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Space — Use of GNSS-based positioning for road Intelligent Transport Systems (ITS)

Part 1: Definitions and system engineering procedures for the establishment and assessment of performances

National foreword

This British Standard is the UK implementation of EN 16803-1:2016.

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Espace - Utilisation de la localisation basée sur les GNSS pour les systèmes de transport routiers intelligents - Partie 1: Définitions et procédure d'ingénierie système pour l'établissement et la vérification des performances

Raumfahrt - Anwendung von GNSS-basierter Ortung für Intelligente Transportsysteme (ITS) im Straßenverkehr - Teil 1: Definitionen und Systemtechnikverfahren für die Festlegung und Überprüfung von Leistungsdaten

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European foreword

This document (EN 16803-1:2016) has been prepared by Technical Committee CEN-CENELEC/TC 5 “Space”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by April 2017, and conflicting national standards shall be withdrawn at the latest by April 2017.

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EN 16803, *Space — Use of GNSS-based positioning for road Intelligent Transport Systems (ITS)* consists of the following parts:

— Part 1: *Definitions and system engineering procedures for the establishment and assessment of performances*

— Part 2[1]: *Performance assessment tests of GNSS-based positioning terminals*

— Part 3[1]: *Security aspects of performance assessment tests*

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

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[1] In preparation.

Introduction

The civil applications of geopositioning are undergoing exponential development. The latest market analysis for the GNSS systems shows 2 major fields of application which, all together, practically share the whole of the market:

- intelligent Transport Systems (ITS), mainly in the Road ITS domain;
- location Based Services (LBS), accessible on smartphones and tablets.

When a *Road ITS system* needs GNSS positioning, which is the case for most of them, there is the question of the choice of the type of terminal or of its minimum performances which are necessary to satisfy the system's final requirements at user level. To meet these requirements, the system includes a processing module called *Road ITS application* which uses the outputs (*PVT* = Position-Velocity-Time) of a *GNSS-based positioning terminal* (*GBPT*) to provide the service with a given *End-to-end performance*. Consequently, this latter depends on the quality of the positioning outputs, which are highly variable with respect to the operational conditions of the system, but also on the performance of the *Road ITS application* itself.

Figure 1 represents the breakdown of a *Road ITS systems* into its 2 main components.

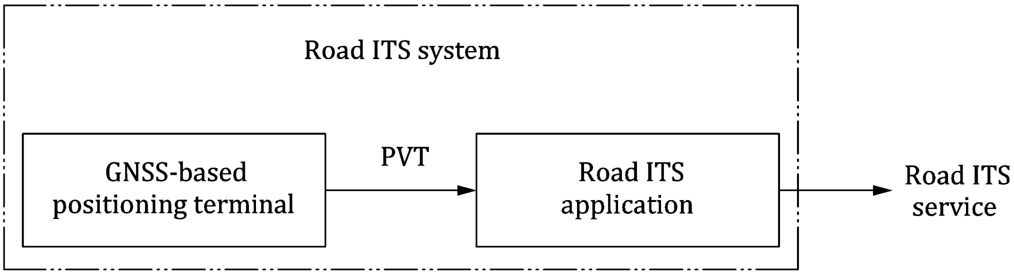


Figure 1 — The two main components of a Road ITS system

The main *Road ITS systems* concerned by this issue are:

- GNSS-based Road User Charging systems (road, parking zone, urban…);
- localized emergency calls (eCall);
- electronic tachograph;
- taximeter;
- regulated freight transport systems (hazardous substances, livestock, etc.);
- “Pay-as-you-drive” insurance;
- road management systems, traffic information systems;
- advanced Driver Assistance Systems (ADAS);
- etc.

Some *Road ITS systems* are considered as “safety critical”, because their failure may cause human death or injury and others are “liability critical”, because they include financial or regulatory aspects. In some cases, their development is subject to an official certification/homologation process.

Particularly for those systems, there exists a strong need to be able to prove they do meet their *End-to-end performance* requirements related to positioning, but, presently, there is no standard that supports such certification process.

The performance management approach proposed in this European Standard is based on a classical system engineering approach and is a support for engineers facing the problem of handling the performances of a *Positioning-based road ITS system* all along the system development.

