TECHNICAL SPECIFICATION

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Electronic fee collection — Charging performance —

Part 1: Metrics

Perception du télépéage — Performance d'imputation —

Partie 1: Métrique

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Foreword

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

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

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

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order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn.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again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

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

ISO/TS 17444-1 was prepared by Technical Committee ISO/TC 204, *Intelligent transport systems*, and by Technical Committee CEN/TC 278, *Road transport and traffic telematics* in collaboration.

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

— *Part 1: Metrics* [Technical Specification]

— *Part 2: Examination framework*[1)]

1) To be published.

Introduction

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

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

Toll schemes take on various forms as identified in ISO/TS 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. 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/TS 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/TS 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 part of ISO/TS 17444 references to a "continuous system" have to be understood as those systems having some continuous behaviour even though they may 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. travelled kilometres) resulting in another continuous parameter, money.

Among the different Interoperability Application Profiles defined in CEN/TS 16331, only Section Road Tolling has a purely discrete nature while the other four profiles have both discrete and continuous natures.

Some features of discrete and continuous toll schemes that are of relevance for the definition of metrics proposed in this part of ISO/TS 17444 are analysed below.

Discrete toll schemes

In a discrete toll scheme, distinct events are associated with the identification of Charge Objects. It can be that a vehicle crossed a cordon, passed a bridge, was present in an area, or 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 Chargeable Event*	
		Yes	*No*
Chargeable Event takes place	*Yes*	**Correct Charging**	**Missed Recognition** (Undercharging)
	No	**False Positive** (Overcharging)	**Correct Non-charging**

In this matrix there 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 Chargeable Event 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 part of ISO/TS 17444 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 Event 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).

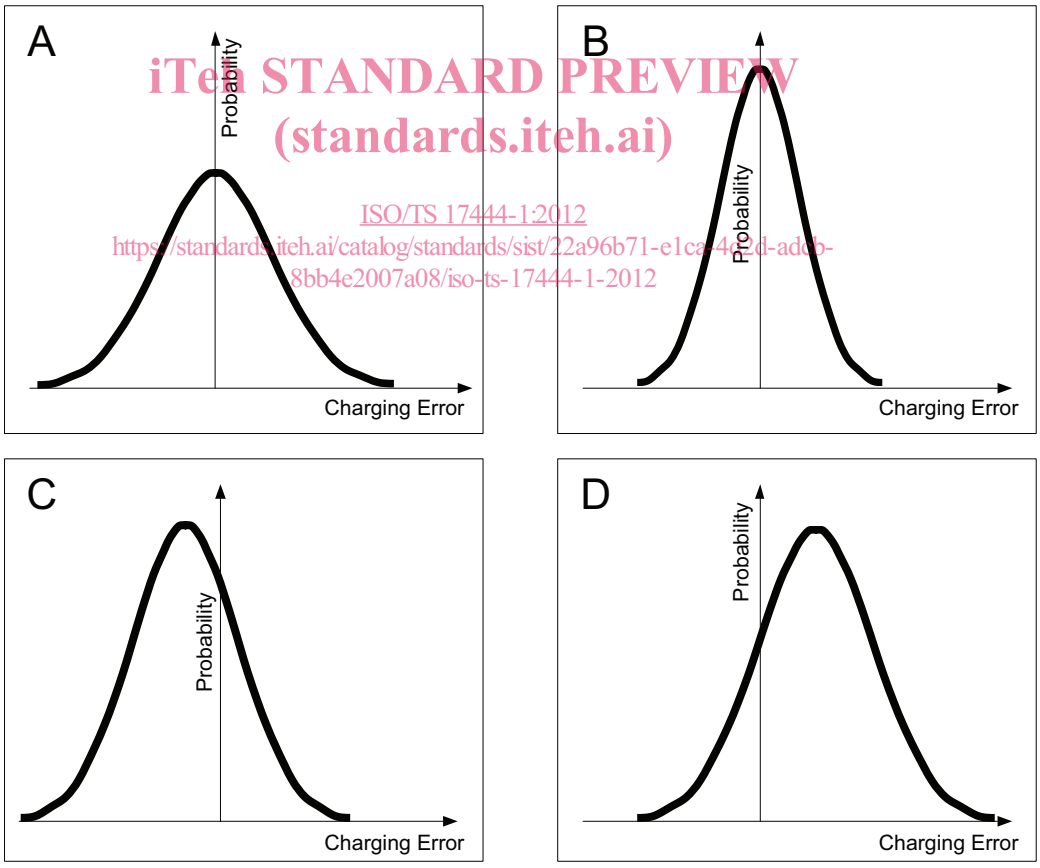

Figure 1 — Idealized plots of error distribution of four different result sets

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 D 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*.

