TECHNICAL SPECIFICATION

ISO/TS 17444-1

Second edition
2017-09

Electronic fee collection — Charging performance —

Part 1: Metrics

Perception du télépéage — Performance d'imputation —

Partie 1: Métrique

Reference number
ISO/TS 17444-1:2017(E)

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Foreword

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

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

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

This second edition cancels and replaces the first edition (ISO/TS 17444-1:2012), which has been revised with the following changes:

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

— updated terminology.

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

Introduction

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

In addition, in order to ensure the interoperability of different systems, it will be necessary to agree on common metrics to be used and on the actual values that define the required acceptable performances. Although this is not covered in this document, it is covered in ISO/TS 17444-2.

Toll schemes take on various forms as identified in ISO 17575 (all parts) and ISO 14906. In order to create a uniform performance metric specification, toll schemes are grouped into two classes, based on the character of their primary charging variable: Charging based on discrete events (charges when a vehicle crosses or stands within a certain zone), and those 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; 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; many of the motorways in Southern Europe belong to this category.

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

  EXAMPLE German heavy goods vehicle (HGV) charge.

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

  EXAMPLE Stockholm congestion charging.

The following are examples of continuous toll schemes.

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

  EXAMPLE Switzerland's HGV charge; US basic vehicle miles travelled approach.

— Charging based on direct distance measurement in different tariff zones or road types: defined as an amount per kilometre 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 many European countries.

  EXAMPLE OReGO, the pilot programme in Oregon, is an example from 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 these examples of toll schemes, tolls may additionally vary as a function of vehicle class characteristics such as trailer presence, number of axles, taxation class, operating function, and depending on time of day or day of week, so that, for example, tariffs are higher in rush hour and lower on the weekends.

With this degree of complexity, it is not surprising to find that the attempts to evaluate and compare technical solutions for Service User charging have been made 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 ISO 17575 (all parts) and their grouping in the mentioned two classes is described in Table 1, which also identifies the examples mentioned above.

Table 1 — Tolling scheme designs grouped according to Scheme categories

Examples	Scheme type	ISO 17575 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 (or time) in different zones (or by road type)	Continuous	Area pricing — distance

No toll schemes are purely continuous. At the very least, a system must be able to stop accumulating charges when it leaves a jurisdiction in which a charge is due, and resume charging when it returns or enters another. Additionally, many Charging Schemes are set up so that the tariff is modified using discrete parameters, such as spatial zones, time spans, vehicle classes, etc. Under those circumstances, each unit of distance or time costs a different amount depending, for example, on whether it takes place inside or outside an area, such as a city, whether a trip takes place in rush hour or at night, or depending on what type of vehicle is used. In this document references to a "continuous system" have to be understood as those systems having some continuous behaviour even though they can also integrate some discrete nature. References to "discrete systems" are limited to those systems that are purely discrete.

In these schemes, all the discrete parts (zones, cordons, events, time, vehicle class, etc.) that a system has to identify are translated into a particular tariff (e.g. price per kilometre) that has to be applied to the measured continuous variable (e.g. distance travelled) resulting in another continuous parameter, money.

Some features of discrete and continuous toll schemes that are of relevance for the definition of metrics proposed in this document are analysed below.

Discrete toll schemes

In a discrete toll scheme, distinct events are associated with the identification of Charge Objects. It can happen that a vehicle crossed a cordon, passed a bridge or was present in an area on a given day. An event that takes place can either be correctly recorded by the system or can be missed. However, there is also the possibility that an event is recorded even though it did not actually take place. This is summarized in the following matrix in Table 2.

Table 2 — Theoretical event decision matrix for discrete schemes

Event Matrix		*System detects charge object detection*	
		Yes	*No*
Charge object detection takes place	*Yes*	**Correct Charging**	**Missed Recognition** (Undercharging)
	No	**False Positive** (Overcharging)	**Correct Non-charging**

In Table 2 are two successful scenarios (Correct Charging and Correct Non-charging) and two unsuccessful (Missed Recognition and False Positive). The unsuccessful scenarios have very different consequences. A Missed Recognition, i.e. a charge object detection that takes place but is not recorded by the system, implies an undercharging, as the Service User is not charged.

In the case of False Positive, a *vehicle that is not using the toll domain* is being charged for an event which did not take place. This implies an overcharging which is in violation of the legal rights of the *Service User*, and ultimately risks eroding trust in the system.

This document therefore makes a distinction between the two types of errors and defines associated metrics to protect the interests of the Toll Charger and Service Users in terms of the allowed probabilities of those events.

Continuous toll schemes

A continuous toll scheme is one where the charge is calculated using accumulated time or distance the base tariff is applied to.

Note that a discrete scheme with a large number of Charge Objects would lead to charging incremental variations, and is hence approaching a continuous scheme (the higher the number of events the closer such schemes are to a continuous scheme). In any case, this would still formally be a discrete scheme.