This overall performance management approach can be summarized as follow:

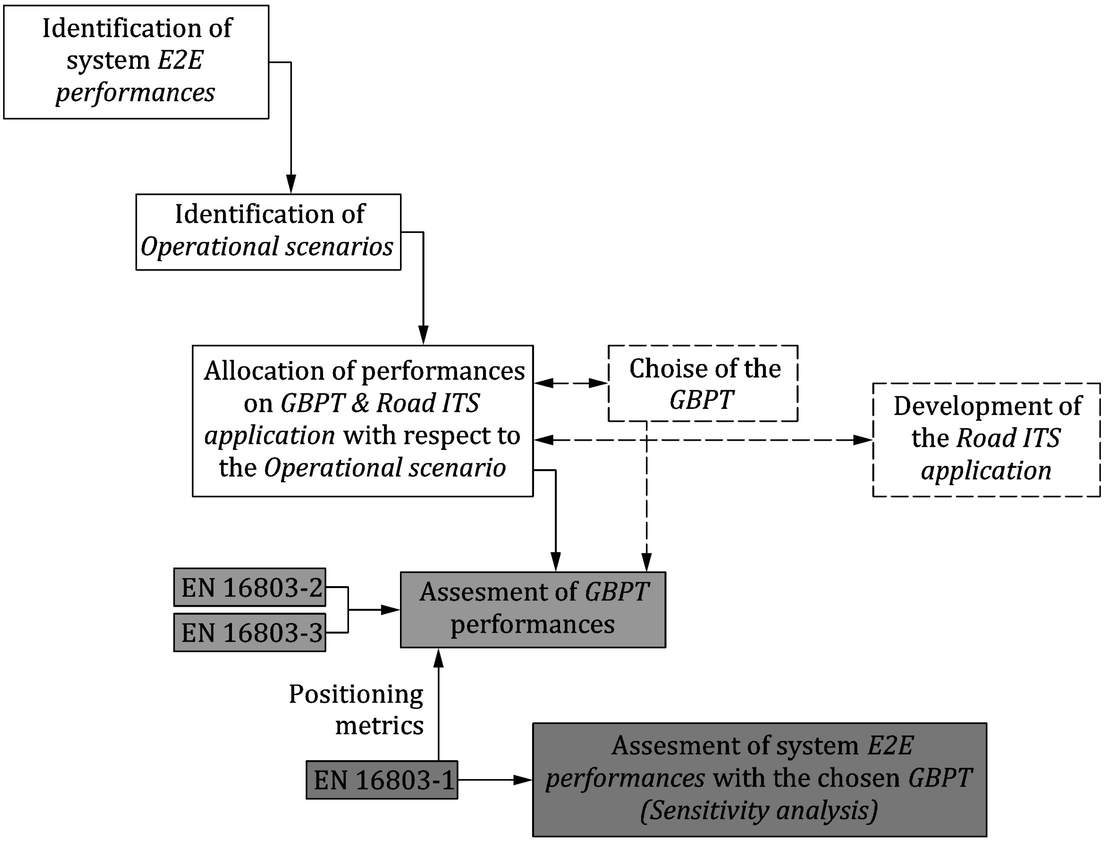


Figure 2 — Logic of the overall performance management approach

The starting point of any performance management of a *Positioning-based road ITS system* **should** be the definition and clear statement of the *E2E performances* which are targeted by the system to design and/or test, as expressed by the customer.

In the context of this European Standard, the system breakdown into components is the one that has been introduced above:

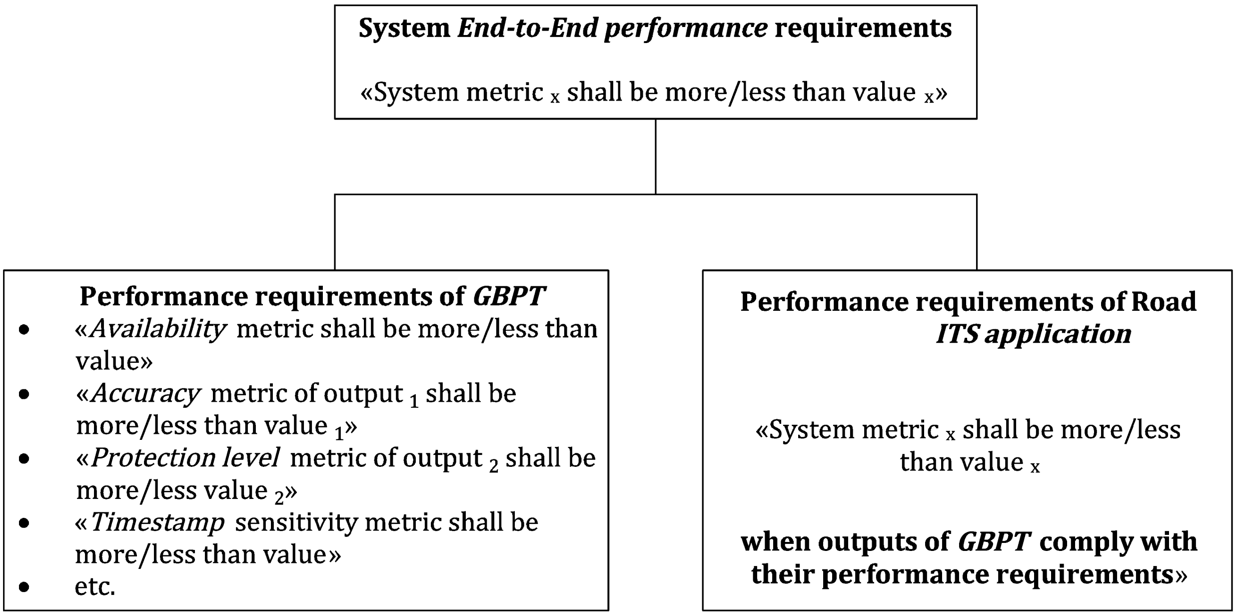
- The GNSS-based positioning terminal (GBPT)

