
Electronic fee collection — Charging performance framework

Perception de télépéage — Cadre de performance d'imputation

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of 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 www.iso.org/iso/foreword.html.

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.

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.

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.

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.

- 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.

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]

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

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]

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]

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

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](#).

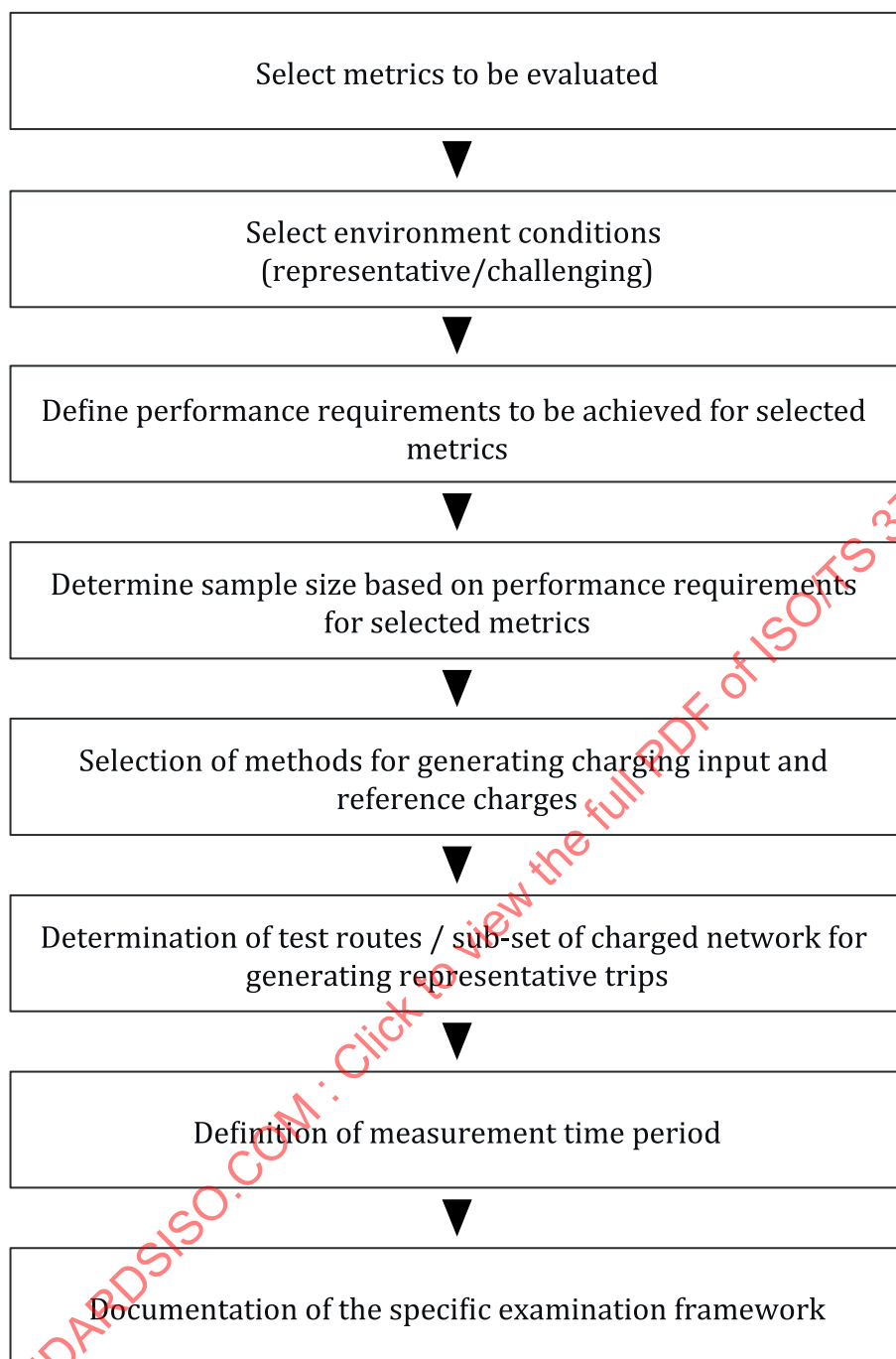


Figure 1 — Method for defining a specific examination framework

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](#).

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.

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.

- 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.

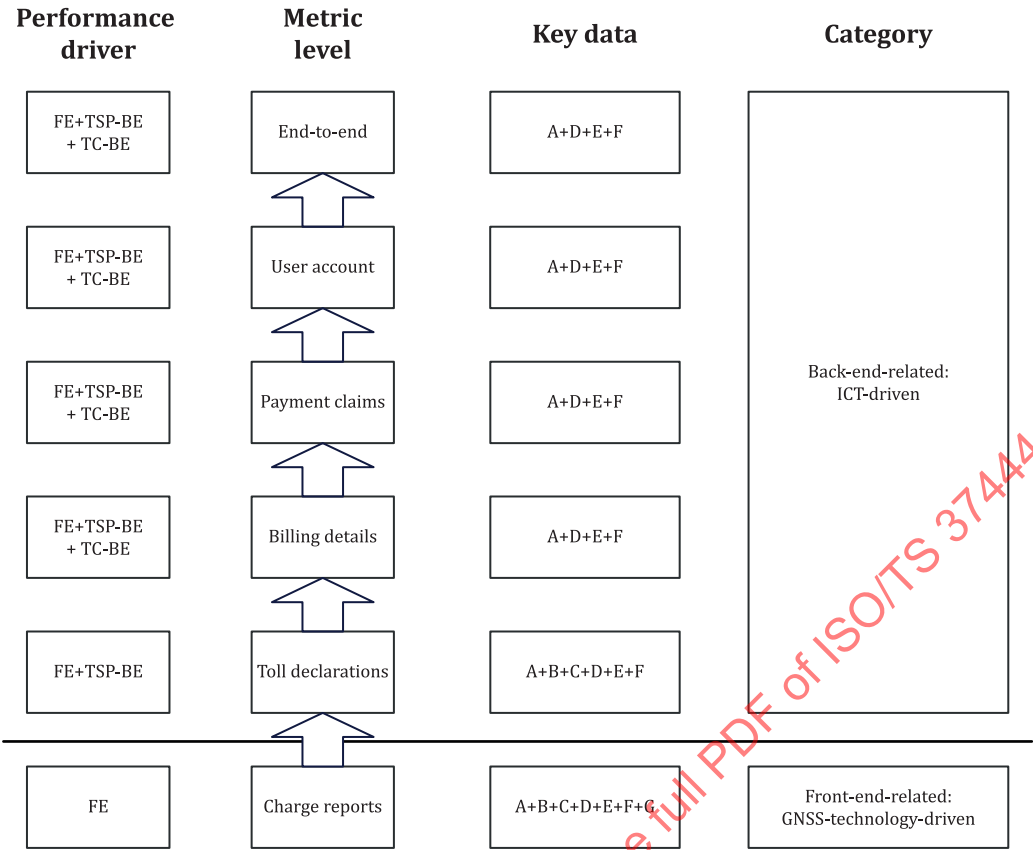
The potential use of these data for the different cases considered is summarized in [Table 2](#) (valid for both discrete and continuous systems).

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

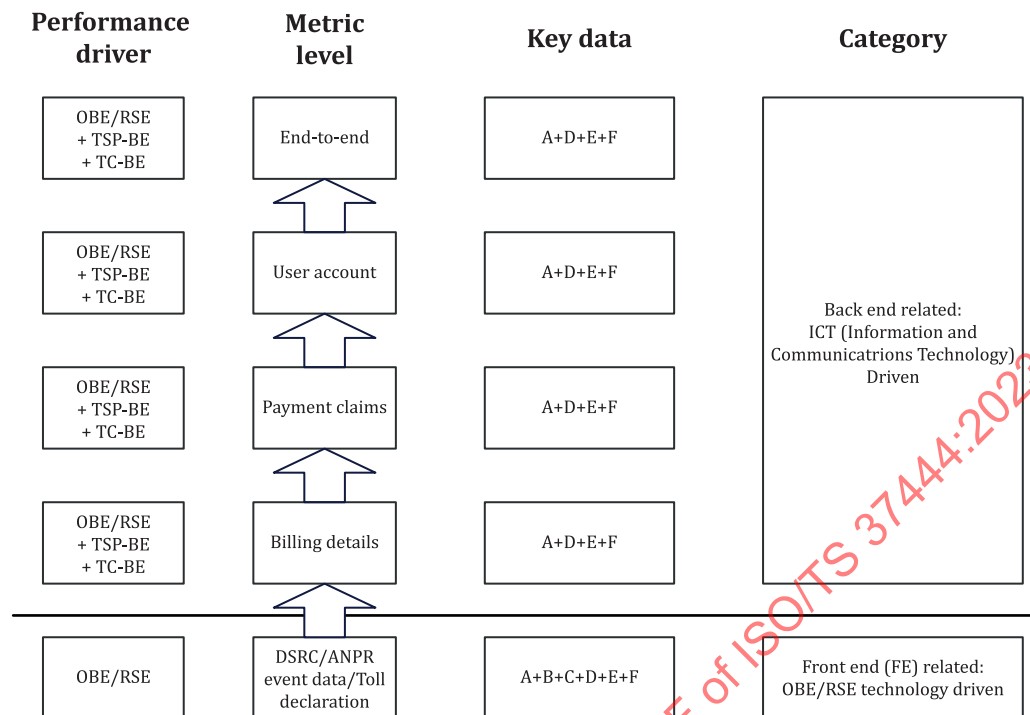
[Figure 2](#) and [Figure 3](#) analyse the metrics defined in each level, taking into consideration the following points:

- 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?



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



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

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)	SU 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.

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.

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,

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.

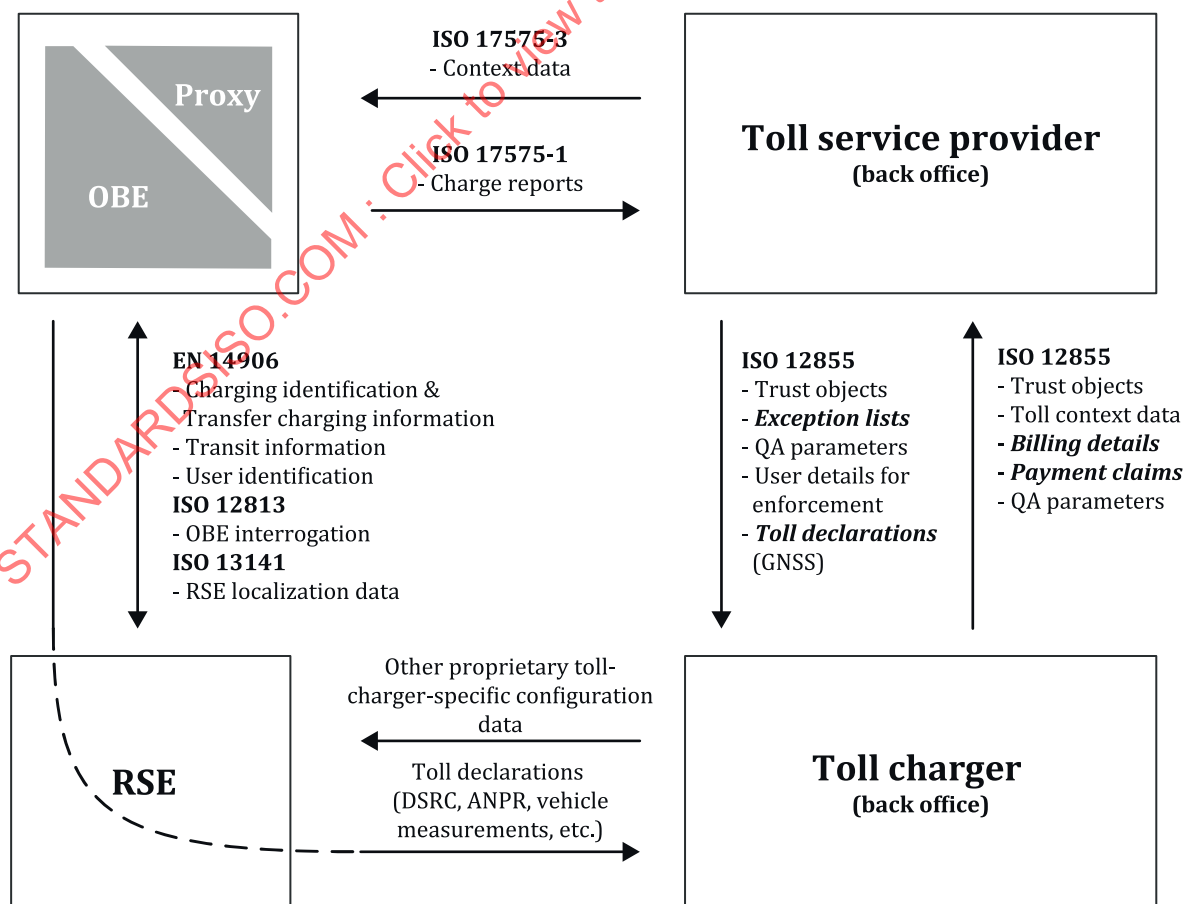


Figure 4 — EFC architecture and interfaces

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](#));

1) Under preparation. Stage at the time of publication: ISO/FDIS 17573-3:2023.

- 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.

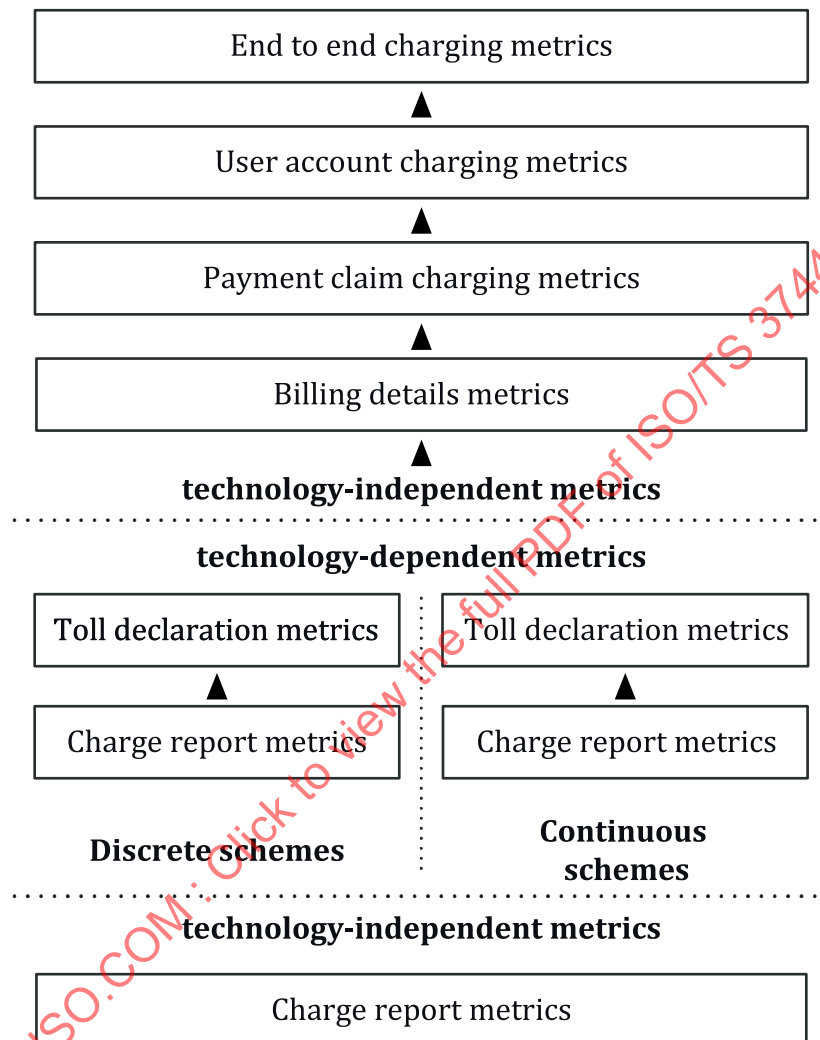


Figure 5 — Charging metrics hierarchy

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.

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

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.