In discrete toll schemes errors are binary: either a charge object detection is correctly recorded or it is not. However, in continuous schemes the errors are relatively small and they vary continuously, i.e. those errors are real (in the mathematical sense) variables instead of logical variables. Figure 1 shows different levels of dispersion and different directions of bias. The horizontal axis shows the size of the errors and the vertical axis the probability density. The vertical line in each plot represents zero charging error. Note that it is possible to have small dispersion (i.e. a small standard deviation) that still biases charging high or low (i.e. not accurate).

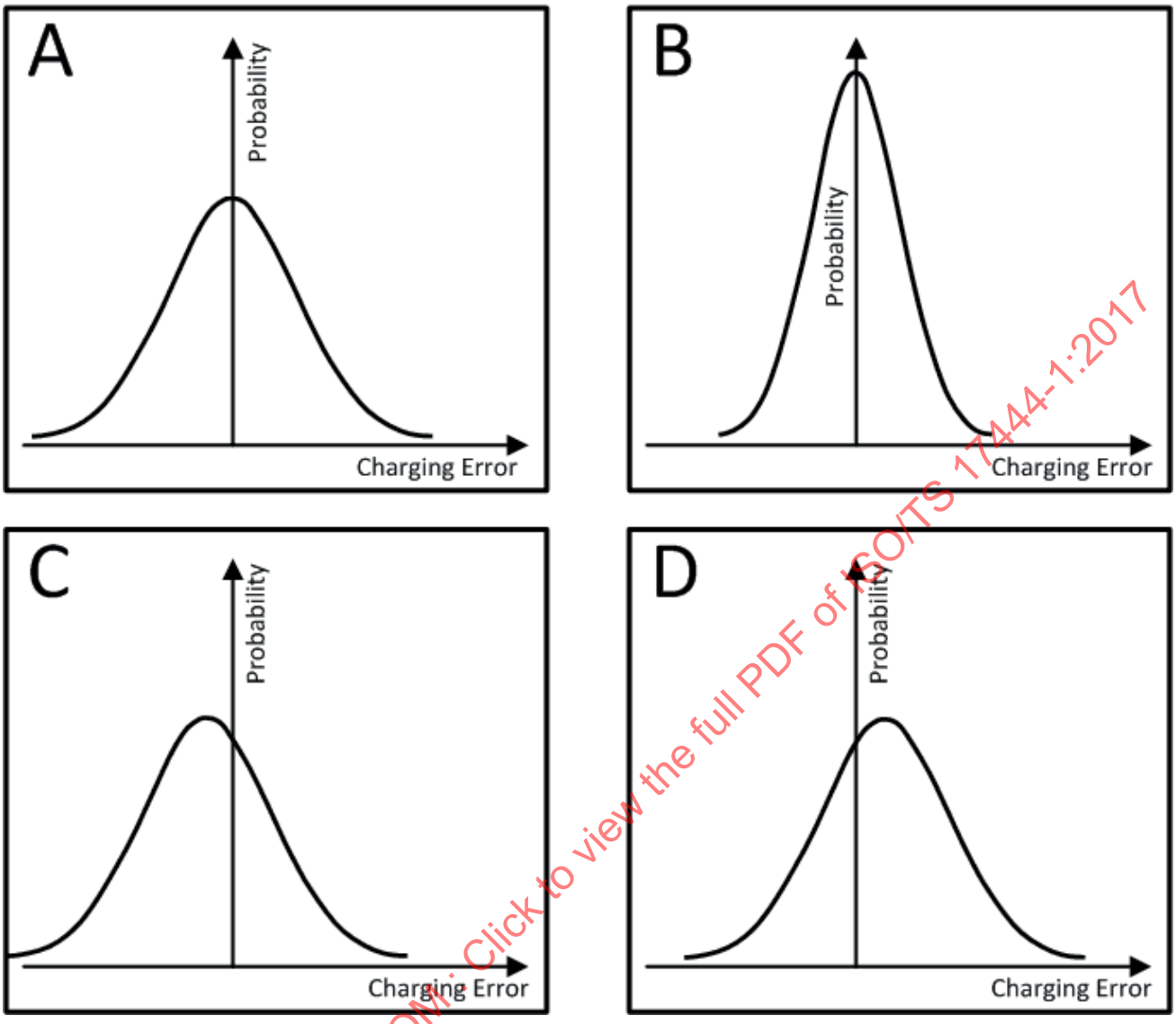

Figure 1 — Idealized plots of error distribution of four different result sets

In Figure 1, Chart A symbolizes the results from a Front End with more dispersion than that used for Chart B. For all parties involved, B is preferable to A. Charts C and D show two Front Ends with the same standard deviation, but where Chart C shows one that is consistently undercharging, and Chart D shows one that is consistently overcharging road usage.

By defining an *Accepted Charging Error Interval* to the chart, with a lower and an upper bound, as shown in Figure 2, it is possible to state that for a system to be accepted it must perform so that some minimum share of the measurements fall inside the interval specified as accepted by the *Toll Charger*.