- The Road ITS application

The interface between these two components is assumed to be the *PVT* information, together with some auxiliary information, for instance *Integrity* information if the *GBPT* is designed to support this kind of feature.

Performance requirements are generally stated as requirements on the outputs of a given system component, assuming that the other components feeding it with input information do respect their own performance requirements.

Hence, the performance allocation of the *E2E performances* between the system components **should** follow the general scheme below.



System *End-to-End performance* requirements

«System metric $_x$ shall be more/less than value $_x$»

Performance requirements of *GBPT*

- «*Availability* metric shall be more/less than value»
- «*Accuracy* metric of output $_1$ shall be more/less than value $_1$»
- «*Protection level* metric of output $_2$ shall be more/less value $_2$»
- « *Timestamp* sensitivity metric shall be more/less than value»
- etc.

Performance requirements of Road *ITS application*

«System metric $_x$ shall be more/less than value $_x$

when outputs of *GBPT* comply with their performance requirements»

Figure 3 — Generic performance allocation process

The performance requirements of the *Road ITS application* are actually the same ones as the system *E2E performance* requirements, but expressed under the condition that the *GBPT* respects certain performances requirements.

NOTE Depending on the application, performance requirements may need to be put only on the position output or only on the velocity output by the *GBPT*.

Due to the specificities of GNSS performances, which have to be defined statistically and which are highly dependent on the operational conditions, margins **should** be planned in the performance allocations, in order to allow the system to meet its performance requirements, even when, in certain conditions, one of its component does not strictly meet its own requirements.

1 Scope

EN 16803-1 addresses the final stage of the performance management approach, i.e. the assessment of the whole *Road ITS system* performance equipped with a given *GBPT*, using the *Sensitivity analysis* method.

EN 16803-1 addresses the assessment of *GBPT* performance, since it identifies and defines the positioning performance features and metrics to be used in the definition of the *GBPT* performance requirements.

This EN gives definitions of the various items to be considered when specifying an *Operational scenario* and provides a method to compare finely two environments with respect to their effects on GNSS positioning performance.

This EN gives definition of the most important terms used all along the document and describes the architecture of a *Road ITS system* based on GNSS as it is intended in this standard.

This EN does not address:

- the performance metrics to be used to define the *Road ITS system* performance requirements, highly depending on the use case and the will of the owner of the system;
- the performance requirements of the various kinds of *Road ITS systems*;
- the tests that are necessary to assess *GBPT* performances (field tests for this purpose will be addressed by EN 16803-2[2] and EN 16803-3[2]).

2 Terms and definitions

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

2.1 General terms

2.1.1
digital map
Digital description of the road network and of a certain number of attributes assigned to the elements of this network

Note 1 to entry: Takes the form of a geo-referenced database at the data processing level.

2.1.2
epoch
time at which a GNSS measurement is made

2.1.3
GNSS
Global Navigation Satellite Systems
general acronym designating satellite positioning systems

2.1.4
GPS
Global Positioning System
name of the GPS-Navstar American satellite positioning system

2.1.5
ITS
Intelligent Transport Systems
systems applying information, communication and positioning technologies to the transport domain

2.1.6
navigation
action of leading a vehicle or pedestrian to a given destination, by calculating the optimal trajectory and giving guidance with reference to this trajectory and its real time position

2.1.7
navigation message
data transmitted by the GNSS satellites and necessary for the position computation

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[2] In preparation.

2.1.8
performance
global characterisation of the quality of the service provided by a system.

Note 1 to entry: The performance is generally composed of several given performance features of given outputs of the system and measured by using given metrics.

2.1.9
performance class
domain delimited by 2 boundaries for a given performance metric

2.1.10
performance feature
given characteristic used to qualify and quantify the service provided by a system

EXAMPLE: *Accuracy* for a *Positioning system*.