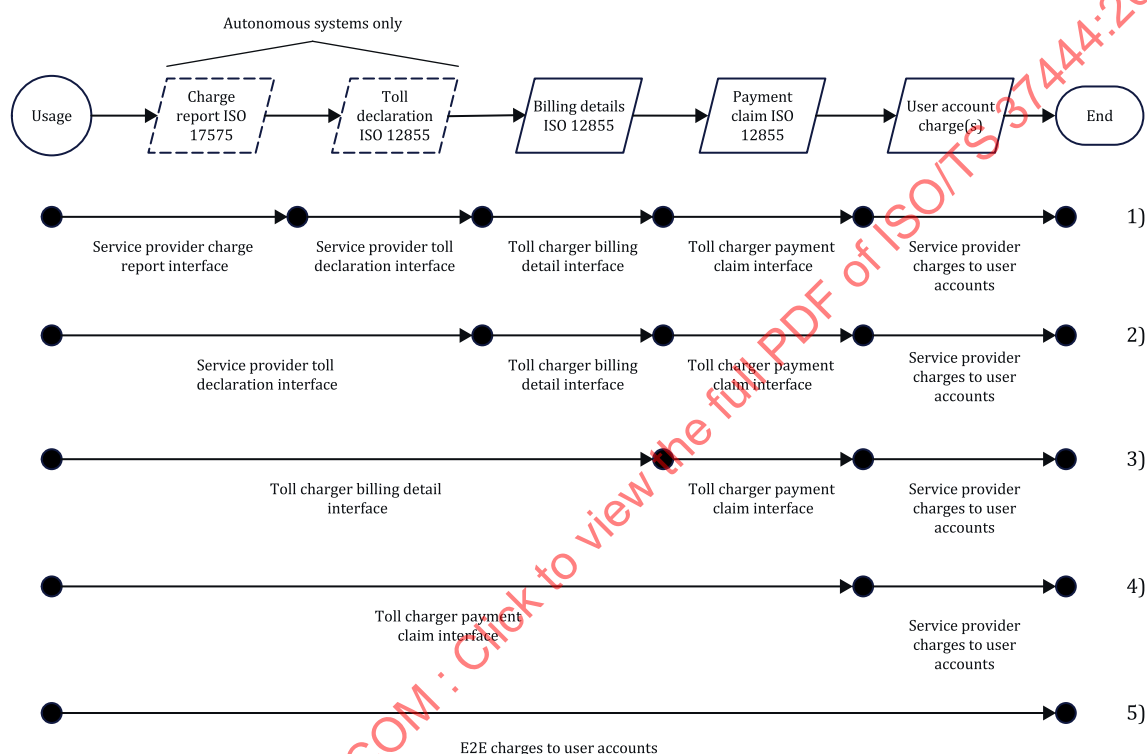


Figure 6 — Charging metrics mapping to toll scheme implementations

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.

- 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.

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.

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.

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 <i>trips</i> 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.

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.

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.

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.

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.

Table 11 (continued)

Metric ID	Metric name	Description	Definition
CM-BD-7	BD — Rejected billing details rate	Metric that measures the level of billing details rejected by the TSP in relation to the total number of sent billing details. A rejection may result from any failed check of authenticators, conformance to tariff objects and the plausibility of the received billing details, etc. by the TSP.	This metric defines the ratio of correctly rejected billing details in relation to the total number of billing details received in the measurement period.
CM-BD-8	BD — Incorrect rejected billing details rate	Metric that measures the level of billing details incorrectly rejected by the TSP in relation to the total number of rejected billing details.	This metric defines the ratio of the incorrectly rejected billing details in relation to the total number of rejected billing details in the measurement period.
CM-BD-9	BD — Inferred billing details rate	Metric that measures the level of inferred billing details in relation to the total number of billing details. An inferred billing detail is derived by either calculating a charge object detection based on neighbouring events or by analysing video pictures.	This metric defines the ratio of inferred billing details in relation to the total number of billing details in the measurement period.

6.6 Payment claim metrics

Payment claim metrics measure the charging performance at the level of the payment claims between TC and TSP, at the level of line items within usage statements. Depending on the level of aggregation within a charging scheme, they can relate to individual billing details.

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

Table 12 provides details of the metrics that have been defined for payment claim metrics.

Table 12 — Payment claim metrics

Metric ID	Metric name	Description	Definition
CM-PC-1	PC — Correct charging rate	Metric that measures the correctness of payment claims produced by the TC.	This metric defines the probability that for any given payment claim, the ARCE is within the accepted charging error interval. It measures the probability that the relative error in the payment claim used for invoicing is within defined limits to protect the interest of both the TC and the SU.

Table 12 (continued)

Metric ID	Metric name	Description	Definition
CM-PC-2	PC — Overcharging rate	Metric that measures the level of overcharging in payment claims produced by the TC.	This metric defines the probability that for any given payment claim, the ARCE is above the accepted charging error interval. It measures the probability that the relative error in the payment claim 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-PC-3	PC — Undercharging rate	Metric that measures the level of undercharging in payment claims produced by the TC.	This metric defines the probability that for any given payment claim, the ARCE is below the accepted charging error interval.
CM-PC-4	PC — Latency — TC	Metric that measures the performance (time delay) of the TC in generating payment claims.	The average time it takes between the approval for a billing detail being received by the TC and the time the associated payment claim is created/sent by the TC.
CM-PC-5	PC — Late payment claims	Metric that measures the overall level of late payment claims within a charging scheme, i.e. the proportion of charges that appear later than the defined period for charge object detections to appear on user statements.	This metric defines the proportion of payment claims received by the TSP in a defined period where the time between the charge object detection and the receipt of the associated payment claim is greater than the defined period for the charging scheme.
CM-PC-6	PC — Rejected payment claim rate	Metric that measures the level of payment claims rejected by the TSP in relation to the transmitted payment claims.	This metric defines the ratio of correctly rejected payment claims in relation to the total number of payment claims received in the measurement period.

6.7 Exception list metrics

Exception list metrics do not measure the charging performance. They measure the correctness of generation of the exception list. However, errors in the process of generating the exception list have a negative effect on the performance of the overall toll charging.

EXAMPLE SUs erroneously added to the exemption list are not expected to be charged for journeys made after the exemption list has been distributed and approved. This can result in a toll income for the TC which is below the expected level.

[Table 13](#) provides details of the metrics that have been defined for exception list performance.

Table 13 — Exception list metrics

Metric ID	Metric name	Description	Definition
CM-EL-1	EL — Correct exception list generation rate	Metric that measures the correctness of the generation of the exception list.	This metric defines the probability that an exception list is correctly generated.
CM-EL-2	EL — Incorrect exception list generation rate	Metric that measures the incorrectness of the generation of the exception list.	This metric defines the probability that an exception list is incorrectly generated.

ISO 12855 defines various types of exception list. Depending on their applicability in the individual toll domain, the metrics CM-EL-1 and CM-EL-2 may be defined per type of exception list.

ISO 12855 uses the following predefined types of exception lists: black list, white list, discount list, icc. However, it also leaves room for toll domain specific extensions to other types of exception lists.

6.8 User account metrics

User account metrics measure the charging performance at the level of the individual users and can be related to the number of SU complaints related to charging received by the TSP.

[Table 14](#) provides details of the metrics that have been defined for user account metrics.

Table 14 — User account metrics

Metric ID	Metric name	Description	Definition
CM-UA-1	UA — Correct charging rate	Metric that measures the level of successful charging at the individual user account level.	This metric defines the probability that for any set of representative trips travelled by a given SU during the invoicing period the ARCE is within the accepted charging error interval.
CM-UA-2	UA — Overcharging rate	Metric that measures the level of overcharging at the individual user account level.	This metric defines the probability that for any set of representative trips travelled by a given SU during the invoicing period the ARCE is above the accepted charging error interval.
CM-UA-3	UA — Undercharging rate	Metric that measures the level of undercharging at the individual user account level.	This metric defines the probability that for any set of representative trips travelled by a given SU during the invoicing period the ARCE is below the accepted charging error interval.
CM-UA-4	UA — Accurate application of payments and refunds	Metric that measures the accuracy of payments and refunds to individual user accounts.	This metric defines the probability that payment transactions associated to a user account are correct.

Table 14 (continued)

Metric ID	Metric name	Description	Definition
CM-UA-5	UA — Accurate personalization of OBE	Metric that measures the accuracy of the personalization of charging relevant parameters into OBE.	This metric defines the probability that the personalization for any set of SUs during a time span, Δa , is correct.

6.9 End-to-end metrics

End-to-end charging performance metrics are defined at a level which determines the overall charging performance of a toll scheme across all interfaces on the overall system level for a group of SUs.

[Table 15](#) provides details of the metrics that have been defined for end-to-end charging metrics.

Table 15 — End-to-end charging metrics

Metric ID	Metric name	Description	Definition
CM-E2E-1	E2E — Correct charging rate	Metric that measures the overall probability that SUs are correctly charged by a toll scheme.	This metric defines the probability that for any set of representative trips travelled by a set of SUs during a time span, Δa , the ARCE is within the accepted charging error interval.
CM-E2E-2	E2E — Overcharging rate	Metric that measures the overall probability that SUs are overcharged by a toll scheme.	This metric defines the probability that for any set of representative trips travelled by a set of SUs during a time span, Δa , the ARCE is above the accepted charging error interval.
CM-E2E-3	E2E — Undercharging rate	Metric that measures the overall probability that SUs are undercharged by a toll scheme.	This metric defines the probability that for any set of representative trips travelled by a set of SUs during a time span, Δa , the ARCE is below the accepted charging error interval.
CM-E2E-4	E2E — Late charging	Metric that measures the overall level of late charging within a toll scheme, i.e. the proportion of charges that appear later than the defined period for charge object detections to appear on user statements.	This metric defines the probability that for any set of representative trips travelled by a set of SUs during a time span, Δa , the charge object detections appear on the user statement later than the defined period for the charging scheme.

6.10 Applicability of metrics scheme types

[Table 16](#) defines the applicability of the defined charging metrics for the following types of toll schemes:

- discrete toll scheme (DD) — TC with one or more toll TSPs;
- autonomous discrete toll scheme (AD) — TC with one or more toll TSPs;
- autonomous continuous toll scheme (AC) — TC with one or more toll TSPs.

The entries in the "scheme type" column [Table 16](#) 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.

- d) Key data requirements — data required to calculate the metric:
 - 1) RD — Reference data;
 - 2) UA — User account;
 - 3) EL — Exception list;
 - 4) PC — Payment claims;
 - 5) BD — Billing details;
 - 6) TD — Toll declarations;
 - 7) CR — Charge reports;
 - 8) CCR — Compliance check records.
- e) Evaluation — Charging input method options — the applicable methods that can 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.
- f) Monitoring — Charging input method options — the applicable methods that can 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.

Table 16 — Applicability of charging metrics for scheme types and roles

Metrics level	Metric ID	Metric name	Scheme type			Key data requirements	Evaluation Charging Input Method Options	Monitoring Charging Input Method Options
			DD	AD	AC			
End-to-end	CM-E2E-1	E2E — Correct charging rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-E2E-2	E2E — Overcharging rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-E2E-3	E2E — Undercharging rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-E2E-4	E2E — Late charging rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
User account	CM-UA-1	UA — Correct charging rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-UA-2	UA — Overcharging rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-UA-3	UA — Undercharging rate	Y	Y	Y	RD, UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-UA-4	UA — Accurate application of payments and refunds	Y	Y	Y	UA	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
Exception list	CM-UA-5	UA — Accurate personalization of OBE	Y	Y	Y	CCR	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-EL-1	EL — Correct exception list generation rate	Y	Y	Y	RD, EL	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-EL-2	EL — Incorrect exception list generation rate	Y	Y	Y	RD, EL	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	CM-PC-1	PC — Correct charging rate	Y	Y	Y	RD, PC	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
Payment claims	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
Billing details	CM-PC-6	PC — Rejected payment claim rate	Y	Y	Y	RD, PC	PVP,PVR,UVR,SO	PVP,PVR,UVR,SO
	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

Table 16 (continued)

Metrics level	Metric ID	Metric name	Scheme type			Key data requirements	Evaluation Charging Input Method Options	Monitoring Charging Input Method Options
			DD	AD	AC			
Toll declaration	CM-TD-1	TD — Correct toll declaration generation 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	Y		RD, TD	PVP,PVR,UVR,IS, SO,DO	PVP,PVR, UVR,IS,SO,DO
	CM-DTD-2	DTD — Incorrect charge event recognition	Y	Y		RD, TD	PVP,PVR,UVR,IS, SO,DO	PVP,PVR, UVR,IS,SO,DO
	CM-DTD-3	DTD — Missed charge object detection Rate	Y	Y		RD, TD	PVP,PVR,UVR,IS, SO,DO	PVP,PVR, UVR,IS,SO,DO
	CM-DTD-4	DTD — Overcharging rate	Y	Y		RD, TD	PVP,PVR,UVR,IS, SO,DO	PVP,PVR, UVR,IS,SO,DO
	CM-CTD-1	CTD — Correct charging rate			Y	RD, TD	PVP,PVR,UVR,IS, SO,DO	PVP,PVR, UVR,IS,SO,DO
	CM-CTD-2	CTD — Overcharging rate			Y	RD, TD	PVP,PVR,UVR,IS, SO,DO	PVP,PVR, UVR,IS,SO,DO
	CM-CTD-3	CTD — Accuracy of distance/time measurement			Y	RD, TD	PVP,PVR,UVR,IS, SO,DO	PVP,PVR, UVR,IS,SO,DO

Table 16 (continued)

Metrics level	Metric ID	Metric name	Scheme type			Key data requirements	Evaluation Charging Input Method Options	Monitoring Charging Input Method Options
			DD	AD	AC			
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-CR-6	CR — Usage evidence availability		Y	Y	RD, CR	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-CR-7	CR — Usage evidence integrity		Y	Y	RD, CR	PVP,PVR,UVR,IS,SO	PVP,PVR,UVR,IS,SO
	CM-CR-8	CR — Usage evidence time-to-first-fix		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, UVR,IS,SO,DO
	CM-DCR-2	DCR — Incorrect charge event recognition		Y		RD, CR	PVP,PVR,UVR,IS,SO,DO	PVP,PVR, UVR,IS,SO,DO
	CM-DCR-3	DCR — Missed charge object detection rate		Y		RD, CR	PVP,PVR,UVR,IS,SO,DO	PVP,PVR, UVR,IS,SO,DO
	CM-DCR-4	DCR — Overcharging rate (Incorrect false positive charge event recognition)		Y		RD, CR	PVP,PVR,UVR,IS,SO,DO	PVP,PVR, UVR,IS,SO,DO
	CM-CCR-1	CCR — Correct charging rate			Y	RD, CR	PVP,PVR,UVR,IS,SO,DO	PVP,PVR, UVR,IS,SO,DO
	CM-CCR-2	CCR — Overcharging rate			Y	RD, CR	PVP,PVR,UVR,IS,SO,DO	PVP,PVR, UVR,IS,SO,DO
	CM-CCR-3	CCR — Accuracy of distance/time measurement			Y	RD, CR	PVP,PVR,UVR,IS,SO,DO	PVP,PVR, UVR,IS,SO,DO

6.11 Charging metric selection tables

6.11.1 General

The entity responsible for the definition of the specific examination framework shall use the appropriate table(s) from 6.11.2 to 6.11.4 to define, for each selected metric to be measured during an evaluation and/or monitoring, the:

- charging input (CI) method to be used;
- selection of minimum, maximum and target value to be achieved (selection is based on the respective charge metric)

The completed table(s) shall form part of the documentation of the specific examination framework.

6.11.2 Discrete

Table 17 should be used to define the examination tests to be performed for a specific examination framework in a discrete scheme.