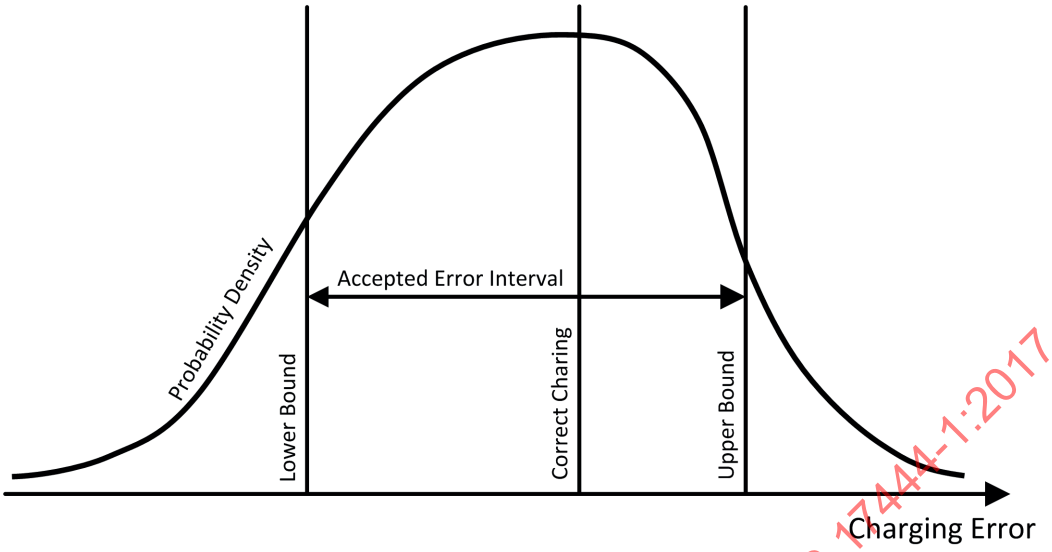

Figure 2 — Definition of Accepted Error Interval

Setting the upper and lower bounds far apart relaxes requirements on the equipment evaluated, while setting them closer together would make the requirement to fulfil harder to pass. By setting the upper bound closer to the correct charging value and the lower bound farther away, the Toll Charger can formalize exactly how much more important it is to avoid overcharging than it is to avoid undercharging. By defining those bounds (*Accepted Charging Error Interval*) together with the probabilities to be inside and above those bounds the Toll Charger can define precisely its requirements distinguishing between overcharging and undercharging. In reality no scheme is purely continuous and all foreseeable continuous schemes have some discrete components. The discrete nature of real systems can be either associated to the physical border of a country (continuous measurements take place only if vehicle is within the country) or to the identification of different urban zones or roads where different tariffs (per unit of time or distance) are applied.

Thus, continuous schemes have associated metrics that are specific to those continuous systems but the ones identified for discrete schemes are also applicable.

Electronic fee collection — Charging performance —

Part 1: Metrics

1 Scope

This document defines metrics for the charging performance of electronic fee collection (EFC) systems in terms of the level of errors associated with charging computation.

This document is a toolbox standard of metrics. The detailed choice of metrics depends on the application and the respective context.

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

The charging performance metrics defined in this document are intended for use with any Charging Scheme, regardless of its technical underpinnings, system architecture, tariff structure, geographical coverage, or organizational model. They are defined to treat technical details that can be different among technologies and vendors or vary over time as a "black box".

They focus solely on the outcome of the charging process, i.e. the amount charged in relation to a pre-measured or theoretically correct amount, rather than intermediate variables from various components as sensors, such as positioning accuracy, signal range, or optical resolution. This approach ensures comparable results for each metric in all relevant situations.

The metrics are designed to cover the information exchanged on the Front End interface and the interoperability interfaces between Toll Service Providers, Toll Chargers and Road Users as well as on the End-to-End level.

Metrics on the following information exchanges are defined:

— Charge Reports;

— Toll Declarations;

— Billing Details and associated event data;

— Payment Claims on the level of toll service user accounts;

— User Accounts;

— End-to-End Metrics which assess the overall performance of the charging process.

The details on the rationale of this choice are described in 5.1.

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

This document recognises two types of situations where a performance assessment is necessary:

a) when an assessment is carried out during a limited time span, such as when formulating requirements and assessing systems for acquisition purposes, conducting acceptance testing as

part of the commissioning process, or as part of a certification procedure. Any one of these types of assessment is referred to as an evaluation;

b) when an assessment is needed as an ongoing supervision process, throughout the lifetime of a system, in order to validate contracted service levels, to identify fraud or malfunction, or to support ongoing maintenance and performance improvement processes. This type of assessment is referred to as monitoring.

NOTE 1 Definitions and metrics proposed in this document are intended for both situations.

The following are not covered by this document.

— This document does not propose specific numeric performance bounds, or average or worst-case error bounds in percentage or monetary units. Those decisions are left to the Toll Charger (or to agreements between Toll Charger and Service Provider), while providing a way to be sure that there is a consistent framework for describing system requirements when writing Request for proposals, for system comparisons during acquisition, for test results, for Service Level Agreements, and ongoing (post-deployment) performance monitoring.

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

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

— This document does not specify metrics on parts of tolling systems other than the charging process chain, such as:

  — enforcement system;

  — security measures.