2.1.11
Performance metric
precise definition of the means of measuring a given performance feature of a given output of a system

EXAMPLE: An *Accuracy* metric can be the median value of an error sample acquired during a given test following a given protocol.

2.1.12
positioning
action of determining the position of a mobile object or a person

2.1.13
Pseudo-range
measurement, by the GNSS receiver, of the distance between a satellite antenna and the receiver antenna, biased by the error due to the difference between the satellite clock and the receiver clock

Note 1 to entry: Belongs to the category of *Raw measurements*.

2.1.14
SBAS
Satellite Based Augmentation System
regional augmentation system of complete satellite systems

EXAMPLE GPS or GLONASS are examples for regional augmentation systems.

Note 1 to entry: In Europe, EGNOS is the regional SBAS system

2.1.15
trajectory
series of time-stamped positions (and possibly speeds) of a mobile object

2.2 Specific terms

2.2.1
application quantity

quantity produced by the *Road ITS application*, from which an *End-to-end performance* can be calculated

Note 1 to entry: This quantity is normally deducted from a set of positions (and/or speeds) produced by the *Positioning system*.

EXAMPLE: The time of presence of a vehicle inside a given zone is an *Application quantity* for a *Geofencing* application.

2.2.2
assisted GNSS

technique consisting in assisting the positioning calculation performed by the GNSS terminal by providing it, via a telecommunication system, with partial or full navigation data as borne by the GNSS signal transmitted by the satellites

NOTE 1 to entry: This technique reduces the *Time To First Fix*, and lowers the acquisition sensitivity threshold.

2.2.3
benchmark GNSS receiver

any off-the-shelf, low-cost and high sensitivity GNSS receiver capable of providing pseudo-range measurements

Note 1 to entry: This kind of receiver is proposed in this EN as a benchmark sensor of the environmental constraints that affect the GNSS signals propagation for fine comparison of environments between themselves.

2.2.4
E2E performance
end-to-end performance

performance of the service provided by a *Road ITS system*

Note 1 to entry: *E2E performance* is measured by applying a performance metric to an *Application quantity*.

EXAMPLE: For a Taximeter, the accuracy of the travelled distance is an *E2E performance*

2.2.5
geofencing

function consisting in determining the presence of certain persons or of certain moving objects within a certain geographical zone

Note 1 to entry: This zone can be defined in several ways.

2.2.6
geo-object

geographic entity, having the form of a virtual polygon, framing a point of interest or delimiting a zone of interest

2.2.7
integrity

general performance feature referring to the trust a user can have in the delivered value of a given *Position* or *Velocity* component

Note 1 to entry: This feature is expressed by 2 quantities: the *Protection level* and the associated *Integrity risk*.

Note 2 to entry: In this EN, the definition of integrity is inspired by, but significantly simpler than, the definition of the same concept for the civil aviation community in ISO/TS 17444-1:2012.

Note 3 to entry: For other domains than GNSS positioning, *Integrity* may have other definitions

2.2.8
IR
integrity risk

for *Positioning terminals* providing a *Protection level* as integrity-related quantity, the probability that the actual error on a given *Position* or *Velocity* component exceeds the associated *Protection level* associated with this component

2.2.9
map-matching

processing operation consisting in determining the position of the mobile on a map representing the road network.

Note 1 to entry: Requires a digital map.

2.2.10
operational scenario

description of the conditions in which the *GNSS-based road ITS system* is operating and particularly affecting the *GNSS-based positioning terminal*

2.2.11
position

location of the positioning terminal or, more specifically, of some reference point attached to it, such as the antenna phase centre

2.2.12
positioning system

set of hardware and software components, which can be in different locations, but interconnected, which contribute to estimating the position, velocity and associated timestamp of a mobile object

2.2.13
positioning terminal

equipment (unit) carried by a vehicle or a person delivering a position solution to a *Road ITS application*

Note 1 to entry: The *Positioning terminal* is the component of the *Positioning system* which is directly interfaced with the position data user (in this document the *Road ITS application*).

Note 2 to entry: The *Positioning terminal* uses a GNSS receiver which may be hybridized or assisted.

2.2.14
positioning module

software component of the *Positioning terminal* processing the *PVT* from the data of different sensors

2.2.15
positioning-based road ITS system

system consisting of one or several *Positioning terminals* and of a *Road ITS application* providing a *Positioning-based Road ITS service*

2.2.16
positioning-based road ITS service

main function(s) of a *Positioning-based Road ITS system*, making use of the *Application quantities*

EXAMPLE: Computation and secure storage of charge events for a road charging system.

2.2.17
protection level

estimation of an upper bound for the error made on a *Position* or *Velocity* component (e.g. the plane position) associated with a given probability called *Integrity risk*

Note 1 to entry: Like the actual error, this quantity can be characterized by its distribution function.