Table 17 — Discrete — Metric selection table

Metric		Evaluation				Monitoring			
Metric ID	Examina- tion test (subclause)	CI meth- od	Min. value	Target value	Max. value	CI meth- od	Min. value	Target value	Max. value
CM-E2E-1 E2E — Correct charging rate	7.2.2								
CM-E2E-2 E2E — Overcharging rate	7.2.3								
CM-E2E-3 E2E — Undercharging rate	7.2.4								
CM-E2E-4 E2E — Late charging rate	7.2.5								
CM-UA-1 UA — Correct charging rate	7.2.6								
CM-UA-2 UA — Overcharging rate	7.2.7								
CM-UA-3 UA — Undercharging rate	7.2.8								
CM-UA-4 UA — Accurate application of payments and refunds	7.2.9								
CM-UA-5 UA — Accurate personalization of OBEs	7.2.10								
CM-EL-1 EL — Correct exception list generation rate	7.2.11								
CM-EL-2 EL — Incorrect exception list generation rate	7.2.12								
CM-PC-1 PC — Correct charging rate	7.2.13								
CM-PC-2 PC — Overcharging rate	7.2.14								
CM-PC-3 PC — Undercharging rate	7.2.15								
CM-PC-4 PC — Latency — TC	7.2.16								

Table 17 (continued)

Metric		Evaluation				Monitoring			
Metric ID	Examination test (subclause)	CI method	Min. value	Target value	Max. value	CI method	Min. value	Target value	Max. value
CM-PC-5 PC — Late payment claims	7.2.17								
CM-PC-6 PC — Rejected payment claim rate	7.2.18								
CM-BD-1 BD — Correct charging rate	7.2.19								
CM-BD-2 BD — Overcharging rate	7.2.20								
CM-BD-3 BD — Undercharging rate	7.2.21								
CM-BD-4 BD — Incorrect charging rate	7.2.22								
CM-BD-5 BD — Latency — TC	7.2.23								
CM-BD-6 BD — Late billing details rate	7.2.24								
CM-BD-7 BD — Rejected billing details rate	7.2.25								
CM-BD-8 BD — Incorrect rejected billing details rate	7.2.26								
CM-BD-9 BD — Inferred billing details rate	7.2.27								
CM-TD-1 TD — Correct toll declaration generation rate	7.3.2.2								
CM-TD-2 TD — Incorrect toll declaration generation rate	7.3.2.3								
CM-TD-3 TD — Late toll declarations rate	7.3.2.4								

Table 18 contains additional tests which can be helpful for discrete systems, but which cannot be prescribed in a normative way, because the respective interfaces are proprietary.

Table 18 — Discrete — Optional toll declaration metric selection table

Metric		Evaluation				Monitoring			
Metric ID	Examination test (subclause)	CI method	Min. value	Target value	Max. value	CI method	Min. value	Target value	Max. value
CM-TD-1 TD — Correct toll declaration generation rate	7.3.2.2								
CM-TD-2 TD — Incorrect toll declaration generation rate	7.3.2.3								
CM-TD-3 TD — Late toll declarations rate	7.3.2.4								
CM-TD-4 TD — TSP charge parameter change rate	7.3.2.5								
CM-TD-5 TD — TSP false positive rate	7.3.2.6								

6.11.3 Autonomous discrete

Table 19 should be used to define the examination tests to be performed for a specific examination framework for an autonomous discrete scheme.

Table 19 — Autonomous discrete — Metric selection table

Metric		Evaluation				Monitoring			
Metric ID	Examination test (subclause)	CI method	Min. value	Target value	Max. value	CI method	Min. value	Target value	Max. value
CM-E2E-1 E2E — Correct charging rate	7.2.2								
CM-E2E-2 E2E — Overcharging rate	7.2.3								
CM-E2E-3 E2E — Undercharging rate	7.2.4								
CM-E2E-4 E2E — Late charging rate	7.2.5								
CM-UA-1 UA — Correct charging rate	7.2.6								
CM-UA-2 UA — Overcharging rate	7.2.7								
CM-UA-3 UA — Undercharging rate	7.2.8								
CM-UA-4 UA — Accurate application of payments and refunds	7.2.9								
CM-UA-5 UA — Accurate personalization of OBEs	7.2.10								
CM-EL-1 EL — Correct exception list generation rate	7.2.11								
CM-EL-2 EL — Incorrect exception list generation rate	7.2.12								
CM-PC-1 PC — Correct charging rate	7.2.13								
CM-PC-2 PC — Overcharging rate	7.2.14								
CM-PC-3 PC — Undercharging rate	7.2.15								
CM-PC-4 PC — Latency — TC	7.2.16								
CM-PC-5 PC — Late payment claims	7.2.17								
CM-PC-6 PC — Rejected payment claim rate	7.2.18								
CM-BD-1 BD — Correct charging rate	7.2.19								
CM-BD-2 BD — Overcharging rate	7.2.20								
CM-BD-3 BD — Undercharging Rate	7.2.21								
CM-BD-4 BD — Incorrect charging rate	7.2.22								
CM-BD-5 BD — Latency — TC	7.2.23								

Table 19 (continued)

Metric		Evaluation				Monitoring			
Metric ID	Examination test (subclause)	CI method	Min. value	Target value	Max. value	CI method	Min. value	Target value	Max. value
CM-BD-6 BD — Late billing details rate	7.2.24								
CM-BD-7 BD — Rejected billing details rate	7.2.25								
CM-BD-8 BD — Incorrect rejected billing details rate	7.2.26								
CM-BD-9 BD — Inferred billing details rate	7.2.27								
CM-TD-1 TD — Correct toll declaration generation rate	7.3.1.2								
CM-TD-2 TD — Incorrect toll declaration generation rate	7.3.1.3								
CM-TD-3 TD — Late toll declarations rate	7.3.1.4								
CM-TD-4 TD — TSP charge parameter change rate	7.3.1.5								
CM-TD-5 TD — TSP false positive rate	7.3.1.6								
CM-DTD-1 DTD — Correct charging rate (charge object detections)	7.3.1.7								
CM-DTD-2 DTD — Incorrect charge event recognition	7.3.1.8								
CM-DTD-3 DTD — Missed charge object detection rate	7.3.1.9								
CM-DTD-4 DTD — Overcharging rate	7.3.1.10								
CM-CR-1 CR — Correct charge report generation	7.3.1.11								
CM-CR-2 CR — Incorrect charge report generation rate	7.3.1.12								
CM-CR-3 CR — Charge report latency	7.3.1.13								
CM-CR-4 CR — TSP-FE charge parameter change rate	7.3.1.14								
CM-CR-5 CR — TSP-FE false positive rate	7.3.1.15								
CM-CR-6 CR — Usage evidence availability	7.2.28								
CM-CR-7 CR — Usage evidence integrity	7.2.29								
CM-CR-8 CR — Usage evidence time-to-first-fix	7.2.30								
CM-DCR-1 DCR — Correct charging rate (charge object detections)	7.3.1.16								
CM-DCR-2 DCR — Incorrect charge event recognition	7.3.1.17								

Table 19 (continued)

Metric		Evaluation				Monitoring			
Metric ID	Examination test (subclause)	CI method	Min. value	Target value	Max. value	CI method	Min. value	Target value	Max. value
CM-DCR-3 DCR — Missed charge object detection rate	7.3.1.18								
CM-DCR-4 DCR — Overcharging rate (Incorrect false positive charge event recognition)	7.3.1.19								

6.11.4 Autonomous continuous

Table 20 should be used to define the examination tests to be performed for a specific examination framework in an autonomous continuous scheme.

Table 20 — Autonomous continuous — Metric selection table

Metric		Evaluation				Monitoring			
Metric ID	Examination test (subclause)	CI method	Min. value	Target value	Max. value	CI method	Min. value	Target value	Max. value
CM-E2E-1 E2E — Correct charging rate	7.2.2								
CM-E2E-2 E2E — Overcharging rate	7.2.3								
CM-E2E-3 E2E — Undercharging rate	7.2.4								
CM-E2E-4 E2E — Late charging rate	7.2.5								
CM-UA-1 UA — Correct charging rate	7.2.6								
CM-UA-2 UA — Overcharging rate	7.2.7								
CM-UA-3 UA — Undercharging rate	7.2.8								
CM-UA-4 UA — Accurate application of payments and refunds	7.2.9								
CM-UA-5 UA — Accurate personalization of OBEs	7.2.10								
CM-EL-1 EL — Correct exception list generation rate	7.2.11								
CM-EL-2 EL — Incorrect exception list generation rate	7.2.12								
CM-PC-1 PC — Correct charging rate	7.2.13								
CM-PC-2 PC — Overcharging rate	7.2.14								
CM-PC-3 PC — Undercharging rate	7.2.15								
CM-PC-4 PC — Latency — TC	7.2.16								
CM-PC-5 PC — Late payment claims	7.2.17								

Table 20 (continued)

Metric		Evaluation				Monitoring			
Metric ID	Examination test (subclause)	CI method	Min. value	Target value	Max. value	CI method	Min. value	Target value	Max. value
CM-PC-6 PC — Rejected payment claim rate	7.2.18								
CM-BD-1 BD — Correct charging rate	7.2.19								
CM-BD-2 BD — Overcharging rate	7.2.20								
CM-BD-3 BD — Undercharging rate	7.2.21								
CM-BD-4 BD — Incorrect charging rate	7.2.22								
CM-BD-5 BD — Latency — TC	7.2.23								
CM-BD-6 BD — Late billing details rate	7.2.24								
CM-BD-7 BD — Rejected billing details rate	7.2.25								
CM-BD-8 BD — Incorrect rejected billing details rate	7.2.26								
CM-BD-9 BD — Inferred billing details rate	7.2.27								
CM-TD-1 TD — Correct toll declaration generation rate	7.3.3.2								
CM-TD-2 TD — Incorrect toll declaration generation rate	7.3.3.3								
CM-TD-3 TD — Late toll declarations rate	7.3.3.4								
CM-TD-4 TD — TSP Charge parameter change rate	7.3.3.5								
CM-TD-5 TD — TSP False positive rate	7.3.3.6								
CM-CTD-1 CTD — Correct charging rate	7.3.3.7								
CM-CTD-2 CTD — Overcharging rate	7.3.3.8								
CM-CTD-3 CTD — Accuracy of distance/time measurement	7.3.3.9								
CM-CR-1 CR — Correct charge report generation	7.3.3.10								
CM-CR-2 CR — Incorrect charge report generation rate	7.3.3.11								
CM-CR-3 CR — Charge report latency	7.3.3.12								
CM-CR-4 CR — TSP-FE charge parameter change rate	7.3.3.13								
CM-CR-5 CR — TSP-FE false positive rate	7.3.3.14								

7 Examination tests

7.1 General

A toolbox of examination tests for the EFC discrete and continuous scheme types are listed in this clause, including:

- technology-independent tests ([7.2](#)), applicable to any type of toll scheme;
- technology-dependent tests ([7.3](#)), further grouped by the scheme types:
 - discrete
 - autonomous (both discrete and continuous).

Each of the subclauses listed above contains the specific examination tests for the applicable charging metrics identified in [Clause 6](#).

7.2 Technology-independent tests

7.2.1 General

The examination tests defined in [7.2.2](#) to [7.2.29](#) are applicable to all scheme types. They may be used in combination with evaluation tests defined in [7.3](#), depending on the scheme type.

The reference data are collected using the methods and prescriptions in [5.4](#).

An example template for a structured documentation of examination tests and their results is provided in [Annex A](#).

Additional supporting considerations for selecting useful examination tests depending on the individual operational phase of a toll system or project, the applied charging technology and other criteria for defining examination tests are provided in [Annex B](#).

Further background and support on statistical elements are outlined in [Annex C](#), while guidelines for reducing sample sizes are given in [Annex D](#).

[Annex E](#) contains examples of performance metrics and measurement methods from operational toll systems.

Initial information on how to define performance requirements and performance parameters in toll systems are provided in [Annex F](#).

7.2.2 ET-CM-E2E-1 E2E — Correct charging rate

7.2.2.1 Metric definition

This metric defines the probability that for a set of representative trips travelled by a set of SUs during a time span, Δa , the ARCE is within the accepted charging error interval.

The calculation method for the metric is specified in [7.2.2.3](#), [Formulae \(1\)](#) and [\(2\)](#).

7.2.2.2 Intended use

Typically, this is the view of the road operator who receives the revenue from the toll collection system. This metric measures the overall correct charging performance across the set of SUs.

NOTE Traditionally, metrics like these were used to specify overall charging performance where the roles of TC and TSP were performed by the same organization.

7.2.2.3 Metric calculation method

$$R_{CCH,E2E} = T_{W,ACEI} / T_{T,TS} \quad (1)$$

where

$R_{CCH,E2E}$ is the E2E correct charging rate;

$T_{W,ACEI}$ is the number of representative trips where the RCE, E_{RCH} , is within the accepted charging error interval;

$T_{T,TS}$ is the total number of representative trips within the time span;

and

$$E_{RCH} = (C_{A,RT} / C_{E,RT}) - 1 \quad (2)$$

where

E_{RCH} is the RCE;

$C_{A,RT}$ is the actual charge for representative trips;

$C_{E,RT}$ is the expected charge for representative trips;

and the accepted charging error interval is defined as the value range between its lower bound (CELB) and its upper bound (CEUB).

CELB and CEUB are determined by the accepted percentage deviation from the correct charge.

7.2.3 ET-CM-E2E-2 E2E — Overcharging rate

7.2.3.1 Metric definition

This metric defines the probability that for any set of representative trips travelled by a set of SUs during a time span, Δa , the ARCE is above the accepted charging error interval.

The calculation method for the metric is specified in [7.2.3.3](#), [Formulae \(3\)](#) and [\(4\)](#).

7.2.3.2 Intended use

Typically, this is the view of the road operator who receives the revenue from the toll collection system. This metric measures the overall overcharging across the set of SUs.

NOTE Traditionally, metrics like these were used to specify overall charging performance where the roles of TC and TSP were performed by the same organization.

7.2.3.3 Metric calculation method

$$R_{OCH,E2E} = T_{G,ACEI} / T_{T,TS} \quad (3)$$

where

$R_{OCH,E2E}$ is the E2E overcharging rate;

$T_{G,ACEI}$ is the number of representative trips where the RCE, E_{RCH} , is greater than the upper bound of the accepted charging error interval in the measurement period;

$T_{T,TS}$ is the total number of representative trips in the measurement period;
and

$$E_{RCH} = (C_{A,RT}/C_{E,RT}) - 1 \quad (4)$$

where

E_{RCH} is the RCE;

$C_{A,RT}$ is the actual charge for representative trips;

$C_{E,RT}$ is the expected charge for representative trips;

and the accepted charging error interval is defined with its upper bound (CEUB).

CEUB is determined by the accepted positive percentage deviation from the correct charge.

7.2.4 ET-CM-E2E-3 E2E — Undercharging rate

7.2.4.1 Metric definition

This metric defines the probability that for a set of representative trips travelled by a set of SUs during a time span, Δa , the ARCE is below the accepted charging error interval.

The calculation method for the metric is specified in 7.2.4.3, [Formulae \(5\)](#) and [\(6\)](#).

7.2.4.2 Intended use

Typically, this is the view of the road operator who receives the revenue from the toll collection system. This metric measures the overall undercharging across the set of SUs.

NOTE Traditionally, metrics like these were used to specify overall charging performance where the roles of TC and TSP were performed by the same organization.

7.2.4.3 Metric calculation method

$$R_{UCH,E2E} = T_{L,ACEI}/T_{T,TS} \quad (5)$$

where

$R_{UCH,E2E}$ is the E2E undercharging rate;

$T_{L,ACEI}$ is the number of representative trips where the RCE, E_{RCH} , is less than the lower bound of the accepted charging error interval in the measurement period;

$T_{T,TS}$ is the total number of representative trips in the measurement period;

and

$$E_{RCH} = (C_{A,RT}/C_{E,RT}) - 1 \quad (6)$$

where

E_{RCH} is the RCE;

$C_{A,RT}$ is the actual charge for representative trip;

$C_{E,RT}$ is the expected charge for representative trip;

and the accepted charging error interval is defined with its lower bound (CELB).

CELB is determined by the accepted negative percentage deviation from the correct charge.

7.2.5 ET-CM-E2E-4 E2E — Late charging rate

7.2.5.1 Metric definition

This metric defines the probability that for any set of representative trips travelled by a set of SUs during a time span, Δa , the charge events appear on the user statement later than the defined period for the charging scheme.

The calculation method for the metric is specified in [7.2.5.3, Formula \(7\)](#).

7.2.5.2 Intended use

Typically, this is the view of the road operator who receives the revenue from the toll collection system. This metric measures the overall late charging across the set of SUs.

NOTE Traditionally, metrics like these were used to specify overall charging performance where the roles of TC and TSP were performed by the same organization.

7.2.5.3 Metric calculation method

$$R_{LCH,E2E} = T_{L,MUSD} / T_{T,TS} \quad (7)$$

where

$R_{LCH,E2E}$ is the E2E late charging rate;

$T_{L,MUSD}$ is the number of representative trips where the charge events appear on the user statement later than the defined maximum user statement delay (MUSD) in the measurement period;

$T_{T,TS}$ is the total number of representative trips in the measurement period;

and where MUSD = x units of time.

