, the TSP properly detects it.
CM-TD-5	TD — TSP False positive rate	Metric that measures the ability of a TSP to avoid false positives in toll declarations.	For vehicles not using the infrastructure, this metric defines the probability that for any defined charge object detection, the TSP improperly detects it during the creation of toll declarations.

6.4.3 Metrics only applicable to discrete schemes

Table 9 provides details of the metrics that have been defined for toll declaration metrics for discrete schemes.

NOTE The following metrics can be applied to both the systems of TCs and TSPs.

Table 9 — Discrete scheme toll declaration metrics

Metric ID	Metric name	Description	Definition
CM-DTD-1	DTD — Correct charging rate (correct charge object detection recognition)	Metric that measures the correct recognition of charge object detections.	This metric defines the probability that for any predefined charge object detection that is recorded, the corresponding toll declaration is correctly generated. “Predefined” may be defined by random measurements of determined charge object detections.

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Table 9 *(continued)*

Metric ID	Metric name	Description	Definition
CM-DTD-2	DTD — Incorrect charge object detection	Metric that measures the incorrect (charging data) recognition of charge object detections (charging data). This happens when a charging event is correctly detected, but the toll declaration contains incorrect data.	This metric defines the probability that for any predefined charge object detection 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 object detections.
CM-DTD-3	DTD — Missed charge object detection	Metric that measures the missed recognition of charge object detections. This happens when either a charge object detection is not detected, or a charge report is generated but is not included in the toll declaration.	This metric defines the probability that for any predefined charge object detection, an entry in the respective toll declaration is not generated.
CM-DTD-4	DTD — Overcharging rate (incorrect false positive charge object detection)	Metric that measures the incorrect (false positives) recognition of charge object detections.	For vehicles not using the infrastructure, this metric defines the probability that for any predefined charge object detection, an additional entry in the respective toll declaration is generated (false positive).

6.4.4 Metrics applicable to continuous schemes

Table 10 provides details of the metrics that have been defined for toll declaration metrics for continuous schemes.

Table 10 — Continuous scheme toll declaration metrics

Metric ID	Metric name	Description	Definition
CM-CTD-1	CTD — Correct charging rate	Metric that measures the level of "acceptable charging" in continuous systems.	This metric defines the probability that for any set of representative trips travelled by a vehicle and during a certain period of time, the ARCE is within the accepted charging error interval. It measures the probability that the relative error in the charge computation is within acceptable limits to protect the interest of both the TC and the SU.

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Table 10 *(continued)*

Metric ID	Metric name	Description	Definition
CM-CTD-2	CTD — Overcharging rate	Metric that measures the level of unacceptable overcharging in continuous systems.	This metric defines the probability that for any single predefined representative trip, the RCE is above the upper bound of the accepted charging error interval. It measures the probability that the relative error in the charge computation is larger than an acceptable limit. Protecting the interest of the SU (i.e. avoiding excessive overcharging) requires that this probability be below a very small value.
CM-CTD-3	CTD — Accuracy of distance/time measurement	Metric that measures the accuracy of distance/time measurement at the toll declaration interface.	The 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.

6.5 Billing details metrics

Billing details metrics measure the charging performance at the level of the billing details exchanged between the TC and TSP. Depending on the level of aggregation within a charging scheme, these can directly relate to line items within usage statements and can relate to individual charge object detections, individual trips or charges incurred for a defined toll declaration period.

NOTE 1 In discrete schemes, the billing details metrics can be used to measure the performance of the TC to correctly detect charge events.

NOTE 2 In charging schemes where billing details are originated by the TSP and forwarded to the TC for checking, these metrics can be applicable to the TSP.

Table 11 provides details of the metrics that have been defined as billing details metrics.

Table 11 — Billing details metrics

Metric ID	Metric name	Description	Definition
CM-BD-1	BD — Correct charging rate	Metric that measures the correctness of billing details produced by the TC.	This metric defines the probability that for any given billing detail, the ARCE is within the accepted charging error interval. It 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 TC and the SU.

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Table 11 *(continued)*

Metric ID	Metric name	Description	Definition
CM-BD-2	BD — Overcharging rate	Metric that measures the level of overcharging in billing details produced by the TC.	This metric defines the probability that for any given billing detail, the ARCE is above the accepted charging error interval. It 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 SU (i.e. avoiding excessive overcharging) requires that this probability be below a very small value.
CM-BD-3	BD — Undercharging rate	Metric that measures the level of undercharging in billing details produced by the TC.	This metric defines the probability that for any given billing detail, the ARCE is below the accepted charging error interval.
CM-BD-4	BD — Incorrect charging rate	Metric that measures the processing of incorrect billing details. This happens when a charge object is correctly detected, but the charge report, toll declaration or usage data contains incorrect data.	This metric defines the probability that for any predefined charge object detection that is recorded, a respective billing detail is incorrectly generated (the incorrect data are not detected). "Predefined" may be defined by random measurements of determined charge object detections.
CM-BD-5	BD — Latency — TC	Metric that measures the performance (time delay) of the TC in generating billing details.	The average time it takes between a toll declaration being received by the TC and the time the associated billing detail is created/sent by the TC. Most relevant for autonomous systems (toll declarations are solely generated by a TSP).
CM-BD-6	BD — Late billing details rate	Metric that measures the overall level of late billing details within a charging scheme, i.e. the proportion of billing details that are received later than the defined period for the delay between charge object detections and billing details to be received in a charging scheme.	This metric defines the proportion of billing details received by the TSP in a defined period where the time between the charge object detection and the receipt of the associated billing detail is greater than the defined period for the charging scheme. Most relevant for infrastructure-based systems.

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