2.2.18
PVT error model

parametric mathematical model representing the errors affecting a *PVT* component, composed with noise and biases observed on this component, output by a *Positioning terminal* operating in a certain environment.

Note 1 to entry: The *PVT error model* is used to draw pseudo-random trajectories representative of real trajectories.

2.2.19
PVT
Position, Velocity and Time

data related with the position, the velocity and the time which is available at the output of a GNSS receiver or of a *Positioning terminal* in general

2.2.20
raw measurements

describe all the quantities available in a GNSS receiver after the signal processing stage from which the *PVT* will be calculated

Note 1 to entry: The *Pseudo-ranges* for each tracked satellite are essential components of the *Raw measurements*.

2.2.21
reference trajectory

series of time-stamped positions of a reference point on a mobile object (test vehicle), produced by a *Reference trajectory measurement system*

Note 1 to entry: This reference trajectory may be called “Ground truth” in some other documents.

2.2.22
RTMeS
reference trajectory measurement system

measurement means capable of accuracy performances better of at least one order of magnitude than those of the required performance of the *Positioning terminal* being tested

2.2.23
road ITS application
processing part downstream of the *Positioning terminal*(s) which computes the *Application quantities* and provides the *Road ITS service*

2.2.24
sensitivity analysis
method to assess the performance of a *Road ITS application* or of a whole *Road ITS system*, consisting in injecting a high number of simulated degraded *PVT* data obtained by adding to a reference trajectory *PVT error models* representing the real errors observed during dedicated field tests

2.2.25
speed
norm of the velocity vector

NOTE: The speed describes how fast the user moves relatively to the ground irrespectively of its direction.

2.2.26
velocity
velocity of the positioning terminal relative to the ground expressed as a three-component vector

2.3 Acronyms

2.3.1
ADAS
Advanced Driver Assistance System

2.3.2
CDF
Cumulative Distribution Function

2.3.3
EFC
Electronic Fee Collection

2.3.4
E2E
End-To-End

2.3.5
EGNOS
European Geostationary Navigation Overlay Service

2.3.6
GBPT
GNSS-based positioning terminal

2.3.7
IMU
Inertial Measurement Unit

2.3.8
NLOS
Non Line Of Sight

2.3.9
PDF
Probability Density Function

2.3.10
TIR
Target Integrity Risk

2.3.11
TTFF
Time To First Fix

3 Description of the generic architecture of a Road ITS System based on GNSS

3.1 Generic architecture

A *Positioning-based road ITS system* based on GNSS consists of a *Positioning system* and of a *Road ITS application*, using positioning data to provide a *Service* for the user (navigation aid, tracking, events or presence detection, etc.). Figure 4 presents the architecture of such a system.