— This document does not cover metrics on parts of the charging processing chain which are considered an internal matter of one of the interoperability partners:

  — equipment performance, e.g. for on-board equipment, road-side equipment 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 Front End. It is masked by correction algorithms, filtering, inferring of data and the robustness of the Charge Object recognition algorithms.

Even though some of these aspects have a direct impact on charging performance, they are not considered explicitly in this document.

NOTE 2 While the Front End interface is considered as internal to the Toll Service Provider domain of responsibility, it is still covered by metrics. There are two reasons for this exception: firstly, a set of standards [ISO 17575 (all parts)] exists on this interface, and secondly, the information exchanged on this interface is also part on the TSP-TC interface (ISO 12855) and therefore metrics are needed.

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 12855:2015, *Electronic fee collection — Information exchange between service provision and toll charging*

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

ISO 17575-1:2016, *Electronic fee collection — Application interface definition for autonomous systems — Part 1: Charging*

3 Terms and definitions

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

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

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

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

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

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

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

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

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

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

[SOURCE: ISO 12855:2015, 3.1]

3.5
charge object detection
event marking the usage of a charge object

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

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

[SOURCE: ISO 17575-1:2016, 3.5]

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 itself

3.8
charging performance metrics
specific calculations used to describe the charging performance of a system

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

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

Note 1 to entry: In 2009/750/EC, Charge Report is referred to as "toll declaration".

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

3.10
continuous toll scheme
toll scheme where the charge is calculated based on the accumulation of continuously measured parameter(s), such as distance, time, etc.

3.11
discrete toll scheme
toll scheme where the charge is calculated based on distinct events associated with the identification of charge objects such as crossing a cordon, passing a bridge, being present in an area, etc.

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

3.12
evaluation
systematic process of determining how individuals, procedures, systems or programs have met formally agreed objectives and requirements

[SOURCE: ISO 10795:2011, 1.90]

3.13
false positive event
event that was erroneously detected, but did not take place

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

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

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

3.15
missed recognition event
usage of a charge object, that is not recorded by the system

3.16
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.

3.17
overcharging
situation where the calculated charge is above the accepted charging error interval

3.18
payment claim
recurring statement referring to concluded billing details made available to the payer by the payee indicating and justifying the amount due

Note 1 to entry: The payment claim is used by the Toll Service Provider to issue financial objects to its customers (e.g. invoices on behalf of the Toll Charger). A given toll payment claim refers to billing details (3.1) and takes into account any specific commercial conditions applicable to a vehicle, a fleet of vehicles, a customer of a Toll Service Provider and/or a Toll Service Provider. A valid "payment claim" has to fulfil formal requirements, including security requirements, agreed between the Toll Service Provider and the Toll Charger.

[SOURCE: ISO 12855:2015, 3.10]

3.19
relative charging error
ratio between the absolute charging error and the reference value

Note 1 to entry: The topic of reference values (actual values) and how to handle them will be dealt with in the examination framework.

3.20
representative trips
trips that are of a distance larger than a defined threshold and so have to be considered by the related metrics

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

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

3.21
successful charging
situation where the toll service user has been correctly charged according to the rules of the system

Note 1 to entry: For discrete Charging Schemes this means that for a given chargeable journey the chargeable events have been correctly identified and for continuous schemes that the charge determined is within the accepted charging error interval.

3.22
toll declaration period
period covered by a toll declaration

Note 1 to entry: If the toll declaration period is set to 24 hr then in the Toll Context Data a single Toll Declaration is submitted for each 24-hr period for each Service User.

3.23
toll service user
customer of a toll service provider, i.e. one liable for toll, owner of the vehicle, fleet operator or driver depending on the context

3.24
toll charger
entity which levies toll for the use of vehicles in a toll domain

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

[SOURCE: ISO 17573:2015, 3.16]

3.25
toll declaration
statement to declare the usage of a given toll service to a toll charger

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

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

3.26
toll service provider
entity providing toll services in one or more toll domains

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

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

Note 3 to entry: The toll service provider is responsible for the operation (functioning) of the OBE with respect to tolling.

3.27
trip
part of space-time trajectory of a particular vehicle within a toll domain

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

3.28
undercharging
situation where the calculated charge is below the accepted charging error interval

3.29
user account
centrally or on-board stored transport related service rights of the user in his relationship to a service provider

3.30
user complaint
complaints from users related to a specific service provision

4 Abbreviated terms

CCTV	Closed Circuit Television
DSRC	Dedicated Short-Range Communications (ISO 14906)
E2E	End-to-End
EFC	Electronic Fee Collection (ISO 17573)
EETS	European Electronic Toll Service (ISO 17573)
FE	Front End (ISO 17575-1)
GNSS	Global Navigation Satellite System NOTE: Generic term used for a satellite localization system such as GPS and GALILEO.
ITS	Intelligent Transport Systems

OBE	On-Board Equipment (ISO 17573)
OBU	On-Board Unit
RSE	Roadside Equipment
SLA	Service Level Agreement (ISO/IEC 20000-1)
TSP	Toll Service Provider (ISO 17573)
TC	Toll Charger (ISO 17573)

5 Definition of charging performance metrics

5.1 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 Toll Chargers and Service Users.