7.2.6 ET-CM-UA-1 UA — Correct charging rate

7.2.6.1 Metric definition

This metric defines the probability that for any set of representative trips travelled by a given SU during the invoicing period, the ARCE is within the accepted charging error interval.

The calculation method for the metric is specified in [7.2.6.3, Formulae \(8\) and \(9\)](#).

7.2.6.2 Intended use

This metric is defined at the user account level which defines the charging performance at the level of the individual SUs.

This metric should be used when there is a defined requirement on the average correct charging for individual SUs.

7.2.6.3 Metric calculation method

$$R_{CCH,UA} = S_{W,ACEI} / S_T \quad (8)$$

where

$R_{CCH,UA}$ is the correct charging rate on user account level

$S_{W,ACEI}$ is the number of SUs where the ARCE, E_{ARCH} , is within the accepted charging error interval during the invoicing period;

S_T is the total number of SUs in the invoicing period;

and

$$E_{ARCH,UA} = (C_{A,RTSU} / C_{E,RTSU}) - 1 \quad (9)$$

where

$E_{ARCH,UA}$ is the ARCE on the user account level;

$C_{A,RTSU}$ is the sum of actual charges for representative trips for an SU;

$C_{E,RTSU}$ is the sum of expected charge for representative trips for an SU;

and the accepted charging error interval is defined as the value range between its lower bound (CELB) its upper bound (CEUB).

CELB and CEUB are determined by the accepted percentage deviation from the correct charge.

7.2.7 ET-CM-UA-2 UA — Overcharging rate

7.2.7.1 Metric definition

This metric defines the probability that for any set of representative trips travelled by a given SU during the invoicing period, the ARCE is above the accepted charging error interval.

The calculation method for the metric is specified in [7.2.7.3](#), [Formulae \(10\)](#) and [\(11\)](#).

7.2.7.2 Intended use

This metric is defined at the user account level which defines the charging performance at the level of the individual SUs.

This metric should be used when there is a defined requirement on the average overcharging for individual SUs.

7.2.7.3 Metric calculation method

$$R_{OCH,UA} = S_{A,ACEI} / S_T \quad (10)$$

where

$R_{OCH,UA}$ is the overcharging rate on the user account level;

$S_{A,ACEI}$ is the number of SUs where the ARCE, E_{ARCH} , is above the accepted charging error interval upper bound (CEUB) during the invoicing period;

S_T is the total number of SUs in the invoicing period;

and

$$E_{ARCH,UA} = (C_{A,RTSU}/C_{E,RTSU}) - 1 \quad (11)$$

where

$E_{ARCH,UA}$ is the ARCE on user account level;

$C_{A,RTSU}$ is the sum of actual charges for representative trips for an SU;

$C_{E,RTSU}$ is the sum of expected charges for representative trips for an SU;

and the accepted charging error interval is defined with its upper bound (CEUB).

CEUB is determined by the accepted positive percentage deviation from the correct charge.

7.2.8 ET-CM-UA-3 UA — Undercharging rate

7.2.8.1 Metric definition

This metric defines the probability that for any set of representative trips travelled by a given SU during the invoicing period, the ARCE is below the accepted charging error interval.

The calculation method for the metric is specified in [7.2.8.3](#), [Formulae \(12\)](#) and [\(13\)](#).

7.2.8.2 Intended use

This metric is defined at the user account level which defines the charging performance at the level of the individual SUs.

This metric should be used when there is a defined requirement on the average under charging for individual SUs.

7.2.8.3 Metric calculation method

$$R_{UCH,UA} = S_{B,ACEI}/S_T \quad (12)$$

where

$R_{UCH,UA}$ is the undercharging rate on the user account level;

$S_{B,ACEI}$ is the number of SUs where the ARCE, E_{ARCH} , is below the accepted charging error lower bound (CELB) during the invoicing period;

S_T is the total number of SUs in the invoicing period;

and

$$E_{ARCH,UA} = (C_{A,RTSU}/C_{E,RTSU}) - 1 \quad (13)$$

where

$E_{ARCH,UA}$ is the ARCE on the user account level;

$C_{A,RTSU}$ is the sum of actual charges for representative trips for an SU;

$C_{E,RTSU}$ is the sum of expected charge for representative trips for an SU;
and the accepted charging error interval is defined with its lower bound (CELB).
CELB is determined by the accepted negative percentage deviation from the correct charge.

7.2.9 ET-CM-UA-4 UA — Accurate application of payments and refunds

7.2.9.1 Metric definition

This metric defines the probability that payment transactions associated to a user account are correct.
The calculation method for the metric is specified in [7.2.9.3](#), [Formula \(14\)](#).

7.2.9.2 Intended use

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

7.2.9.3 Metric calculation method

$$R_{APR,UA} = B_{T,C}/B_T \quad (14)$$

where

- $R_{APR,UA}$ is the rate of the correctly applied payments and refunds on user accounts;
- $B_{T,C}$ is the total number of correctly applied payments and refunds on user accounts in a measurement period;
- B_T is the total number of applied payments and refunds on user accounts in a measurement period.

7.2.10 ET-CM-UA-5 UA — Accurate personalization of OBEs

7.2.10.1 Metric definition

This metric defines the probability that the OBE personalization for any set of SUs during a time span, Δa , is correct. The OBE personalization is a given set of parameters with defined values stored in the OBE. The personalization is correct when all parameters are readable and the read values are equal to the defined ones.

The calculation method for the metric is specified in [7.2.10.3](#), [Formula \(15\)](#).

7.2.10.2 Intended use

This metric can be measured by TCs using their existing compliance-checking infrastructure. It is in the TC's interest to ensure that this is maximized, as incorrectly personalized OBE will potentially lead to detected non-compliance.

7.2.10.3 Metric calculation method

$$R_{PER,UA} = Z_{S,CC}/Z_{T,C} \quad (15)$$

where

- $R_{\text{PER,UA}}$ is the correct OBE personalization rate;
- $Z_{\text{S,CC}}$ is the number of **OBE where the agreed subset of OBE parameters has been verified as correct by the TC** compliance equipment in the selected time period;
- $Z_{\text{T,C}}$ is the total number of OBE checked by the TC compliance equipment in the selected time period.

7.2.11 ET-CM-EL-1 EL — Correct exception list generation rate

7.2.11.1 Metric definition

This metric defines the probability that the exception list (of a defined type x) at a defined time, m , is correct. The exception list shall be considered as correct in case all list entries are present with the full set of mandatory and correct parameters per list entry and no list entries are present that shall not be in the exception list.

The calculation method for the metric is specified in [7.2.11.3, Formula \(16\)](#).

7.2.11.2 Intended use

This metric can be measured by TCs using data from the charging chain and data from compliance-checking infrastructure. TCs may also make use of reference data (SU account data) provided by the TSPs. It is in the TC's interest to ensure that this rate is maximized, as incorrect exception lists will potentially lead to impact on toll revenues and also increase the processing efforts in compliance check processes.

7.2.11.3 Metric calculation method

$$R_{\text{COR,EL}}(x) = e_{\text{S,CC}}/e_{\text{T,E}} \quad (16)$$

where

- $R_{\text{COR,EL}}(x)$ is the rate of correctly generated and transmitted exception list of type x ;
- $e_{\text{S,CC}}$ is the number of entries in the exception list of type n at a defined time, m , where the agreed subset of parameters per list entry has been verified as correct by the TC;
- $e_{\text{T,E}}$ is the total number of expected entries in the exception list of type n at a defined time m ;
- x is the type of the exception list according to ISO 12855.

7.2.12 ET-CM-EL-2 EL — Incorrect exception list generation rate

7.2.12.1 Metric definition

This metric defines the probability that the exception list (of a defined type x) at a defined time, m , is incorrect. The exception list shall be considered as incorrect if not all list entries are present or not the full set of mandatory parameters per list entry is present. The exception list shall also be considered as incorrect if one or more parameters of a list entry is not correct, or the list contains entries which shall not be in the exception list.

The calculation method for the metric is specified in [7.2.12.3, Formula \(17\)](#).

7.2.12.2 Intended use

This metric can be measured by TCs using data from the charging chain and data from compliance-checking infrastructure. TCs may also make use of reference data (SU account data) provided by the TSPs. It is in the TC's interest to ensure that this rate is at a minimum level, as incorrect exception lists will potentially lead to impact on toll revenues, but can also add processing efforts in compliance check processes.

7.2.12.3 Metric calculation method

$$R_{\text{INC,EL}}(x) = e_{\text{S,CI}}/e_{\text{T,E}} \quad (17)$$

where

$R_{\text{INC,EL}}(x)$	is the rate of incorrectly generated and transmitted exception list of type x ;
$e_{\text{S,CI}}$	is the number of entries in the exception list of type n at a defined time, m , where the list entry or the agreed subset of parameters per list entry has been verified as incorrect by the TC;
$e_{\text{T,E}}$	is the total number of expected entries in the exception list of type n at a defined time, m ;
x	is the type of the exception list according to ISO 12855.

7.2.13 ET-CM-PC-1 PC — Correct charging rate

7.2.13.1 Metric definition

This metric defines the probability that for any given payment claim, the ARCE is within the accepted charging error interval.

This metric measures the probability that the relative error in the payment claim used for invoicing is within defined limits to protect the interest of both the TC and the SU.

The calculation method for the metric is specified in [7.2.13.3](#), [Formulae \(18\)](#) and [\(19\)](#).

7.2.13.2 Intended use

This metric can be used to measure the average level of correct charging at the level of payment claims on the user account statement.

7.2.13.3 Metric calculation method

$$R_{\text{CCH,PC}} = A_{\text{W,ACEI}}/A_{\text{T}} \quad (18)$$

where

$R_{\text{CCH,PC}}$	is the correct charging rate on payment claim level
$A_{\text{W,ACEI}}$	is the number of payment claims where the ARCE, E_{ARCH} , is within the accepted charging error interval in the measurement period;
A_{T}	is the total number of payment claims in the measurement period;

and

$$E_{\text{ARCH,PC}} = (C_{\text{A,PC}}/C_{\text{E,PC}}) - 1 \quad (19)$$

where

$E_{ARCH,PC}$ is the ARCE on the payment claim level;

$C_{A,PC}$ is the sum of the actual charges for the payment claim;

$C_{E,PC}$ is the sum of the expected charge for the payment claim;

and the accepted charging error interval is defined as the value range between its lower bound (CELB) its upper bound (CEUB).

CELB and CEUB are determined by the accepted percentage deviation from the correct charge.

7.2.14 ET-CM-PC-2 PC — Overcharging Rate

7.2.14.1 Metric definition

This metric defines the probability that for any given payment claim, the ARCE is above the accepted CEUB.

This metric measures the probability that the relative error in the payment claim used for invoicing is above a defined limit. Protecting the interest of the SU (i.e. avoiding excessive overcharging) requires this probability to remain below a very small value.

The calculation method for the metric is specified in [7.2.14.3, Formulae \(20\)](#) and [\(21\)](#).

7.2.14.2 Intended use

This metric can be used to measure the average level of overcharging at the level of payment claims on the user account statement.

7.2.14.3 Metric calculation method

$$R_{OCH,PC} = A_{A,ACEI} / A_T \quad (20)$$

where

$R_{OCH,PC}$ is the overcharging rate on payment claim level;

$A_{A,ACEI}$ is the number of payment claims where the ARCE, E_{ARCH} , is above the accepted charging error interval in the measurement period;

A_T is the total number of payment claims in the measurement period;

and

$$E_{ARCH,PC} = (C_{A,PC} / C_{E,PC}) - 1 \quad (21)$$

where

$E_{ARCH,PC}$ is the ARCE on payment claim level;

$C_{A,PC}$ is the sum of the actual charges for the payment claim;

$C_{E,PC}$ is the sum of the expected charge for the payment claim;

and the accepted charging error interval is defined with its upper bound (CEUB).

CEUB is determined by the accepted positive percentage deviation from the correct charge.

7.2.15 ET-CM-PC-3 PC — Undercharging rate

7.2.15.1 Metric definition

This metric defines the probability that for any given payment claim, the ARCE is below the accepted charging error interval.

The calculation method for the metric is specified in [7.2.15.3](#), [Formulae \(22\)](#) and [\(23\)](#).

7.2.15.2 Intended use

This metric can be used to measure the average level of undercharging at the level of payment claims on the user account statement.

7.2.15.3 Metric calculation method

$$R_{UCH,PC} = A_{B,CELB} / A_T \quad (22)$$

where

- $R_{UCH,PC}$ is the undercharging rate on payment claim level;
- $A_{B,CELB}$ is the number of payment claims where the ARCE, E_{ARCH} , is below the CELB in the measurement period;
- A_T is the total number of payment claims in the measurement period;

and

$$E_{ARCH,PC} = (C_{A,PC} / C_{E,PC}) - 1 \quad (23)$$

where

- $E_{ARCH,PC}$ is the ARCE on the payment claim level;
- $C_{A,PC}$ is the sum of the actual charges for the payment claim;
- $C_{E,PC}$ is the sum of the expected charge for the payment claim;

and the accepted charging error interval is defined with its lower bound (CELB).

CELB is determined by the accepted negative percentage deviation from the correct charge.

7.2.16 ET-CM-PC-4 PC — Latency — TC

7.2.16.1 Metric definition

This metric defines the average time it takes between the approval for a billing detail being received by the TC and the time the associated payment claim is created/sent by the TC.

The calculation method for the metric is specified in [7.2.16.3](#), [Formulae \(24\)](#) and [\(25\)](#).

7.2.16.2 Intended use

This metric provides an indication of the average processing time for TCs to create payment claims following the receipt of approved billing details from the TSP.

7.2.16.3 Metric calculation method

$$t_{\text{DEL,PC}} = L_{\text{PC,TS}} / A_{\text{TS,TS}} \quad (24)$$

where

- $t_{\text{DEL,PC}}$ is the average delay for creating payment claims by the TC;
- $L_{\text{PC,TS}}$ is the sum of the payment claim delays, $\Sigma t_{\text{PC,DEL}}$, in the measurement period;
- $A_{\text{TS,TS}}$ is the number of payment claims sent in the measurement period;

and

$$t_{\text{PC,DEL}} = M_{\text{PC,S}} - M_{\text{BD,RA}} \quad (25)$$

where

- $t_{\text{PC,DEL}}$ is the delay for the individual payment claim
- $M_{\text{PC,S}}$ is the time the payment claim was sent;
- $M_{\text{BD,RA}}$ is the time of receipt of the first associated approved billing detail.

7.2.17 ET-CM-PC-5 PC — Late payment claims rate

7.2.17.1 Metric definition

This metric defines the proportion of payment claims received by the TSP in a defined period where the time between the charge object detection and the receipt of the associated payment claim is greater than the defined period for the charging scheme.

The calculation method for the metric is specified in [7.2.17.3, Formula \(26\)](#).

7.2.17.2 Intended use

This metric can be used where there is a requirement for the timeliness of providing payment claims to the TSP. It may be used in conjunction with similar metrics defined for toll declarations and billing details.

7.2.17.3 Metric calculation method

$$R_{\text{LATE,PC}} = A_{\text{TL,TS}} / A_{\text{TR,TS}} \quad (26)$$

where

- $R_{\text{LATE,PC}}$ is the rate of late payment claims;
- $A_{\text{TL,TS}}$ is the number of late payment claims in the measurement period;
- $A_{\text{TR,TS}}$ is the number of payment claims received in the measurement period;

and a late payment claim is where the payment claim delay is greater than the maximum payment claim delay (MPCD).

7.2.18 ET-CM-PC-6 PC — Rejected payment claim rate

7.2.18.1 Metric definition

This metric defines the ratio of correctly rejected payment claims in relation to the total number of payment claims received in the measurement period.

The calculation method for the metric is specified in [7.2.18.3, Formula \(27\)](#).

7.2.18.2 Intended use

This metric measures the rate at which the TC generates incorrect payment claims that are detected by the TSP.

7.2.18.3 Metric calculation method

$$R_{\text{REJ,PC}} = A_{\text{TRC,TS}} / A_{\text{TS,TS}} \quad (27)$$

where

$R_{\text{REJ,PC}}$ is the rate of rejected payment claims;

$A_{\text{TRC,TS}}$ is the number of payment claims correctly rejected by the TSP in the measurement period;

$A_{\text{TS,TS}}$ is the total number of payment claims sent by the TC in the measurement period.

7.2.19 ET-CM-BD-1 BD — Correct charging rate

7.2.19.1 Metric definition

This metric defines the probability that for any given billing detail, the ARCE is within the accepted charging error interval.