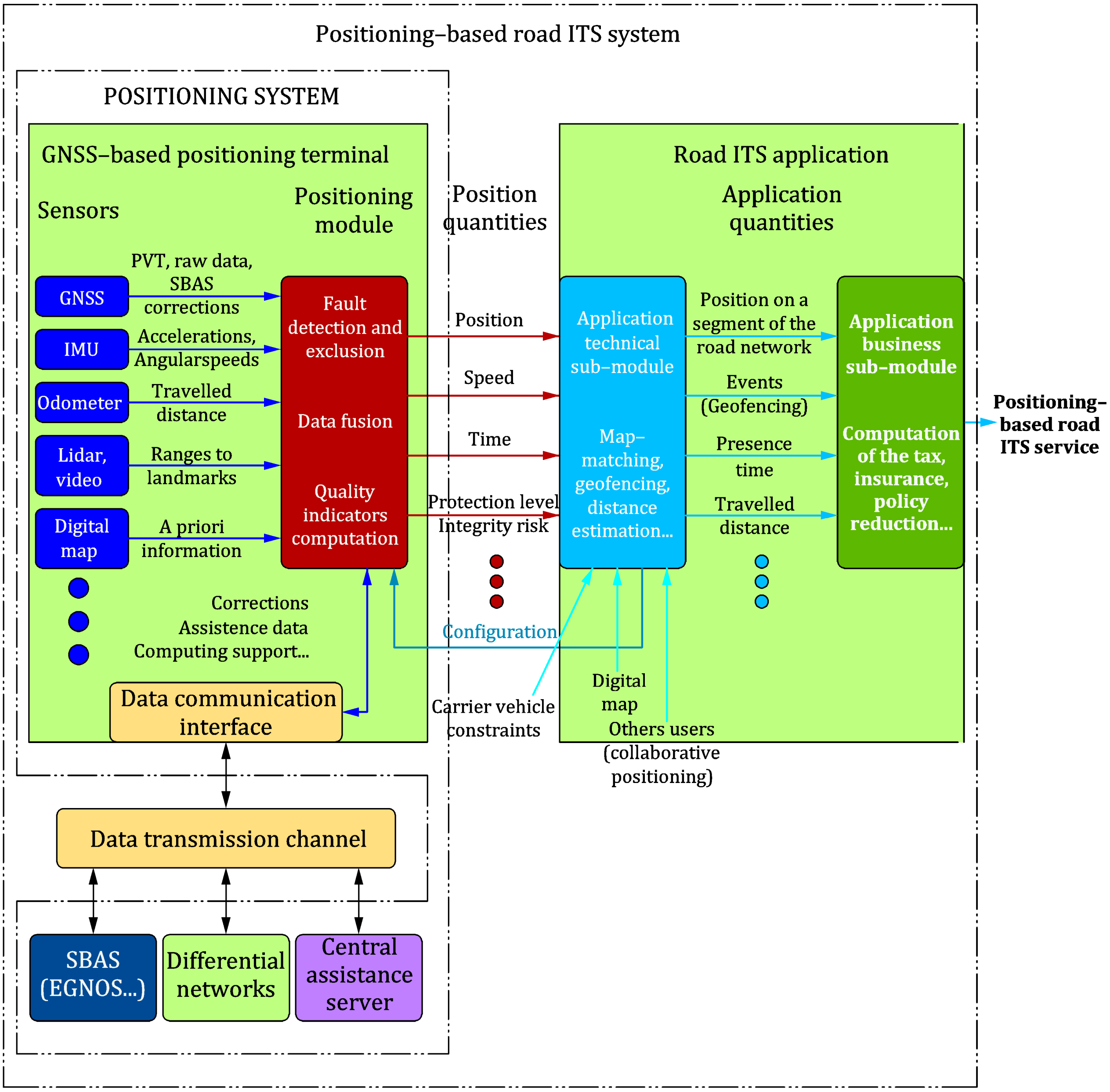

Figure 4 — Generic architecture of a Road ITS system

3.2 Components

3.2.1 Positioning components and outputs

The *Positioning terminal* is the on-board part of the *Positioning system*, i.e. the part attached to the mobile object (vehicle), which position is expected by the application. In this respect, the terminal is the component of the *Positioning system* which is directly interfaced with the *Position quantities* user (in our case the *Road ITS application*). More precisely, since this EN is addressing the uses cases where a GNSS receiver is used, the terminal is called *GNSS-based positioning terminal*, or *GBPT*.

The terminal itself consists of a series of on-board sensors and a positioning software component (*Positioning module*) supplying the *Road ITS application* with *Position quantities*. The *Positioning module* inside the terminal, or the GNSS sensor itself, can use external GNSS data provided through a data transmission channel, for instance assistance data, differential GNSS data or SBAS data. The position computation can also be partially or totally performed by a module external to the vehicle. In both of these cases, the *Positioning system* is only partially on-board the vehicle, but the *GBPT* is always on-board and remains the component providing the final position output to the application.

In the frame of this EN, the *GBPT* **shall** use at least a *GNSS receiver* which can be hybridized or assisted.

In the frame of this EN, the *Position quantities* output by the *GBPT* **shall** comprise at least one of the two following quantities:

- the position of the phase centre of the GNSS receiver antenna or of any other reference point of the vehicle, expressed in a standard geodetic reference system;
- the velocity of this point;

each of them being associated with a timestamp indicating the time to which the output corresponds.

Depending on the application, the position can be either the 3 components of the 3D position (i.e. a vector), or a subset of them, for example the 2D horizontal position (projection of the 3D position on the horizontal plane or on a plane tangent to the ellipsoid used by the geodetic reference frame) or the vertical position.

The same way, the velocity can be limited to the horizontal 2D velocity or even to the module of it, i.e. the horizontal speed, or to any single component of the 3D velocity.

In the case when the *Positioning terminal* is delivering *Integrity* information on any position or velocity component of the *PVT*, this information **shall** comprise at least:

- a *Protection level* on the concerned *PVT* component, according to the definition given in this EN, that is to say a value that statistically bounds the error of the position or velocity component provided by the positioning terminal with a very high probability,
- computed for a given *Integrity risk*, which is the complementary probability of the latter, that is to say the probability that the actual error on the component actually exceeds the associated *Protection level*.

3.2.2 Road ITS application and outputs

The *Road ITS application* is a software module which is broken down for the purpose of this document into 2 sub-modules:

1) The *Technical sub-module* which transforms the *Position quantities* into *Application quantities* derived directly from the *PVT* and other data depending on the application and which are the key quantities necessary to deliver the final service to the user.