In practice, it is worth defining the metrics for information transmitted through established (and standardized) interfaces, including those that can be defined at an overall Tolling Scheme Level, or the so-called End-to-End Metrics.

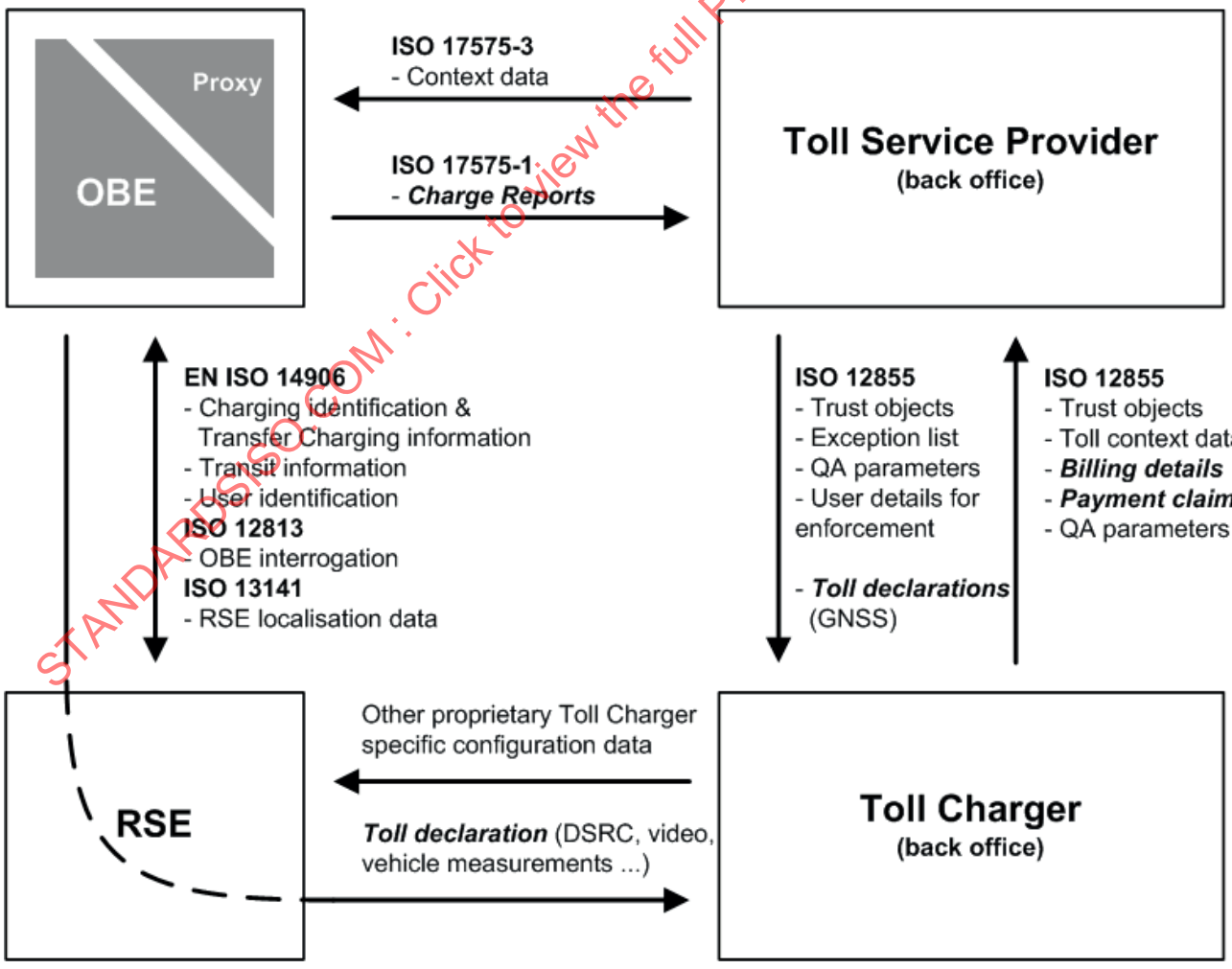

Figure 3 — EFC Architecture and Interfaces

In accordance with ISO 17573, and with the associated interface standards ISO 17575-1 and ISO 12855, metrics shall be based on the following charging information exchanges highlighted in bold italics in Figure 3:

— Charge Reports as transmitted from the Front End to the Service Provider's Back End (ISO 17575-1:2016, 6.2);

— Charging identification and Transfer Charging information as exchanged between the OBE and the RSE for DSRC systems (ISO 14906);

— Toll Declarations as transmitted from the Service Provider to the Toll Charger for autonomous systems (ISO 12855:2015, 5.2.7);

— Billing Details as transmitted from the Toll Charger to the Service Provider (ISO 12855:2015, 5.2.8);

— Payment Claims transmitted from the Toll Charger to the Service Provider (ISO 12855:2015, 5.2.9).

NOTE 1 Payment Claims form the basis for User Statements/Invoices as transmitted in the interface between Service Provider and the User (User Account).