This metric 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.

The calculation method for the metric is specified in [7.2.19.3, Formulae \(28\) and \(29\)](#).

7.2.19.2 Intended use

This metric can be used to measure the average level of correct charging at the level of trips or line items on the user account statement.

7.2.19.3 Metric calculation method

$$R_{\text{CCH,BD}} = I_{\text{A,ACEI}} / I_{\text{T}} \quad (28)$$

where

$R_{\text{CCH,BD}}$ is the correct charging rate on billing details level;

$I_{\text{A,ACEI}}$ is the number of billing details where the ARCE, E_{ARCH} , is within the accepted charging error interval in the measurement period;

I_{T} is the total number of billing details in the measurement period;

and

$$E_{\text{ARCH,BD}} = (C_{\text{A,BD}}/C_{\text{E,BD}}) - 1 \quad (29)$$

where

$E_{\text{ARCH,BD}}$ is the ARCE on billing details level;

$C_{\text{A,BD}}$ is the sum of the actual charges for the billing detail;

$C_{\text{E,BD}}$ is the sum of the expected charge for the billing detail;

and, the accepted charging error interval is defined as the value range between its lower bound (CELB) its upper bound (CEUB).

CELB and CEUB are determined by the accepted percentage deviation from the correct charge.

7.2.20 ET-CM-BD-2 BD — Overcharging rate

7.2.20.1 Metric definition

This metric defines the probability that for any given billing detail, the ARCE is above the accepted charging error interval

This metric 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 this probability to remain below a very small value.

The calculation method for the metric is specified in [7.2.20.3](#), [Formulae \(30\)](#) and [\(31\)](#).

7.2.20.2 Intended use

This metric can be used to measure the average level of overcharging at the level of trips or line items on the user account statement.

7.2.20.3 Metric calculation method

$$R_{\text{OCH,BD}} = I_{\text{A,ACEI}}/I_{\text{T}} \quad (30)$$

where

$R_{\text{OCH,BD}}$ is the overcharging rate on billing details level;

$I_{\text{A,ACEI}}$ is the number of billing details where the ARCE error, E_{ARCH} , is above the accepted charging error interval in the measurement period;

I_{T} is the total number of billing details in the measurement period;

and

$$E_{\text{ARCH,BD}} = (C_{\text{A,BD}}/C_{\text{E,BD}}) - 1 \quad (31)$$

where

$E_{\text{ARCH,BD}}$ is the ARCE on the billing details level;

$C_{\text{A,BD}}$ is the sum of the actual charges for the billing detail;

$C_{E,BD}$ is the sum of the expected charge for the billing detail;
and the accepted charging error interval is defined with its upper bound (CEUB).
CEUB is determined by the accepted positive percentage deviation from the correct charge.

7.2.21 ET-CM-BD-3 BD — Undercharging rate

7.2.21.1 Metric definition

This metric defines the probability that for any given billing detail, the ARCE is below the accepted charging error interval.

The calculation method for the metric is specified in 7.2.21.3, [Formulae \(32\)](#) and [\(33\)](#).

7.2.21.2 Intended use

This metric can be used to measure the average level of undercharging at the level of trips or line items on the user account statement.

7.2.21.3 Metric calculation method

$$R_{UCH,BD} = I_{B,CELB} / I_T \quad (32)$$

where

$R_{UCH,BD}$ is the undercharging rate on billing details level;

$I_{B,CELB}$ is the number of billing details where the ARCE, E_{ARCH} , is below the accepted charging error lower bound (CELB) in the measurement period;

I_T is the total number of billing details in the measurement period;

and

$$E_{ARCH,BD} = (C_{A,BD} / C_{E,BD}) - 1 \quad (33)$$

where

$E_{ARCH,BD}$ is the ARCE on billing details level;

$C_{A,BD}$ is the sum of the actual charges for the billing detail;

$C_{E,BD}$ is the sum of the expected charge for the billing detail;

and the accepted charging error interval is defined with its lower bound (CELB).

CELB is determined by the accepted negative percentage deviation from the correct charge.

7.2.22 ET-CM-BD-4 BD — Incorrect charging rate

7.2.22.1 Metric definition

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 is not detected).

“Predefined” may be defined by random measurements of determined charge events.

The calculation method for the metric is specified in [7.2.22.3, Formula \(34\)](#).

7.2.22.2 Intended use

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

7.2.22.3 Metric calculation method

$$R_{\text{INC,BD}} = G_{\text{TIBD,TS}}/G_{\text{T}} \quad (34)$$

where

- $R_{\text{INC,BD}}$ is the incorrect charging rate on the billing details level;
- $G_{\text{TIBD,TS}}$ is the number of charge object detections incorrectly associated to billing details, i.e. total number of charge object detections assigned to billing details in the measurement period which are not correctly representing reference data;
- G_{T} is the total number of charge object detections, i.e. total number of charge object detections resulting from the reference data in the measurement period.

7.2.23 ET-CM-BD-5 BD — Latency — TC

7.2.23.1 Metric definition

This metric defines the average time taken between a charge object detection occurring and the associated billing detail being created/sent by the TC.

The calculation method for the metric is specified in [7.2.23.3, Formulae \(35\) and \(36\)](#).

7.2.23.2 Intended use

This metric can be used where there is a requirement for the timeliness of providing charging information to the SU. It may be used in conjunction with similar metrics defined for toll declarations and payment claims, to identify the average processing times for each step of the charging process.

7.2.23.3 Metric calculation method

$$t_{\text{DEL,BD}} = t_{\text{BD,TS}}/I_{\text{TS,TS}} \quad (35)$$

where

- $t_{\text{DEL,BD}}$ is the average delay for creating billing details by the TC;
- $t_{\text{BD,TS}}$ is the sum of billing details delays, $\Sigma t_{\text{BD,DEL}}$, in the measurement period;
- $I_{\text{TS,TS}}$ is the number of billing details sent in the measurement period;

and

$$t_{\text{BD,DEL}} = M_{\text{BD,S}} - M_{\text{CH,F}} \quad (36)$$

where

- $t_{\text{BD,DEL}}$ is the delay for the individual billing detail;

- $M_{BD,S}$ is time the billing detail was sent;
- $M_{CH,F}$ is time of the first associated charge object detection.

7.2.24 ET-CM-BD-6 BD — Late billing details rate

7.2.24.1 Metric definition

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.

The calculation method for the metric is specified in [7.2.24.3, Formula \(37\)](#).

7.2.24.2 Intended use

This metric can be used where there is a requirement for the timeliness of providing charging information to the SU. It may be used in conjunction with similar metrics defined for toll declarations and payment claims.

7.2.24.3 Metric calculation method

$$R_{LATE,BD} = I_{L,TS} / I_{R,TS} \quad (37)$$

where

- $R_{LATE,BD}$ is the rate of late billing details;
- $I_{L,TS}$ is the number of late billing details in the measurement period;
- $I_{R,TS}$ is the number of billing details received in the measurement period;

and late billing detail is where the billing detail delay is greater than the maximum billing detail delay (MBDD).

7.2.25 ET-CM-BD-7 BD — Rejected billing details rate

7.2.25.1 Metric definition

This metric defines the ratio of correctly rejected billing details in relation to the total number of billing details received in the measurement period.

The calculation method for the metric is specified in [7.2.25.3, Formula \(38\)](#).

7.2.25.2 Intended use

This metric can be used to measure the performance of the TC in its ability to correctly generate billing details.

7.2.25.3 Metric calculation method

$$R_{REJ,BD} = I_{CR,TS} / I_{TS,TS} \quad (38)$$

where

- $R_{REJ,BD}$ is the rate of rejected billing details;

$I_{CR,TS}$ is the number of billing details correctly rejected by the TSP in the measurement period;

$I_{TS,TS}$ is the total number of billing details sent by the TC in the measurement period.

7.2.26 ET-CM-BD-8 BD — Incorrectly rejected billing details rate

7.2.26.1 Metric definition

This metric defines the ratio of the incorrectly rejected billing details in relation to the total number of rejected billing details in the measurement period.

The calculation method for the metric is specified in [7.2.26.3, Formula \(39\)](#).

7.2.26.2 Intended use

This metric can be used to measure the TSP's performance in terms of incorrectly rejected billing details, i.e. those which contain no errors and, in case of autonomous schemes, are based on toll declarations.

7.2.26.3 Metric calculation method

$$R_{INCREJ,BD} = I_{IR,TS} / I_{S,TS} \quad (39)$$

where

$R_{INCREJ,BD}$ is the rate of incorrectly rejected billing details;

$I_{IR,TS}$ is the number of billing details incorrectly rejected by the TSP in the measurement period;

$I_{S,TS}$ is the total number of billing details sent by the TC in the measurement period.

7.2.27 ET-CM-BD-9 BD — Inferred billing details rate

7.2.27.1 Metric definition

This metric defines the ratio of inferred billing details in relation to the total number of billing details in the measurement period.

The calculation method for the metric is specified in [7.2.27.3, Formula \(40\)](#).

7.2.27.2 Intended use

This metric is most applicable to discrete schemes where, based on the information in received toll declarations, the TC is able to identify missing charges and generate inferred billing details.

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

7.2.27.3 Metric calculation method

$$R_{INF,BD} = I_{MTD,TS} / I_{S,TS} \quad (40)$$

where

$R_{INF,BD}$ is the rate of inferred billing details;

$I_{\text{MTD,TS}}$ is the number of billing details generated by the TC without an associated toll declaration in the measurement period;

$I_{\text{S,TS}}$ is the total number of billing details sent by the TC in the measurement period.

7.2.28 ET-CM-CR-1 CR— Usage evidence availability

7.2.28.1 Metric definition

This metric measures the time ratio for which an input sensor delivers raw usage data for detection of individual charging events.

NOTE An input sensor in the sense of this metric is understood as a single sensor or a cluster of sensors and can optionally be supported by additional FE functions and algorithms.

The calculation method for the metric is specified in [7.2.28.3, Formula \(41\)](#).

7.2.28.2 Intended use

This metric can be used to measure the ratio of time during which a sensor provides valid usage evidence for detection of individual charging events, e.g. measuring the ratio of time frames where raw usage data like GNSS positions are gathered and delivered for subsequent charging event detection in relation to the total measured time.

7.2.28.3 Metric calculation method

$$M_{\text{EVID,CR}} = M_{\text{T,VUE}} / M_{\text{T}} \quad (41)$$

where

$M_{\text{EVID,CR}}$ is the relative time for providing usage evidence for the detection of charging events;

$M_{\text{T,VUE}}$ is the cumulated time in which the input sensors provide valid usage evidence for detection of charging events;

M_{T} is the total amount of time.

7.2.29 ET-CM-CR-2 CR— Usage evidence integrity

7.2.29.1 Metric definition

This metric measures the quality of the raw usage data.

The calculation method for the metric is specified in [7.2.29.3, Formulae \(42\) and \(43\)](#).

7.2.29.2 Intended use

This metric can be used to evaluate the quality of raw usage data as generated by the input sensors.

For example, it is intended to evaluate the quality of positioning outputs generated by GNSS receivers in autonomous systems and measure the relative amount of data points for a parameter of positioning outputs whose accuracy is within a specified error bound. An individual integrity value can be measured separately for all possible different input parameters. In autonomous systems, parameters of the positioning outputs may include:

- position of the vehicle in a reference coordinate system;

- velocity as the vector describing the magnitude of rate of change for a vehicle in a given direction and speed as the scalar quantity of the velocity vector; and
- heading as the angle between a vehicle's longitudinal axis forward direction and the North direction measured clockwise along the horizontal plane (e.g. for vehicles looking northwards, eastwards, southwards and westwards, the corresponding headings would be 0°, 90°, 180° and 270° respectively), as described in EN 16803-1.

7.2.29.3 Metric calculation method

$$R_{\text{UEINT,CR}} = W_{\text{W,AERI}} / W_{\text{T}} \quad (42)$$

where

$R_{\text{UEINT,CR}}$ is the rate of usage evidence integrity;

$W_{\text{W,AERI}}$ is the number of raw data points where the relative evidence error, E_{RE} , is within the accepted evidence error intervals in the measurement period;

W_{T} is the number of raw usage data points in the measurement period;

and

$$E_{\text{RE}} = (Q_{\text{A}} / Q_{\text{E}}) - 1 \quad (43)$$

where

E_{RE} is the relative evidence error;

Q_{A} is the actual evidence accuracy;

Q_{E} is the expected evidence accuracy;

and the accepted evidence error interval shall be specified as a target quality parameter.

7.2.30 ET-CM-CR-3 CR- Usage evidence time-to-first-fix

7.2.30.1 Metric definition

This metric is defined as the average time for an input sensor to be ready to start collecting and sending relevant usage evidence.

The calculation method for the metric is specified in [7.2.30.3, Formula \(44\)](#).

7.2.30.2 Intended use

This metric measures the average time an input sensor needs for start-up in order to start collecting and sending relevant usage evidence for detection of individual charge events.

In the context of autonomous systems, this metric measures how long it takes to obtain a positioning fix in a GNSS-based positioning terminal (GBPT). Following the description in EN 16803-1, different starting conditions of the OBE may be distinguished:

- cold start, where neither information on satellites (i.e. the almanac), their current trajectories (i.e. the ephemeris), nor time and last position of the vehicle is available;
- warm start, where almanac, time and last position but no ephemeris is available;

- hot start, where almanac and ephemeris of satellites and time and last position of the vehicle is available.

7.2.30.3 Metric calculation method

$$M_{FF,CR} = t_{FF,TS} / N_{SUI,TS} \quad (44)$$

where

- $M_{FF,CR}$ is the average time to first fix (i.e. to start generating raw usage data);
- $t_{FF,TS}$ is the sum of the total delay until a first fix over all input sensors in the measurement period;
- $N_{SUI,TS}$ is the number of start-ups of all input sensors in the measurement report.

7.3 Technology-dependent tests

7.3.1 Autonomous discrete specific examination tests

7.3.1.1 General

For autonomous discrete systems, all tests defined in 7.2 are applicable. In addition, the measurements defined in 7.3.1 can be used.

The toll declarations are sent by the TSP back end on the respective interface to the TC. This interface conforms to ISO 12855.

The charge reports are sent by the TSP front end to the TSP back end.

The reference data is collected using the methods and prescriptions of 5.4.

7.3.1.2 ET-CM-TD-1 TD — Correct toll declaration generation rate

7.3.1.2.1 Metric definition

This metric defines the probability that a toll declaration is correctly generated.

The calculation method for the metric is specified in 7.3.1.2.3, Formula (45).

7.3.1.2.2 Intended use

This metric measures the performance of a TSP system in generating correct toll declarations.

7.3.1.2.3 Metric calculation method

$$R_{COR,TD} = O_{TC,TS} / O_{T,TS} \quad (45)$$

where

- $R_{COR,TD}$ is the rate of the correct toll declarations;
- $O_{TC,TS}$ is the number of correctly generated toll declarations, i.e. the number of toll declarations generated during the measurement period by the TSP-BE which are consistent with the respective total number of charge object detections resulting from the reference data correctly assigned to toll declarations in the measurement period; consistency requires correct representation of all charge object detections;

$O_{T,TS}$ is the total number of toll declarations, i.e. the number of toll declarations generated by the TSP-BE in the measurement period.

7.3.1.3 ET-CM-TD-2 TD — Incorrect toll declaration generation rate

7.3.1.3.1 Metric definition

This metric defines the probability that a toll declaration is incorrectly generated.

The calculation method for the metric is specified in [7.3.1.3.3](#), [Formula \(46\)](#).

7.3.1.3.2 Intended use

This metric measures the performance of a TSP system in generating incorrect toll declarations.

7.3.1.3.3 Metric calculation method

$$R_{INC,TD} = O_{TI,TS} / O_{T,TS} \quad (46)$$

where

$R_{INC,TD}$ is the rate of incorrect toll declarations

$O_{TI,TS}$ is the **number of incorrectly generated toll declarations**, i.e. the number of toll declarations generated during the measurement period by the TSP-BE which are inconsistent with the respective total number of charge object detections resulting from the reference data correctly assigned to toll declarations in the measurement period. Consistency requires correct representation of all charge object detections;

$O_{T,TS}$ is the total number of toll declarations, i.e. the number of toll declarations generated by the TSP-BE in the measurement period.

7.3.1.4 ET-CM-TD-3 TD — Late toll declarations rate

7.3.1.4.1 Metric definition

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.