EXAMPLE Position on a road segment (map-matched position), charging point detection, zone entry/exit detection, distance covered are examples of *Application quantities*.

2) The *Business sub-module* which is dedicated to the provision of the final service and highly dependent on the business model chosen by the operator of the system.

EXAMPLE Computation of the bill to be sent to the user for a road user charging system is an example of processing done by this sub-module. Since this processing can be extremely variable, this sub-module is out of the scope of this EN, and will be considered in this EN only the cases when the *End-to-end performances* of the system providing the service are established on the *Application quantities*.

4 Definition of performance metrics for positioning terminals

4.1 General

This section provides the definition of the positioning metrics. The metrics defined herein shall be used for the characterization of the *PVT* performances as the basis for establishing requirements, and for evaluation and validation purposes. The logic for performance metrics definition comprises:

- A detailed definition of position terminal outputs to which the different metrics will be defined (see 4.2).
- An identification of characteristics of those outputs that are relevant for the identification of performance features (see 4.3)
- An identification of the performance features to be described (see 4.4)
- A definition of metrics (see 4.5).

4.2 Outputs of the Positioning terminal

The outputs expected from the *Positioning terminal*, also called *Position quantities*, were specified in 4.1 to be those related to position, velocity and time (*PVT*). The following list aims at identifying all the parameters that can be of interest to the vast majority of *Road ITS applications* that take advantage of *PVT* information:

- **Position**: is the location of the positioning terminal (or, more specifically, of some reference point attached to it, such as the antenna phase centre) expressed in some specified reference frame (e.g. WGS84) and system of coordinates (e.g. geodetic or Cartesian). The position output can include all position components (e.g. longitude, latitude and height) or just a subset of them (e.g. longitude and latitude) depending on the needs of the application.
- **Velocity**: is the velocity of the positioning terminal relative to the ground. In its more general form it is a three-component vector which will most typically be expressed in a Cartesian coordinate system whose frame is centred at the user position (e.g. the local horizontal reference frame, with coordinates referring to North, East and Up directions).
- **Speed**: is the norm of the velocity vector, and hence describes how fast the user moves (relative to the ground) irrespective of the direction. It is of relevance in many applications and hence it shall be specifically addressed. When accompanied by heading, speed provides an equivalent description of the velocity vector of a vehicle (provided that its motion is mainly horizontal, which is typically the case with land vehicles). Depending on the specific application, it can be convenient to present the motion information to the user in the form of speed and heading, but in general, the velocity vector is the most informative.
- **Protection levels**: a *Protection level* (PL) is a value that bounds the error of position or velocity components provided by the positioning terminal with a very high probability. Therefore, protection levels shall be so that the complementary probability (known as *Integrity risk*) that the position or velocity error exceeds its associated protection level is very small. The associated target *Integrity risk* is application-specific and known to the positioning terminal, so it does not need to be provided as an output. *Protection level* is a real-time and dynamic quantity which is valid for each measurement epoch.
- **Quality indicators**: in addition to the above, quality indicators may be provided such as *Dilution of precision* (DOP), covariances from the estimation process, etc. Parameters of this type are only

vaguely indicative of the quality of the other outputs, so they are not considered to be reliable measurements of performance and will be disregarded in the following discussion.

- **Timestamp**: is a tag that indicates the time to which all other items in this list correspond, and is usually referred to some well-known time standard, such as UTC.

4.3 Inputs to the performance characterization process

The performance characterization process is the process of characterizing the *Positioning terminal* performance based on a number of metrics that will be defined in next section. Prior to defining the performance metrics it is important to note that most of the metrics will not address directly the outputs of the positioning terminal, but rather their errors. Thus, the inputs to the performance characterization process are not exactly the outputs of the positioning terminal, but rather the following:

- **Position error**: is the difference between the true position and the position provided by the positioning terminal. It shall be understood as a vector expressed in some convenient local reference frame (e.g. local horizontal frame).

- **Velocity error**: is the difference between the true velocity vector and the one estimated by the positioning terminal. It shall be understood as a vector expressed in some convenient local reference frame (e.g. local horizontal frame).

- **Speed error**: it is the difference between the true speed and the speed provided by the positioning terminal.

- **Protection levels**: either of position or velocity components, they are both outputs of the positioning terminal and inputs of the performance characterization process (they need no further manipulation). It is important to note that, those epochs in which, for whatever reason, the positioning terminal is unable to provide a protection level, the said protection level is assumed to be of infinite size for performance characterization purposes.

- **Timestamp**: same as corresponding output from the positioning terminal.

- **Time of output**: is the time at which the positioning terminal provides its output, and is referred to the same time frame as the timestamp. This time is always posterior to the one of the Timestamp and the difference between these 2 times is called **Output latency**.