Charging Metrics defined at the level of Charge Reports and Toll Declarations focus on the ability of the Service Provider Front End and associated back-office functions to correctly detect and report Charging Events. Charging Metrics defined at the level of Billing Details and Payment Claims focus on the Toll Charger's ability to correctly determine the Charges incurred by Users based on the Toll Declarations received. Charging Metrics defined at the level of User Statements/invoices cover the overall Charging Performance for an individual User, 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 Toll Charger and Service Provider are provided by a single entity; these are defined as End-to-End Metrics in this document. In toll schemes where the roles of Toll Charger and Service Provider are performed by different entities then the E2E metrics measure the combined performance of the Toll Charger and Service Provider.

For the purposes of this document, charging performance metrics are defined for the six levels below and are independently presented in 5.3 to 5.8:

— End-to-End Metrics;

— User Account Metrics;

— Payment Claim Metrics;

— Billing Details Metrics;

— Toll Declaration Metrics;

— Charge Report Metrics.

NOTE 2 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.

Figure 4 shows the hierarchy of Charging Metrics as defined in this document and illustrates how the discrete and continuous nature of Tolling Schemes have an impact on the metrics that can be defined for a particular scheme under consideration.

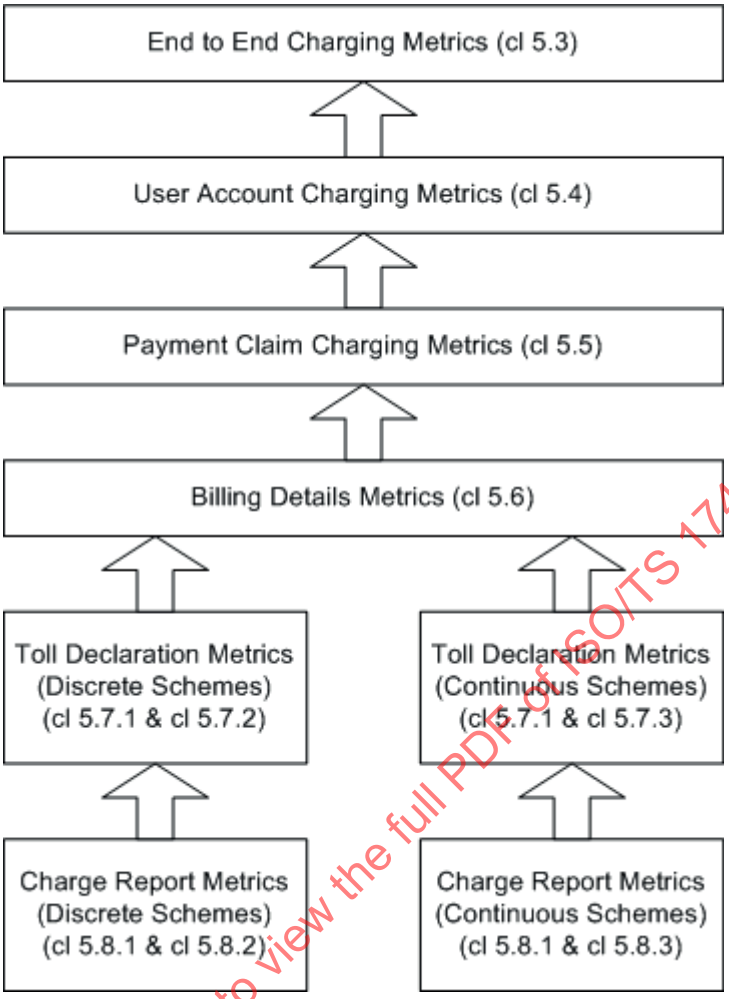

Figure 4 — Charging Metrics Hierarchy

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 Tolling 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 5 presents five different examples for defining options for measuring Charging Metrics in a particular Tolling Scheme.

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

b) Measures charging performance at each information interface between Toll Service Provider and Toll Charger. This is most applicable to Autonomous systems.

c) Measures charging performance of the Toll Charger at the Billing Detail and Payment Claim levels independently from the performance of the Toll Service Provider for allocating charges to User Accounts. This is only recommended for scenarios where the Toll Charger is responsible for the Usage Evidence (DSRC or CCTV tolling). Otherwise, the performance cannot be attributed to a single responsible entity.

d) Measures charging performance of the Toll Charger at the Payment Claim level independently from the performance of the Toll Service Provider for allocating charges to User Accounts. This is only recommended for scenarios where the Toll Charger is responsible for the Usage Evidence (DSRC or CCTV tolling) and where there is no aggregation of Billing Details within Payment Claims.

e) Measures End-to-End charging performance of the whole Tolling Scheme. This measurement represents the User's perception. It can further be recommended if all charging functions are performed by the same monolithic entity.