The calculation method for the metric is specified in [7.3.1.4.3](#), [Formula \(47\)](#).

7.3.1.4.2 Intended use

This metric measures the performance of the TSP system in terms of the delays occurring in the process of generating toll declarations.

7.3.1.4.3 Metric calculation method

$$R_{LATE,TD} = O_{TL,TS} / O_{T,TS} \quad (47)$$

where

$R_{LATE,TD}$ is the rate of the late toll declarations;

$O_{TL,TS}$ is the number of late toll declarations, i.e. the number of toll declarations generated during the measurement period by the TSP-BE which are delayed by a time longer than maximum toll declaration delay (MTDD) after the actual occurrence of the last of the respective charging events as determined from the reference data;

$O_{T,TS}$ is the total number of toll declarations, i.e. the number of toll declarations generated by the TSP-BE in the measurement period.

The maximum toll declaration delay (MTDD), i.e. maximum acceptable delay, shall be chosen before performing the test and agreed upon by the parties involved, e.g. with an SLA.

7.3.1.5 ET-CM-TD-4 TD — TSP charge parameter change rate

7.3.1.5.1 Metric definition

This metric defines the probability that for any predefined charge parameter change that takes place the TSP properly detects it.

The calculation method for the metric is specified in [7.3.1.5.3, Formula \(48\)](#).

7.3.1.5.2 Intended use

This metric measures the reliability of the detection and representation in toll declarations of charge parameter changes in the TSP system.

NOTE It is important to be aware of the distinction between charge parameter changes and charging events.

7.3.1.5.3 Metric calculation method

$$R_{PARA,TD} = O_{TC,TS} / O_{T,TS} \quad (48)$$

where

$R_{PARA,TD}$ is the rate of correct detection of charge parameter changes;

$O_{TC,TS}$ is the number of correct toll declarations, i.e. the number of toll declarations containing the charge parameter changes expected based on the reference data during the measurement period;

$O_{T,TS}$ is the total number of toll declarations sent by the TSP in the measurement period.

7.3.1.6 ET-CM-TD-5 TD — TSP False positive rate

7.3.1.6.1 Metric definition

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.

The calculation method for the metric is specified in [7.3.1.6.3, Formula \(49\)](#).

7.3.1.6.2 Intended use

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

7.3.1.6.3 Metric calculation method

$$R_{\text{FPOS,TD}} = O_{\text{TFFP,TS}} / O_{\text{T,TS}} \quad (49)$$

where

- $R_{\text{FPOS,TD}}$ is the value of the false positive rate in toll declarations;
- $O_{\text{TFFP,TS}}$ is the number of toll declarations containing false positives which occur during the measurement period;
- $O_{\text{T,TS}}$ is the total number of toll declarations sent by the TSP in the measurement period.

7.3.1.7 ET-CM-DTD-1 DTD — Correct charging rate (charge object detections)

7.3.1.7.1 Metric definition

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 events.

The calculation method for the metric is specified in [7.3.1.7.3, Formula \(50\)](#).

7.3.1.7.2 Intended use

This metric tests if each single charge object detection in the reference data is represented accordingly in the respective toll declaration, measuring the performance of the TSP system for single charge object detections.

7.3.1.7.3 Metric calculation method

$$R_{\text{CCH,TD}} = G_{\text{TCTD,TS}} / G_{\text{T,TS}} \quad (50)$$

where

- $R_{\text{CCH,TD}}$ is the correct charging rate on the toll declaration level;
- $G_{\text{TCTD,TS}}$ is the number of charge object detections associated to toll declarations, i.e. total number of charge object detections resulting from the reference data correctly assigned to toll declarations in the measurement period;
- $G_{\text{T,TS}}$ is the total number of charge object detections, i.e. total number of charge object detections resulting from the reference data in the measurement period.

7.3.1.8 ET-CM-DTD-2 DTD — Incorrect charge event recognition rate

7.3.1.8.1 Metric definition

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 events.

The calculation method for the metric is specified in [7.3.1.8.3, Formula \(51\)](#).

7.3.1.8.2 Intended use

This metric measures the rate of charge object detections incorrectly detected by the TSP system, i.e. which contain incorrect information (e.g. vehicle category, time, road category, etc.).

7.3.1.8.3 Metric calculation method

$$R_{\text{INC,TD}} = G_{\text{TITD,TS}}/G_{\text{T,TS}} \quad (51)$$

where

- $R_{\text{INC,TD}}$ is the rate of incorrectly detected charge objects in toll declarations;
- $G_{\text{TITD,TS}}$ is the number of charge object detections incorrectly associated to toll declarations, i.e. the total number of charge object detections assigned to toll declarations in the measurement period which are not correctly representing reference data;
- $G_{\text{T,TS}}$ is the total number of charge object detections, i.e. total number of charge object detections resulting from the reference data in the measurement period.

7.3.1.9 ET-CM-DTD-3 DTD — Missed charge object detection rate

7.3.1.9.1 Metric definition

This metric defines the probability that for any predefined charge object detection, an entry in the respective toll declaration is not generated.

The calculation method for the metric is specified in [7.3.1.9.3, Formula \(52\)](#).

7.3.1.9.2 Intended use

This test measures the rate of missed recognition of charge events, i.e. the rate of charge events missing in the toll declarations.

7.3.1.9.3 Metric calculation method

$$R_{\text{MIS,TD}} = G_{\text{TNTD,TS}}/G_{\text{T,TS}} \quad (52)$$

where

- $R_{\text{MIS,TD}}$ is the rate of the missed charge objects in toll declarations;
- $G_{\text{TNTD,TS}}$ is the number of charge object detections not associated to toll declarations, i.e. total number of charge object detections resulting from the reference data in the measurement period not assigned to toll declarations;
- $G_{\text{T,TS}}$ is the total number of charge object detections, i.e. the total number of charge object detections resulting from the reference data in the measurement period.

7.3.1.10 ET-CM-DTD-4 DTD — Overcharging rate

7.3.1.10.1 Metric definition

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).

The calculation method for the metric is specified in [7.3.1.10.3, Formula \(53\)](#).

7.3.1.10.2 Intended use

While the test ET-CM-TD-5 TD — TSP false positive rate counts the rate of toll declarations containing false positives, this test measures the rate of single false positives compared to the overall number of charge events.

7.3.1.10.3 Metric calculation method

$$R_{\text{OCH,TD}} = V_{\text{TITD}}/G_{\text{T,TS}} \quad (53)$$

where

- $R_{\text{OCH,TD}}$ is the overcharging rate on toll declaration level;
- V_{TITD} is the number of charge events associated to toll declarations which do not result from the reference data, i.e. number of charge events in toll declarations which do not represent actual usage of charged infrastructure;
- $G_{\text{T,TS}}$ is the total number of charge object detections, i.e. the total number of charge object detections resulting from the reference data in the measurement period.

7.3.1.11 ET-CM-CR-1 CR — Correct charge report generation rate

7.3.1.11.1 Metric definition

This metric defines the probability that a charge report is correctly generated.

The calculation method for the metric is specified in [7.3.1.11.3, Formula \(54\)](#).

7.3.1.11.2 Intended use

This test measures the rate of charge reports not containing errors.

7.3.1.11.3 Metric calculation method

$$R_{\text{COR,CR}} = P_{\text{TCCE}}/P_{\text{T,TS}} \quad (54)$$

where

- $R_{\text{COR,CR}}$ is the rate of correct charge report generation;
- P_{TCCE} is the number of correctly generated charge reports, i.e. the number of charge reports which contain only charge events and charge parameter changes consistent with the reference data in the measurement period;
- $P_{\text{T,TS}}$ is the total number of charge reports, i.e. the total number of charge reports generated by the TSP-FE in the measurement period.

7.3.1.12 ET-CM-CR-2 CR — Incorrect charge report generation rate

7.3.1.12.1 Metric definition

This metric defines the probability that a charge report is incorrectly generated.

The calculation method for the metric is specified in [7.3.1.12.3, Formula \(55\)](#).

7.3.1.12.2 Intended use

This test measures the rate of charge reports containing errors.

7.3.1.12.3 Metric calculation method

$$R_{\text{INC,CR}} = P_{\text{TICE}}/P_{\text{T,TS}} \quad (55)$$

where

$R_{\text{INC,CR}}$ is the rate of incorrect charge report generation;

P_{TICE} is the number of incorrectly generated charge reports, i.e. the number of charge reports which contain charge events that are not consistent with the reference data in the measurement period;

$P_{\text{T,TS}}$ is the total number of charge reports, i.e. the total number of charge reports generated by the TSP-FE in the measurement period.

7.3.1.13 ET-CM-CR-3 CR — Charge report latency

7.3.1.13.1 Metric definition

This metric defines the average time it takes between a charge event and the time the charge report is created/received by the TSP.

The calculation method for the metric is specified in [7.3.1.13.3, Formula \(56\)](#).

7.3.1.13.2 Intended use

This test gives the average latency of charge events until they are received from the FE. Therefore, it gives information about the average FE performance.

7.3.1.13.3 Metric calculation method

$$t_{\text{DEL,CR}} = \frac{1}{n} \sum_{i=1}^n a_i \quad (56)$$

where

$t_{\text{DEL,CR}}$ is the average delay in charge report generation;

a_i is the time span between the occurrence of charge object detection with index i as determined from the reference data and the reception of the respective charge report from the FE in the measurement period;

n is the number of charge object detections in the measurement period.

If the measurement period was chosen accordingly, this test could be used to determine the average delay for the data in a single charge report. If a longer period was chosen, it could also give the average delay over multiple charge reports.

Be aware that the measurement period influences this metric. If 24 h is chosen, for example, the average resulting latency shall be greater than 12 h for evenly spaced charge object detections.

7.3.1.14 ET-CM-CR-4 CR — TSP-FE charge parameter change rate

7.3.1.14.1 Metric definition

This metric defines the probability that the FE properly detects any defined charge parameter change that takes place.

The calculation method for the metric is specified in [7.3.1.14.3](#), [Formula \(57\)](#).

7.3.1.14.2 Intended use

This test measures the percentage of charge parameter changes which are correctly reflected in charge reports generated by the TSP-FE.

NOTE It is important to be aware of the distinction between charge parameter changes and charging events.

7.3.1.14.3 Metric calculation method

$$R_{\text{PARA,CR}} = F_{\text{CCCR}}/F_{\text{T,TS}} \quad (57)$$

where

$R_{\text{PARA,CR}}$ is the rate of correct detection of charge parameter changes in charge reports;

F_{CCCR} is the number of charge parameter changes which are correctly represented in charge reports received from the TSP-FE;

$F_{\text{T,TS}}$ is the total number of charge parameter changes as determined from the reference data in the measurement period.

7.3.1.15 ET-CM-CR-5 CR — TSP-FE false positive rate

7.3.1.15.1 Metric definition

For vehicles not using the infrastructure, this metric defines the probability that for any predefined charge object detection, the FE improperly detects it.

The calculation method for the metric is specified in [7.3.1.15.3](#), [Formula \(58\)](#).

7.3.1.15.2 Intended use

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

7.3.1.15.3 Metric calculation method

$$R_{\text{FPOS,CR}} = P_{\text{TFP,TS}}/P_{\text{T,TS}} \quad (58)$$

where

$R_{\text{FPOS,CR}}$ is the false positive rate in charge reports;

$P_{\text{TFP,TS}}$ is the number of charge reports containing false positives, i.e. containing charge events relevant for the measurement period which do not correspond to actual usage of charged infrastructure;

$P_{T,TS}$ is the total number of charge reports, i.e. the total number of charge reports generated by the TSP front end for the measurement period.

7.3.1.16 ET-CM-DCR-1 DCR — Correct charging rate (charge object detections)

7.3.1.16.1 Metric definition

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.

The calculation method for the metric is specified in [7.3.1.16.3, Formula \(59\)](#).

7.3.1.16.2 Intended use

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

7.3.1.16.3 Metric calculation method

$$R_{DET,CR} = G_{TCCR,TS}/G_{T,TS} \quad (59)$$

where

$R_{DET,CR}$ is the rate of correctly detected charge objects in charge reports;

$G_{TCCR,TS}$ is the number of correctly detected charge object detections in all charge reports relevant for the measurement period;

$G_{T,TS}$ is the total number of charge object detections, i.e. the total number of charge object detections as determined from the reference data in the measurement period.

7.3.1.17 ET-CM-DCR-2 DCR — Incorrect charge event recognition rate

7.3.1.17.1 Metric definition

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.

The calculation method for the metric is specified in [7.3.1.17.3, Formula \(60\)](#).

7.3.1.17.2 Intended use

This test measures the percentage of charge events in the charge reports containing errors, but which correspond to actual charge object detections.

7.3.1.17.3 Metric calculation method

$$R_{INC,CR} = V_{IICR,TS}/V_{T,TS} \quad (60)$$

where

$R_{INC,CR}$ is the rate of the incorrectly detected charge objects in charge reports;

$V_{\text{IICR,TS}}$ is the number of charge events in all charge reports containing wrong information (not detected correctly) relevant for the measurement period;

$V_{\text{T,TS}}$ is the total number of charge events, i.e. the total number of charge events as determined from the charge reports relevant for the measurement period.

7.3.1.18 ET-CM-DCR-3 DCR — Missed charge object detection rate

7.3.1.18.1 Metric definition

This metric defines the probability that for any predefined *charge object detection*, an entry in the respective charge report is not generated.

The calculation method for the metric is specified in [7.3.1.18.3, Formula \(61\)](#).

7.3.1.18.2 Intended use

This test determines the percentage of charge object detections which are missed by the TSP-FE, resulting in undercharging.

7.3.1.18.3 Metric calculation method

$$R_{\text{MIS,CR}} = G_{\text{NRCS,TS}}/G_{\text{T,TS}} \quad (61)$$

where

$R_{\text{MIS,CR}}$ is the rate of missed charge objects in toll declarations;

$G_{\text{NRCS,TS}}$ is the number of charge object detections not represented in any charge report relevant for the measurement period;

$G_{\text{T,TS}}$ is the total number of charge object detections, i.e. the total number of charge object detections as determined from the reference data in the measurement period.

7.3.1.19 ET-CM-DCR-4 DCR — Overcharging rate (Incorrect false positive charge event recognition)

7.3.1.19.1 Metric definition

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").

The calculation method for the metric is specified in [7.3.1.19.3, Formula \(62\)](#).

7.3.1.19.2 Intended use

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

7.3.1.19.3 Metric calculation method

$$R_{\text{OCH,CR}} = V_{\text{TIU}}/G_{\text{T,TS}} \quad (62)$$

where

- $R_{\text{OCH,CR}}$ is the overcharging rate on the charge report level;
- V_{TIU} is the number of charge events in the charge reports which do not correspond to actual infrastructure usage as determined from the reference data in the measurement period;
- $G_{\text{T,TS}}$ is the total number of charge object detections, i.e. the total number of charge object detections as determined from the reference data in the measurement period.

7.3.2 Discrete — Optional toll declaration metrics

7.3.2.1 General

For discrete scheme types, discrete schemes evaluation tests may be selected from 7.2. In addition, the metrics in 7.3.2.2 to 7.3.2.6 may be selected to measure the internal performance of the TC.

NOTE Formally, these metrics can only be specified for autonomous systems, where the interfaces for charge reports and toll declarations are standardized. On the other hand, it can also be used in discrete systems. In this case, the transactions (whether on the air interface OBE-RSE in case of DSRC-based systems or detection and correct recognition of the vehicle licence plate in case of ANPR-based system) replace the ISO 12855 charge reports. The toll declarations of proprietary format on the interface RSE - TC-BE replace the toll declarations defined in ISO 12855.

7.3.2.2 ET-CM-TD-1 TD — Correct toll declaration generation rate

7.3.2.2.1 Metric definition

This metric defines the probability that a toll declaration is correctly generated.

The calculation method for the metric is specified in 7.3.2.2.3, Formula (63).

7.3.2.2.2 Intended use

This metric measures the performance of a TC system in generating correct toll declarations.

7.3.2.2.3 Metric calculation method

$$R_{\text{CORDIS,TD}} = O_{\text{TCCH,TS}} / O_{\text{T,TS}} \quad (63)$$

where

- $R_{\text{CORDIS,TD}}$ is the correct toll declaration generation rate in discrete schemes;
- $O_{\text{TCCH,TS}}$ is the number of correctly generated toll declarations, i.e. number of toll declarations generated during the measurement period by the TC front end which are consistent with the respective total number of charge object detections resulting from the reference data correctly assigned to toll declarations in the measurement period. Consistency requires correct representation of all charge object detections;
- $O_{\text{T,TS}}$ is the total number of toll declarations, i.e. number of toll declarations generated by the TC front end in the measurement period.