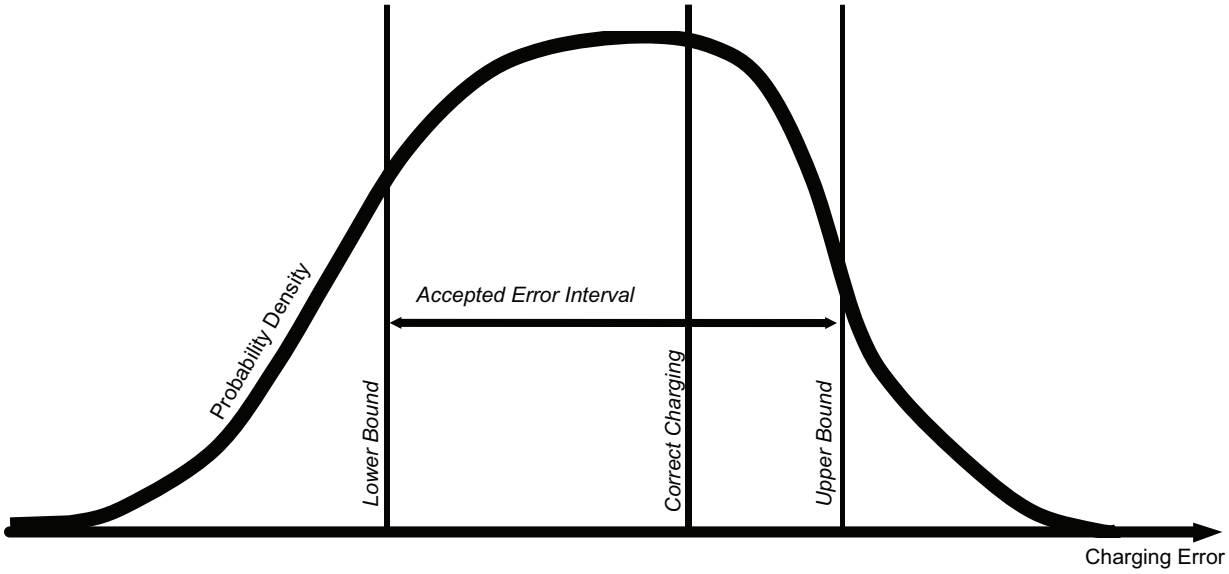

Figure 2 — Definition of Accepted Error Interval

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

Electronic fee collection — Charging performance —

Part 1: Metrics

1 Scope

This part of ISO/TS 17444 defines metrics for the charging performance of electronic fee collection (EFC) systems in terms of the level of errors associated with charging computation.

This part of ISO/TS 17444 is a toolbox standard of metrics. The detailed choice of metrics depends on the application and the respective context.

This part of ISO/TS 17444 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 part of ISO/TS 17444 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 may 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 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 part of ISO/TS 17444 recognizes 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 part of ISO/TS 17444 are intended for both situations.

The following are not covered by this part of ISO/TS 17444.

— This part of ISO/TS 17444 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 part of ISO/TS 17444 does not consider the evaluation of the expected performance of a system based on modelling and measured data from trial at another place.

— This part of ISO/TS 17444 does not consider the specification of a common reference system which would be required for comparison of performance between systems.

— This part of ISO/TS 17444 does not specify metrics on parts of tolling systems other than the charging process chain, such as:

  — enforcement system;

  — security measures.

— This part of ISO/TS 17444 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 part of ISO/TS 17444.

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/TS 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 referenced documents are indispensable for the application 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 14906, *Electronic fee collection — Application interface definition for dedicated short-range communication*

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

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

ISO/TS 17575-1, *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.

3.1
Absolute Charging Error
difference between the measured charge (toll) value and the actual value (as measured by a reference system)

NOTE A positive error means that the measurement exceeds the actual one.

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

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

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

NOTE 1 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 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.

[ISO 12855:2012, definition 3.1]

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

NOTE This event refers to the use of a certain object and not to the mechanisms by which detection is produced.

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

NOTE Adapted from ISO/TS 17575-1:2010.

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

NOTE If the Charging Period is set to 24 hrs then in the Toll Context Data a single Toll Declaration is submitted for each 24 hr period for each Service User.

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

NOTE Examples of this type of event are changes in vehicle category or time zone.

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

NOTE In 2009/750/EC Charge Report is referred as “Toll Declaration”.

[ISO 12855:2012, definition 3.2]

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

NOTE Each event is associated with a certain charge.

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

3.12
Event Detection
element of the system responsible for detecting Chargeable Events associated with a Charge Object

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

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

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

NOTE The Front End comprises the on-board equipment and an optional proxy.

[ISO/TS 17575-1:2010, definition 3.13]

3.15
False Positive Event
Chargeable Event that did not take place but is recorded by the system

3.16
Missed Recognition Event
Chargeable Event that takes place but is not recorded by the system

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

NOTE This can be used to observe metrics during operation.

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