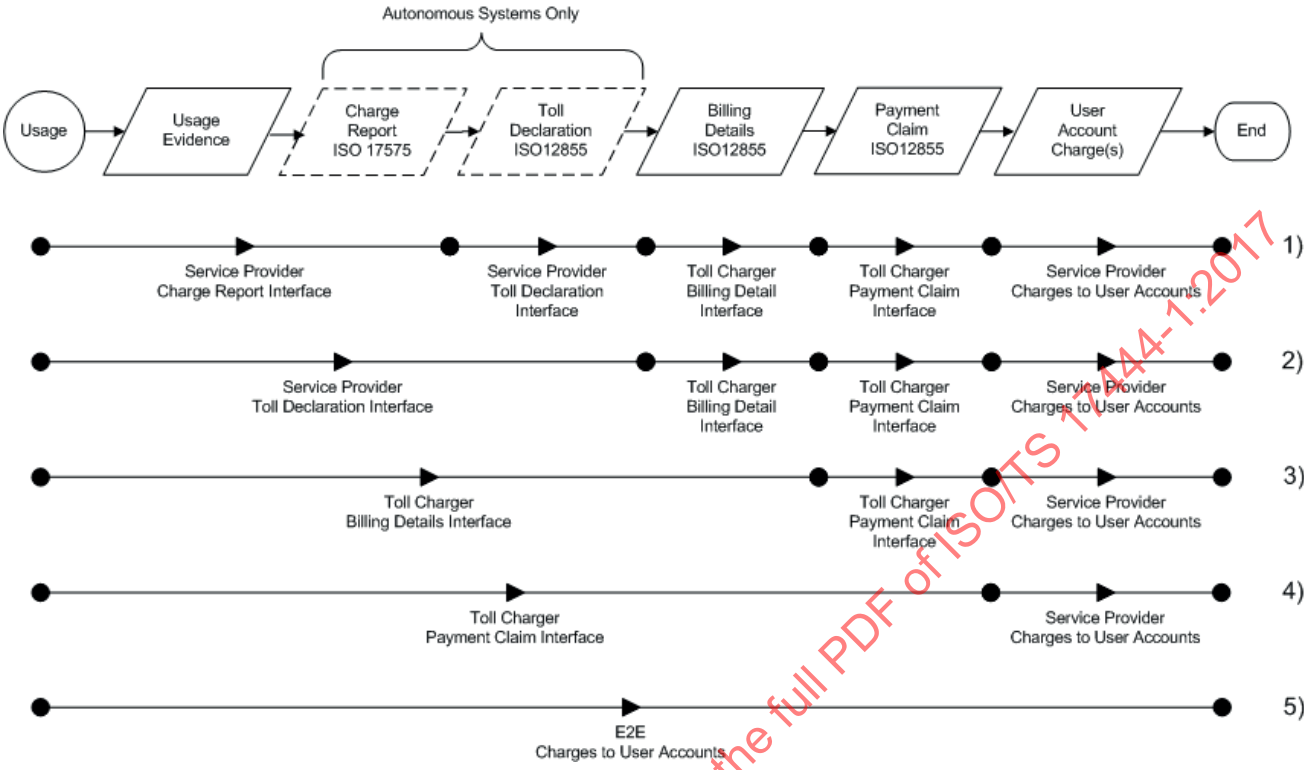

Figure 5 — Charging Metrics mapping to toll scheme Implementations

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).

NOTE 3 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: the record generated to monitor the performance (CCTV, loop detection, manual auditor log file, Enforcement Record, etc.) is elaborated in ISO/TS 17444-2.

5.2 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:

— "E2E" for "End-to-End";

— "UA" for "User Account";

— "PC" for "Payment Claim";

— "BD" for "Billing Details";

— "TD" for "Toll Declaration/Charge Report", which is also subdivided into:

  — "DTD", signifying "Toll Declaration/Charge Report" for discrete systems, and

  — "CTD", signifying "Toll Declaration/Charge Report" for continuous systems;

— "CR" for "Charge Report", which is also subdivided into:

  — "DCR", signifying "Charge Report" for discrete systems, and

  — "CCR", signifying "Charge Report" for continuous systems;

c) aa identifies the unique number within the level.

5.3 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 toll service users.

Table 3 provides details of the metrics that have been defined for End-to-End Charging Metrics.

Table 3 — 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 Users are correctly Charged by a toll scheme.	This metric defines the probability that for any set of *representative trips* travelled by a set of Users during a time span, Δt, the Average Relative Charging Error is within the Accepted Charging Error Interval.
CM-E2E-2	E2E — Overcharging Rate	Metric that measures the overall probability that Users are overcharged by a toll scheme.	This metric defines the probability that for any set of *representative trips* travelled by a set of Users during a time span, Δt, the Average Relative Charging Error is above the Accepted Charging Error Interval.
CM- E2E-3	E2E — Undercharging Rate	Metric that measures the overall probability that Users are undercharged by a toll scheme.	This metric defines the probability that for any set of *representative trips* travelled by a set of Users during a time span, Δt, the Average Relative Charging Error is 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 Users during a time span, Δt, the charge object detections appear on the User Statement later than the defined period for the Charging Scheme.

5.4 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 User Complaints related to Charging received by the Toll Service Provider.

Table 4 provides details of the metrics that have been defined for User Account Metrics.