7.3.2.3 ET-CM-TD-2 TD — Incorrect toll declaration generation rate

7.3.2.3.1 Metric definition

This metric defines the probability that a DSRC toll declaration is incorrectly generated.

The calculation method for the metric is specified in [7.3.2.3.3, Formula \(64\)](#).

7.3.2.3.2 Intended use

This metric measures the performance of a TC system in generating incorrect toll declarations.

7.3.2.3.3 Metric calculation method

$$R_{\text{INCDIS,TD}} = O_{\text{TICH,TS}} / O_{\text{T,TS}} \quad (64)$$

where

- $R_{\text{INCDIS,TD}}$ is the rate of incorrect toll declarations in discrete schemes;
- $O_{\text{TICH,TS}}$ is the number of incorrectly generated toll declarations, i.e. the number of toll declarations generated during the measurement period by the TC front end which are inconsistent with the respective total number of charge object detections resulting from the reference data correctly assigned to toll declarations in the measurement period; consistency requires correct representation of all charge object detections;
- $O_{\text{T,TS}}$ is the total number of toll declarations, i.e. the number of toll declarations generated by the TC front end in the measurement period.

7.3.2.4 ET-CM-TD-3 TD — Late toll declarations rate

7.3.2.4.1 Metric definition

This metric defines the proportion of toll declarations generated by the TC in a defined period where the time between the charge object detection and the generation of the associated toll declaration is greater than the defined period for the charging scheme.

The calculation method for the metric is specified in [7.3.2.4.3, Formula \(65\)](#).

7.3.2.4.2 Intended use

This metric measures the performance of the TC system in terms of the delays occurring in the process of generating toll declarations. Late toll declarations are most likely to occur when there is a communication outage between the RSE and the TC-BE.

7.3.2.4.3 Metric calculation method

$$R_{\text{LATEDIS,TD}} = O_{\text{TDTD,TS}} / O_{\text{T,TS}} \quad (65)$$

where

- $R_{\text{LATEDIS,TD}}$ is the rate of late toll declarations in discrete schemes;
- $O_{\text{TDTD,TS}}$ is the number of late toll declarations, i.e. the number of toll declarations generated during the measurement period by the TC front end which are delayed by a time longer than maximum toll declaration delay (MTDD) after the actual occurrence of the respective charging events as determined from the reference data;
- $O_{\text{T,TS}}$ is the total number of toll declarations, i.e. the number of toll declarations generated by the TC front end in the measurement period.

The maximum toll declaration delay (MTDD), i.e. maximum acceptable delay, shall be chosen before performing the test and agreed upon by the parties involved, e.g. with an SLA.

7.3.2.5 ET-CM-TD-4 TD — TSP Charge parameter change rate

7.3.2.5.1 Metric definition

This metric defines the probability that for any predefined charge parameter change that takes place, the TC properly detects it.

The calculation method for the metric is specified in [7.3.2.5.3, Formula \(66\)](#).

7.3.2.5.2 Intended use

This metric measures the reliability of the detection and representation in toll declarations of DSRC charge parameter changes in the TC system.

NOTE It is important to be aware of the distinction between charge parameter changes and charging events.

7.3.2.5.3 Metric calculation method

$$R_{\text{PARADIS,TD}} = O_{\text{TCCP,TS}} / O_{\text{T,TS}} \quad (66)$$

where

$R_{\text{PARADIS,TD}}$ is the rate of correct detection of charge parameter changes in toll declarations in discrete schemes;

$O_{\text{TCCP,TS}}$ is the number of correct toll declarations, i.e. the number of toll declarations containing the DSRC charge parameter changes expected based on the reference data during the measurement period;

$O_{\text{T,TS}}$ is the total number of toll declarations generated by the TC in the measurement period.

7.3.2.6 ET-CM-TD-5 TD — TSP False positive rate

7.3.2.6.1 Metric definition

For vehicles not using the infrastructure, this metric defines the probability that for any defined charge object detection, the TC improperly detects it during the creation of toll declarations.

The calculation method for the metric is specified in [7.3.2.6.3, Formula \(67\)](#).

7.3.2.6.2 Intended use

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

7.3.2.6.3 Metric calculation method

$$R_{\text{FPOSDIS,TD}} = O_{\text{TFTP,TS}} / O_{\text{T,TS}} \quad (67)$$

where

$R_{\text{FPOSDIS,TD}}$ is the rate of the false positives in toll declarations in discrete schemes;

$O_{\text{TFTP,TS}}$ is the number of toll declarations containing false positives which occur during the measurement period;

$O_{T,TS}$ is the total number of toll declarations generated by the TC in the measurement period.

7.3.3 Autonomous continuous specific examination tests

7.3.3.1 General

For autonomous continuous systems, all tests defined in [7.2](#) are applicable. In addition, the measurements defined in [7.3.3](#) can be used.

The toll declarations are sent by the TSP-BE on the respective interface to the TC. This interface conforms to ISO 12855.

The charge reports are sent by the TSP-FE end to the TSP-BE. This interface is designed according to ISO 17575-1.

The reference data are collected using the methods and prescriptions defined in [5.4](#).

7.3.3.2 ET-CM-TD-1 TD — Correct toll declaration generation rate

7.3.3.2.1 Metric definition

This metric defines the probability that a toll declaration (based on a GNSS OBE) is correctly generated.

The calculation method for the metric is specified in [7.3.3.2.3](#), [Formula \(68\)](#).

7.3.3.2.2 Intended use

With this metric, a TSP can measure the overall performance of the system, including its own TSP-BE (in generating toll declarations) and its own TSP-FE (in generating charge reports).

7.3.3.2.3 Metric calculation method

$$R_{\text{CORCONT,TD}} = O_{\text{TC,TS}} / O_{\text{T,TS}} \quad (68)$$

where

$R_{\text{CORCONT,TD}}$ is the rate of correct toll declarations in continuous schemes;

$O_{\text{TC,TS}}$ is the number of correctly generated toll declarations during the measurement period by the TSP-BE;

$O_{\text{T,TS}}$ is the total number of toll declarations, i.e. number of toll declarations generated by the TSP-BE in the measurement period.

7.3.3.3 ET-CM-TD-2 TD — Incorrect toll declaration generation rate

7.3.3.3.1 Metric definition

This metric defines the probability that a toll declaration (based on a GNSS OBE) is incorrectly generated.

The calculation method for the metric is specified in [7.3.3.3.3](#), [Formula \(69\)](#).

7.3.3.3.2 Intended use

With this metric, a TSP can measure the overall performance of the system, including its own TSP-BE (in generating toll declarations) and its own TSP-FE (in generating charge reports).

7.3.3.3.3 Metric calculation method

$$R_{\text{INCCONT,TD}} = O_{\text{TI,TS}} / O_{\text{T,TS}} \quad (69)$$

where

$R_{\text{INCCONT,TD}}$ is the rate of incorrect toll declarations in continuous schemes;

$O_{\text{TI,TS}}$ is the number of incorrectly generated toll declarations, i.e. the number of incorrect toll declarations generated during the measurement period by the TSP-BE;

$O_{\text{T,TS}}$ is the total number of toll declarations, i.e. the number of toll declarations generated by the TSP-BE in the measurement period.

7.3.3.4 ET-CM-TD-3 TD — Late toll declarations rate

7.3.3.4.1 Metric definition

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.

The calculation method for the metric is specified in [7.3.3.4.3, Formula \(70\)](#).

7.3.3.4.2 Intended use

This metric measures the performance of the TSP system in terms of the delays occurring in the process of generating toll declarations.

7.3.3.4.3 Metric calculation method

$$R_{\text{LATECONT,TD}} = O_{\text{TDTD,TS}} / O_{\text{T,TS}} \quad (70)$$

where

$R_{\text{LATECONT,TD}}$ is the rate of late toll declarations in continuous schemes;

$O_{\text{TDTD,TS}}$ is the number of late toll declarations, i.e. the number of toll declarations generated during the measurement period by the TSP-BE which are delayed by a time longer than the maximum toll declaration delay (MTDD) after the actual occurrence of the last of the respective charging events;

$O_{\text{T,TS}}$ is the total number of toll declarations, i.e. the number of toll declarations generated by the TSP-BE in the measurement period.

7.3.3.5 ET-CM-TD-4 TD — TSP charge parameter change rate

7.3.3.5.1 Metric definition

This metric defines the probability that for any predefined charge parameter change that takes place, the TSP properly detects it.

The calculation method for the metric is specified in [7.3.3.5.3, Formula \(71\)](#).

7.3.3.5.2 Intended use

This metric measures the reliability of the detection of charge parameter changes in the TSP system.

NOTE It is important to be aware of the distinction between charge-relevant events and charging events.

7.3.3.5.3 Metric calculation method

$$R_{\text{PARACONT,TD}} = F_{\text{CTD,TS}} / F_{\text{TTD,TS}} \quad (71)$$

where

$R_{\text{PARACONT,TD}}$ is the rate of correct detection of charge parameter changes in toll declarations in continuous schemes;

$F_{\text{CTD,TS}}$ is the number of correctly detected charge parameter changes in the toll declarations, during the measurement period;

$F_{\text{TTD,TS}}$ is the total number of detected charge parameter changes in the toll declarations sent by the TSP in the measurement period.

7.3.3.6 ET-CM-TD-5 TD — TSP false positive rate

7.3.3.6.1 Metric definition

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.

The calculation method for the metric is specified in [7.3.3.6.3, Formula \(72\)](#).

7.3.3.6.2 Intended use

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

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

7.3.3.6.3 Metric calculation method

$$R_{\text{FPOSCONT,TD}} = U_{\text{TTD,TS}} / Y_{\text{OT,TS}} \quad (72)$$

where

$R_{\text{FPOSCONT,TD}}$ is the rate of the false positives in toll declarations in continuous schemes;

$U_{\text{TTD,TS}}$ is the number of false positives identified in all toll declarations which are generated during the measurement period;

$Y_{\text{OT,TS}}$ is the total number of passes of vehicles in the proximity (but outside) the charging objects in the measurement period.

7.3.3.7 ET-CM-CTD-1 CTD — Correct charging rate

7.3.3.7.1 Metric definition

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.

The calculation method for the metric is specified in [7.3.3.7.3, Formula \(73\)](#).

7.3.3.7.2 Intended use

This metric provides overall information for the TSP and the TC on the capabilities of the system, in particular the OBE, to compute toll declarations whose charges are within the accepted charging interval, i.e. ensuring that charges cover a very high percentage of the due incomes (to ensure the viability of the system) and limiting the charges in excess (overcharging) to avoid claims and for providing credibility for the SUs and the authority.

7.3.3.7.3 Metric calculation method

$$R_{\text{CORCONT,TD}} = T_{\text{S,W,ACEI,TS}} / T_{\text{T,S}} \quad (73)$$

where

- $R_{\text{CORCONT,TD}}$ is the rate of the correct toll declarations in continuous schemes;
- $T_{\text{S,W,ACEI,TS}}$ is the number of sets of representative trips travelled by a vehicle during a certain period of time whose ARCE is within the accepted charging error interval in the measurement period;
- $T_{\text{T,S}}$ is the overall number of sets of representative trips analysed in the measurement period.

It shall be determined whether several sets of representative trips shall be independent for each sample or the same trips can be used for more than one set. The second option seems to provide a more reliable metric.

7.3.3.8 ET-CM-CTD-2 CTD — Overcharging rate

7.3.3.8.1 Metric definition

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.

The calculation method for the metric is specified in [7.3.3.8.3, Formula \(74\)](#).

7.3.3.8.2 Intended use

This metric provides overall information for the TSP, the TC, authority and users on the capabilities of the system, in particular the OBE, to compute toll declarations whose charges are not larger than the accepted charging interval, i.e. ensuring that the probability of charges in excess (overcharging) is properly bounded providing credibility for the users and the authority.

7.3.3.8.3 Metric calculation method

$$R_{\text{TDOCH,CONT}} = T_{\text{W,ACEI,TS}} / T_{\text{T}} \quad (74)$$

where

- $R_{\text{OCHCONT,TD}}$ is the overcharging rate on toll declaration level in continuous schemes;
- $T_{\text{W,ACEI,TS}}$ is the number of representative trips travelled by a vehicle during a certain period of time whose RCE is above the upper bound of the accepted charging error interval in the measurement period;
- T_{T} is the overall number of representative trips analysed in the measurement period.

7.3.3.9 ET-CM-CTD-3 CTD — Accuracy of distance/time measurement

7.3.3.9.1 Metric definition

This metric defines 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.

The calculation method for the metric is specified in 7.3.3.9.3, Formulae (75), (76) and (77).

7.3.3.9.2 Intended use

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

7.3.3.9.3 Metric calculation method

$$q_{\text{ACC,TD}} = \frac{\left(\sum_{i=0}^n E_{\text{REL,TD},i} \right)}{n} \quad (75)$$

$$q_{\text{DEV,ACC,TD}} = \sqrt{\frac{\left(\sum_{i=0}^n E_{\text{REL,TD},i}^2 \right)}{n}} \quad (76)$$

where

$$E_{\text{REL,TD},i} = \frac{(m-r)}{r} \quad (77)$$

and where

- $q_{\text{ACC,TD}}$ is the average value of the accuracy of the time/distance measurement;
- $q_{\text{DEV,ACC,TD}}$ is the standard deviation of the average value of the accuracy of the time/distance measurement;
- $E_{\text{REL,TD}}$ is the relative error of the time/distance measurement;
- n is the number of representative trips considered;
- m is the one supplied by the system (could also be time);
- r is the one measured by the reference system (could also be time).

7.3.3.10 ET-CM-CR-1 CR — Correct charge report generation rate

7.3.3.10.1 Metric definition

This metric defines the probability that a charge report (based on a GNSS OBE) is correctly generated.

The calculation method for the metric is specified in [7.3.3.10.3](#), [Formula \(78\)](#).

7.3.3.10.2 Intended use

With this metric, a FE provider and a TSP can measure the performance of the FE as far as computation of charge reports is concerned.

7.3.3.10.3 Metric calculation method

$$R_{\text{CORCONT,CR}} = P_{\text{TCV,TS}} / P_{\text{TV,TS}} \quad (78)$$

where

$R_{\text{CORCONT,CR}}$ is the rate of correct charge reports in continuous schemes;

$P_{\text{TCV,TS}}$ is the number of correctly generated charge reports during the measurement period and for a given number of vehicles by the FE;

$P_{\text{TV,TS}}$ is total number of charge reports, i.e. the number of charge reports generated by a given number of vehicles by the FE in the measurement period.

7.3.3.11 ET-CM-CR-2 CR — Incorrect charge report generation rate

7.3.3.11.1 Metric definition

This metric defines the probability that a charge report (based on a GNSS OBE) is incorrectly generated.

The calculation method for the metric is specified in [7.3.3.11.3](#), [Formula \(79\)](#).

7.3.3.11.2 Intended use

With this metric, a FE provider and a TSP can measure the performance of the FE in respect to the computation of charge reports.

7.3.3.11.3 Metric calculation method

$$R_{\text{INCCONT,CR}} = P_{\text{TIV,TS}} / P_{\text{TV,TS}} \quad (79)$$

where

$R_{\text{INCCONT,CR}}$ is the rate of incorrect charge reports in continuous schemes;

$P_{\text{TIV,TS}}$ is the number of incorrectly generated charge reports during the measurement period for a given number of vehicles by the FE;

$P_{\text{TV,TS}}$ is total number of charge reports, i.e. number of charge reports generated by a given number of vehicles by the FE in the measurement period.

7.3.3.12 ET-CM-CR-3 CR — Charge report latency

7.3.3.12.1 Metric definition

This metric defines the average time it takes between a charge event and the time the charge report is created/received by the TSP.

The calculation method for the metric is specified in [7.3.3.12.3, Formula \(80\)](#).

7.3.3.12.2 Intended use

This test gives the average latency of charge events until they are received from the FE. Therefore, it gives information about the average FE performance.

7.3.3.12.3 Metric calculation method

$$t_{\text{DELCONT,CR}} = \frac{1}{n} \sum_{i=1}^n a_i \quad (80)$$

where

$t_{\text{DELCONT,CR}}$ is the average delay in charge report generation in continuous schemes;

a_i is the time span between the occurrence of the charge object detection with index i as determined from the reference data and the reception of the respective charge report by the FE in the measurement period;

n is the number of charge object detections in the measurement period.