Table 4 — 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 User during the invoicing period the Average Relative Charging Error 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 User during the invoicing period the Average Relative Charging Error 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 User during the invoicing period the Average Relative Charging Error 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.
CM-UA-5	UA — Accurate Personalisation of OBUs	Metric that measures the accuracy of the personalisation of charging relevant parameters into OBUs.	This metric defines the probability that the personalisation for any set of Users during a time span, Δt, is correct.

5.5 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 and, depending on the level of aggregation within a Charging Scheme, it can relate to individual Billing Details.

NOTE In Charging Schemes where Payment Claims are originated by the Toll Service Provider and forwarded to the Toll Charger for checking, these metrics could be applicable to the Toll Service Provider.

Table 5 provides details of the metrics that have been defined for Payment Claim Metrics.

Table 5 — 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 Toll Charger.	This metric defines the probability that for any given Payment Claim, the Average Relative Charging Error 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 Toll Charger and the Service User.
CM-PC-2	PC — Overcharging Rate	Metric that measures the level of overcharging in Payment Claims produced by the Toll Charger.	This metric defines the probability that for any given Payment Claim, the Average Relative Charging Error 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 Service User (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 Toll Charger.	This metric defines the probability that for any given Payment Claim, the Average Relative Charging Error is below the Accepted Charging Error Interval.
CM-PC-4	PC — Latency — TC	Metric that measures the performance (Time Delay) of the Toll Charger in generating Payment Claims.	The Average Time it takes between the approval for a Billing Detail being received by the Toll Charger and the time the associated Payment Claim is created/sent by the Toll Charger.
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 Service Provider 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.

5.6 Billing Details Metrics

Billing Details Metrics measure the Charging Performance at the level of the Billing Details exchanged between TC and TSP and depending on the level of aggregation within a Charging Scheme, 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.

In DSRC Schemes, the Billing Details Metrics can be used to measure the performance of the Toll Charger to correctly detect Charge events.

NOTE In Charging Schemes where Billing Details are originated by the Toll Service Provider and forwarded to the Toll Charger for checking, these metrics could be applicable to the Toll Service Provider.

Table 6 provides details of the metrics that have been defined for Billing Details Metrics.

Table 6 — 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 Toll Charger.	This metric defines the probability that for any given Billing Detail, the Average Relative Charging Error 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 Toll Charger and the Service User.
CM-BD-2	BD — Overcharging Rate	Metric that measures the level of overcharging in Billing Details produced by the Toll Charger.	This metric defines the probability that for any given Billing Detail, the Average Relative Charging Error 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 Service User (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 Toll Charger.	This metric defines the probability that for any given Billing Detail, the Average Relative Charging Error 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 Toll Charger in generating Billing Details.	The Average Time it takes between a Toll Declaration being received by the Toll Charger and the time the associated Billing Detail is created/sent by the Toll Charger. Most relevant for autonomous systems (Toll Declarations are solely generated by a TSP).

Table 6 *(continued)*

Metric ID	Metric name	Description	Definition
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.
CM-BD-7	BD — Rejected Billing Details Rate	Metric that measures the level of Billing Details rejected by the Service Provider 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 Service Provider 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 analyzing video pictures.	This metric defines the ratio of inferred Billing Details in relation to the total number of Billing Details in the measurement period.

5.7 Toll Declaration Metrics

5.7.1 General

Charging Metrics defined at the level of Toll Declarations generated by the Toll Service Provider assess the Charging Performance at the level of the contents of individual Toll Declarations and are only applicable for autonomous systems.

Because of the substantial difference between discrete and continuous systems as far as the nature 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, may also include some discrete behaviour (e.g. price per kilometre, depending on the type of road).

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

5.7.2 Metrics relevant for all schemes

Table 7 provides details of the metrics that have been defined for Toll Declaration that are common for both discrete and continuous Charging Schemes.

Table 7 — Common Toll Declaration Scheme 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 Declarations 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 Toll Charger 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 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.

5.7.3 Metrics only applicable to discrete schemes

Table 8 provides details of the metrics that have been defined for Toll Declaration Metrics for discrete schemes.

NOTE 1 The metrics defined in 5.7.2 are also relevant for discrete schemes.

NOTE 2 The following metrics can be applied both to the systems of Toll Chargers and Toll Service Providers.

Table 8 — 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.
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).

5.7.4 Metrics applicable to continuous schemes

Table 9 provides details of the metrics that have been defined for Toll Declaration Metrics for continuous schemes.

NOTE The metrics defined in 5.7.2 are also relevant for continuous schemes.

Table 9 — 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 Average Relative Charging Error 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 Toll Charger and the Service User.
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 Relative Charging Error 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 Road User (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.

5.8 Charge Report Metrics

5.8.1 General

Charging Metrics, defined at the level of Charge Reports generated by the Front End, assess Charging Performance at the level of the contents of individual Charge Reports for autonomous systems.

NOTE These metrics can also be used to measure the ability of the Toll Charger to correctly detect charging events in DSRC systems.

As in 5.7, metrics are defined for the three identified groups.

5.8.2 Metrics relevant for all schemes

Table 10 provides details of the metrics that have been defined for Charge Reports that are common for both discrete and continuous Charging Schemes.