If the measurement period was chosen accordingly, this test could be used to determine the average delay for the data in a single charge report. If a longer period was chosen, it could also give the average delay over multiple charge reports.

It is important to be aware that the reporting period influences this metric. If, for example, 24 h is chosen, the average resulting latency shall be greater than 12 h for evenly spaced charge object detections.

7.3.3.13 ET-CM-CR-4 CR — TSP-FE charge parameter change rate

7.3.3.13.1 Metric definition

This metric defines the probability that the FE properly detects any defined charge parameter change that takes place.

The calculation method for the metric is specified in [7.3.3.13.3, Formula \(81\)](#).

7.3.3.13.2 Intended use

This test measures the percentage of charge parameter changes which are correctly reflected in charge reports generated by the TSP-FE.

NOTE It is important to be aware of the distinction between charge parameter changes and charging events.

7.3.3.13.3 Metric calculation method

$$R_{\text{PARACONT,CR}} = F_{\text{TCCR}}/F_{\text{T,TS}} \quad (81)$$

where

- $R_{\text{PARACONT,CR}}$ is the value of the rate of correct detection of charge parameter changes in charge reports in continuous schemes;
- F_{TCCR} is the number of charge parameter changes which are correctly represented in charge reports received from the TSP-FE in the measurement period;
- $F_{\text{T,TS}}$ is the total number of charge parameter changes as determined from the reference data in the measurement period.

7.3.3.14 ET-CM-CR-5 CR — TSP-FE end false positive rate

7.3.3.14.1 Metric definition

For vehicles not using the infrastructure, this metric defines the probability that for any predefined charge object detection, the FE improperly detects it.

The calculation method for the metric is specified in [7.3.3.14.3, Formula \(82\)](#).

7.3.3.14.2 Intended use

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

7.3.3.14.3 Metric calculation method

$$R_{\text{FPOSCONT,CR}} = U_{\text{TCR,TS}} / Y_{\text{OT,TS}} \quad (82)$$

where

- $R_{\text{FPOSCONT,CR}}$ is the value of the false positive rate in charge reports in continuous schemes;
- $U_{\text{TCR,TS}}$ is the number of false positives identified in all charge reports which are generated during the measurement period;
- $Y_{\text{OT,TS}}$ is the total number of passes of vehicles in the proximity (but outside) the charging objects in the measurement period.

7.3.3.15 ET-CM-CCR-1 CCR — Correct charging rate

7.3.3.15.1 Metric definition

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.

The calculation method for the metric is specified in [7.3.3.15.3, Formula \(83\)](#).

7.3.3.15.2 Intended use

This metric provides overall information for the FE provider, the TSP and the TC on the capabilities of the system, in particular the OBE, to compute the charges within the accepted charging interval, i.e. ensuring that charges cover a very high percentage of the due incomes (to ensure the viability of the system) and limiting the charges in excess (overcharging) to avoid claims and to provide credibility for the users and the authority.

7.3.3.15.3 Metric calculation method

$$R_{\text{CORCONT,CR}} = T_{\text{S,W,ACEI,TS}} / T_{\text{T,S}} \quad (83)$$

where

$R_{\text{CORCONT,CR}}$ is the rate of the correct charging rates in charge reports in continuous schemes;

$T_{\text{S,W,ACEI,TS}}$ is the number of sets of representative trips travelled by a vehicle during a certain period of time whose ARCE is within the accepted charging error interval in the measurement period;

$T_{\text{T,S}}$ is the overall number of sets of representative trips analysed in the measurement period.

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

7.3.3.16 ET-CM-CCR-2 CCR — Overcharging rate

7.3.3.16.1 Metric definition

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.

The calculation method for the metric is specified in [7.3.3.16.3, Formula \(84\)](#).

7.3.3.16.2 Intended use

This metric provides overall information for the FE provider, the TSP, the TC, authority and users on the capabilities of the system, in particular the OBE, to compute the charges that are not larger than the accepted charging interval, i.e. ensuring that the probability of charges in excess (overcharging) is properly bounded providing credibility for the users and the authority.

7.3.3.16.3 Metric calculation method

$$R_{\text{OCHCONT,CR}} = T_{\text{A,ACEI,TS}} / T_{\text{T}} \quad (84)$$

where

$R_{\text{OCHCONT,CR}}$ is the overcharging rate on charge report level in continuous schemes;

$T_{\text{A,ACEI,TS}}$ is the number of representative trips travelled by a vehicle during a certain period of time whose RCE is above the accepted charging error interval in the measurement period;

T_{T} is the overall number of representative trips analysed in the measurement period.

7.3.3.17 ET-CM-CCR-3 CCR — Accuracy of distance/time measurement

7.3.3.17.1 Metric definition

This metric defines 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.

The calculation method for the metric is specified in [7.3.3.17.3, Formulae \(85\), \(86\) and \(87\)](#).

7.3.3.17.2 Intended use

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

7.3.3.17.3 Metric calculation method

$$q_{\text{ACC,CR}} = \frac{\left(\sum_{i=0}^n E_{\text{REL,CR},i} \right)}{n} \quad (85)$$

$$q_{\text{DEV,ACC,CR}} = \sqrt{\frac{\left(\sum_{i=0}^n E_{\text{REL,CR},i}^2 \right)}{n}} \quad (86)$$

where

$$E_{\text{REL,CR},i} = \frac{(m-r)}{r} \quad (87)$$

and where

- $q_{\text{ACC,CR}}$ is the average value of the accuracy of the time/distance measurement;
- $q_{\text{DEV,ACC,CR}}$ is the standard deviation of the average value of the accuracy of the time/distance measurement;
- $E_{\text{REL,CR}}$ is the relative error of the time/distance measurement;
- m is the relative error supplied by the system (could also be time);
- r is the relative error measured by the reference system (could also be time).

Annex A (informative)

Examination test documentation template

A.1 Examination test template

[Table A.1](#) provides a template for the documentation of examination tests.

Table A.1 — Examination test template

Measured metric					
Metric definition					
Metric measurement data requirements					
Reference data	Charge report	Toll declaration	Billing details	Payment claim	User account charges
Environmental conditions					
Performance requirement					
Sample size					
Details of method for generating charging input					
Method for generating reference data					
Test route/Subset of charge network					
Metric calculation details					

Annex B (informative)

Examination framework considerations

B.1 General

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

The following systematic three-step process is applied:

- a) identification of sources of relevant data, e.g. an operational enforcement system;
- b) measurement methods for collected data from the sources identified in list item a), e.g. comparison with data collected by an enforcement system;
- c) definition of the examination framework for each metric, e.g. CM-DCR-1 DCR — Correct charging rate (charge object detections) in an operational tolling system.

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

B.2 Criteria for definition of tests

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

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

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

- identify possible sources of influences on metrics, considering differences due to phase, scheme type and technology;
- design tests which “provoke” errors, exploit possible vulnerabilities.

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

B.3 Dependency on scheme type

The design of a valid examination framework differs widely depending on the type of scheme.

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

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

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

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

The type of scheme also has an impact on the information flows and on the metrics that can be defined. While the metrics are independent of schemes on the higher levels (billing details to end-to-end), there are major differences for the low-level metrics (charge report and toll declaration).

The roles in the collection of charge data differ.

- In autonomous systems, the TSP is the operator of the FE; therefore, charge reports and toll declarations are within its realm of responsibility.
- In tolling systems, the RSE and the corresponding parts of the central system are under the control of the TC.
- In DSRC-based systems, the interface for exchanging the equivalent to charge reports in autonomous systems was not standardized until the preparation of the current document and therefore, it is difficult to put metrics on them.

B.4 Dependency on phase

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

a) Evaluation phase

There are not yet any SUs. All tests should be performed with selected vehicles, either driven by personnel of the entity performing the tests, or volunteers who allow their vehicles to be equipped. This situation results in relatively small sample sizes, potentially with controlled behaviour of test vehicles and controllable influences on metrics (e.g. mounting position of OBE).

b) Monitoring phase

Usually, a large number of toll system users are active in the system. Therefore, very large sample sizes are possible, but with unknown behaviour of the vehicles and potentially uncontrollable influences on metrics. In principle, all measurements from the implementation phase are possible here.

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

B.5 Dependency on technology

Sources of influences on metrics depend on technology.

EXAMPLE 1 In GNSS systems, performance is influenced by accuracy and availability of GNSS position data/events. Key issues are:

- environment of the road (refers to obstacles, buildings, etc.);
- solar activity (affecting the ionosphere, weather conditions, etc.);
- vehicle speed;
- quality of toll context data from the TC (ISO 12855).

EXAMPLE 2 In DSRC systems, performance is influenced by:

- traffic density;
- vehicle speed;
- OBE mounting position;
- weather conditions;
- SU behaviour;
- battery life.

In both technologies, interference (spoofing, jamming) in the respective frequency bands used degrades performance.

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

B.6 Simultaneous measurement of metrics

The metrics in the examination framework have been defined based on the sequential information flows within a charging system, which means that there is a hierarchy of metrics; hence, an examination test designed to measure metrics at the end-to-end level can, with additional observation points, be used to simultaneously measure metrics at the charge report, billing details, payment claim and user account metric levels.

Annex C (informative)

Statistical considerations

C.1 Basics

All statistical considerations should reflect existing ISO International Standards.^[17]

Four particularly relevant International Standards for basic statistical analysis of EETS data are ISO 2602, ISO 3534-1, ISO 3534-2 and ISO 11453:1996/Cor 1:1999.

NOTE More specific aspects and alternative approaches can also be found Reference ^[17].

These documents should be used as the base reference for all standard operating procedures defining statistical characterizations of performance measures. Standard operating procedures should not only describe data analysis, but should also have to define unambiguously all steps of sampling, data ascertainment, data description and statistical evaluation. When necessary, approaches for validation of measurement systems, identification of sources of bias and of extra variability, etc. have to be provided.

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

Vocabulary and terms used should be standardized and as precise as possible. Therefore, all documents should use the ISO 3534 series as a common reference. In addition, there are glossaries of statistical terms widely accepted internationally. OECD offers an online statistics portal.^[18] From this website, a downloadable version is available as well. Translations into 31 languages are offered by the International Statistical Institute (ISI).^[19]

The following subclauses give a short overview of the basic terminologies, elementary formulae for computing estimates of performance parameters and confidence limits, including example calculations. They are not intended to replace the International Standards mentioned at the beginning of this clause.

C.2 Point and interval estimation for binary and continuous data

C.2.1 Binary data

C.2.1.1 General

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

[Formulae \(C.1\)](#) and [\(C.2\)](#) are used for the normal approximation approach, expressing point estimate and confidence limits respectively.

$$\hat{p} = x / n \quad (C.1)$$

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

where

$z_{1-\alpha/2}$ denotes the normal percentile;

x is the number of successes;

n is the sample size.

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

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

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

NOTE 2 For very small underlying probabilities, samples with zero response occur quite often. In this case, one-sided confidence intervals can easily be constructed giving an upper bound.

NOTE 3 A testing-based approach for inference on binary data can be found in the ISO 2859 series.

NOTE 4 More sophisticated analysis of binary data is provided when logistic regression models are used, giving the opportunity to model detection probabilities for different times, segments, devices, etc.

C.2.1.2 Binary data examples

C.2.1.2.1 Probability

[Formula C.3](#) shows an estimation of probability/proportion.

$$\hat{p} = \frac{v_S}{v_0} = \text{number of successful events/overall events} \quad (\text{C.3})$$

where

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

v_S is the number of successful events;

v_0 is the number of overall events.

C.2.1.2.2 Margin of error

A simple approach for calculating the confidence interval of a binomial proportion is the normal approximation interval shown in [Formula C.4](#):

$$\hat{p} \pm z_{1-\alpha/2} \sqrt{\frac{\hat{p}(1-\hat{p})}{n}} \quad (\text{C.4})$$

where

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

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

α is the error percentile;

n is the sample size.

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

EXAMPLE The following provides a simple example with proportions near 50 %. To analyse the proportion of defective units, a sample is drawn of 1 000 units; 529 of the 1 000 units are defective.

$$\hat{p} = \frac{529}{1\,000} = 0,529$$

The confidence interval, c , is:

$$c = 0,529 \pm 1,96 \sqrt{\frac{0,529(1-0,529)}{1\,000}} = 0,529 \pm 0,031$$

C.2.1.2.3 Estimation of probabilities near 0 or 100 %

EXAMPLE The following provides an example of a significant estimation of the overall detection rate [most important key performance indicator (KPI)] of segment-based toll systems. To analyse the overall detection rate of a toll system, 1 000 detection events are considered as a sample; 995 of the events were successful.

$$\hat{p} = \frac{995}{1\,000} = 0,995$$

The confidence interval, c , is:

$$c = 0,995 \pm 1,96 \sqrt{\frac{0,995(1-0,995)}{1\,000}} = 0,995 \pm 0,004$$

Note that the margin of error in this example is smaller.

C.2.1.2.4 One-sided confidence intervals

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

For the special case of 0 events among n units under test, an upper $1 - \alpha$ confidence limit for the underlying response probability is given by [Formula C.5](#):

$$\hat{p}_{\text{low}} = 1 - \sqrt[n]{\alpha} \quad (\text{C.5})$$

For sample sizes of 100, 1 000 and 10 000, this calculation produces the upper 95 % limits: 0,029 5, 0,003 0 and 0,000 3.

C.2.2 Continuous data

C.2.2.1 General

Continuous data can be of various forms. For toll data, information on the expected value can be the most important, as the total of charges equals the number of rides multiplied by the expected toll. Inference is supported by the central limit theorem of mathematical statistics. For large samples, approximations

based on normal theory can be regarded as reliable. Point and interval estimates assume independent, identically distributed data. The following information applies:

- Formulae for the normal approximation approach: $x_1, x_2, \dots, x_n$ denoting the sample data; data is assumed to be drawn from a distribution with expected value μ and variance σ^2 ;
- Point estimate: $\hat{\mu} = \bar{x}$ (mean);
- Confidence limits: denoting the standard deviation by s . The standard deviation is the point estimate of σ .
- Confidence limits for the median, non-parametric approach:

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

NOTE 1 For normal data, the distribution would be perfectly characterized by the parameters μ and σ . For general distributions, interpretation of parameter estimates depends on the form of the distribution. A continuous variable is not fully characterized by the expected value and variance. As a minimum, it is recommended to address questions of symmetry.

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

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

NOTE 4 Instead of the mean, the median or other percentiles of a distribution could be chosen as a parameter of interest. There are non-parametric methods for interval estimates available, either based on empirical quantiles or on re-sampling methods, including the bootstrap approach (see ISO 16269-7).

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

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

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

C.2.2.2 Continuous data example

C.2.2.2.1 General

The following example uses artificial data and five measurements of a distance: 3,351 km, 3,353 km, 3,349 km, 3,348 km and 3,352 km. The true distance determined by a high precision reference is 3,35 km.

C.2.2.2.2 Normal approximation approach

The mean is defined as: $\bar{x} = 3,350\ 6$

The standard deviation is defined as: $s = 0,002\ 073\ 644$.

The 95 % confidence interval is calculated as:

$$3,350\ 6 \pm 2,776 \times \frac{0,002\ 073\ 644}{\sqrt{5}} = 3,350\ 6 \pm 0,002\ 575 = (3,348\ 025, 3,353\ 175)$$

using the t -value $t_{4, 0,975} = 2,776$.

This confidence interval covers the “true” value. There does not appear to be any systematic error in the measurements.

C.2.2.2.3 Non-parametric approach

The interval given by the minimum and maximum values is (3,348, 3,352), virtually identical to the normal approximation. The confidence level is $1 - (1/2)^{5-1} = 93,74 \%$.

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

C.2.3 Dealing with non-normal data

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

Modelling of the real distribution based on pseudo range measurements is possible only theoretically. In practice, the complexity of data processing and the missing information about the real methods do not allow the calculation of error distributions.

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

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

C.2.4 Quality of reference systems

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

As the costs for reference systems are nearly exponentially linked with the required accuracy, a typical approach would be to choose the quality of the reference based on practical considerations.

Based on available measurement systems with specified accuracy (and acceptable price range), it needs to be determined if the reachable accuracy fulfils the minimum requirements.

Afterwards, the reachable confidence levels can be specified based on the specified accuracy of the device under test and the reference system.