4.4 Performance features

Performance of the positioning terminal can be characterized in terms of different features (or characteristics).

NOTE These features resemble, to some extent, those identified by the Civil Aviation community regarding “Required Navigation Performances”, but with some key differences which reflect the peculiarities and specific needs of *Road ITS applications*.

The aforesaid features are:

- **Accuracy**: it refers to statistical figures of merit of position error, velocity error or speed error (as defined in 4.3).

- **Integrity**: it refers to the characteristic of the *Protection level* and its associated *Integrity risk*, in terms of reliability (verification of the risk) but also its efficiency and usability (size of the *Protection level*, which is directly related to their usability for the intended application).

- **Availability**: generally speaking, it refers to the percentage of time during which the output of the positioning terminal is available. This feature can be defined in many different manners according to the application needs. The metric defined in the EN is a somehow generic metric which allows the measurement of the percentage of operating time intervals of length T during which the positioning terminal provides at least one position output.
- **Timing performance**: it refers to timestamp resolution, output latency, rate stability and Time To First Fix.

4.5 Performance metrics

The following table summarizes all potential metrics for all different output components. The rationale behind them is provided in Annex A.

In all the definitions below mentioning the 50th, 75th and 95th percentiles of the cumulative distribution of errors, it is implicitly understood that the errors sample on which these percentiles are calculated is the result of a given performance assessment test, respecting a given operational scenario and following a given test protocol. Below are given only the basic definitions, the specification of the test itself is out of the scope of this EN.

The cumulative distribution function of a real-valued random variable X is the function given by:

$$F_X(x) = P(X \leq x) \tag{1}$$

Table 1 — Accuracy metrics summary

Output	Component	Accuracy metric
Position	3D	3D Position Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of 3D position errors.
	Horizontal	Horizontal Position Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of horizontal position errors.
	East	East Position Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the absolute values of position errors along the East–west direction
	North	North Position Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the absolute values of position errors along the North–south direction.
	Along track	Along Track Position Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the absolute values of Along Track position errors.
	Cross track	Cross Position Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the absolute values of Cross-Track position errors.
	Vertical	Vertical Position Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the absolute values of Vertical position errors.
Velocity	3D	3D Velocity Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of 3D Velocity errors.
	Horizontal	Horizontal Velocity Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of horizontal Velocity errors.
	East	East Velocity Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the absolute values of Velocity errors along the East–west direction.
	North	North Velocity Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the absolute values of Velocity errors along the North–south direction.
	Along track	Along Velocity Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the absolute values of Along Track Velocity errors.
	Cross track	Cross Velocity Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the absolute values of Cross-Track Velocity errors.
	Vertical	Vertical Velocity Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the absolute values of Vertical Velocity errors.
Speed	-	Speed Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of Speed errors.

Table 2 — Integrity metrics summary

Output	Component	Protection Level Performances Metric	Integrity Risk Metric
Position Protection Level	3D	3D Position Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of 3D position Protection Levels computed for that target integrity risk.	The 3D Position Integrity Risk is the probability that the 3D position error exceeds the 3D position Protection Level.
	Horizontal	Horizontal Position Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of horizontal position Protection Levels computed for that target integrity risk.	The Horizontal Position Integrity Risk is the probability that the horizontal position error exceeds the horizontal position Protection Level.
	East	East Position Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of East position Protection Levels computed for that target integrity risk.	The East Position Integrity Risk is the probability that the East position error exceeds the East position Protection Level.
	North	North Position Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of North position Protection Levels computed for that target integrity risk.	The North Position Integrity Risk is the probability that the North position error exceeds the North position Protection Level.
	Along track	Along Track Position Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of Along Track position Protection Levels computed for that target integrity risk.	The Along Track Position Integrity Risk is the probability that the Along Track position error exceeds the Along Track position Protection Level.
	Cross track	Cross Track Position Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of Cross Track position Protection Levels computed for that target integrity risk.	The Cross Track Position Integrity Risk is the probability that the Cross Track position error exceeds the Cross Track position Protection Level.
	Vertical	Vertical Position Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of Vertical position Protection Levels computed for that target integrity risk.	The Vertical Position Integrity Risk is the probability that the Vertical position error exceeds the Vertical position Protection Level.

Output	Component	Protection Level Performances Metric	Integrity Risk Metric
Velocity Protection Level	3D	3D Velocity Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of 3D Velocity Protection Levels computed for that target integrity risk.	The 3D Velocity Integrity Risk is the probability that the horizontal Velocity error exceeds the 3D Velocity Protection Level.
	Horizontal	Horizontal Velocity Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of horizontal Velocity Protection Levels computed for that target integrity risk.	The Horizontal Velocity Integrity Risk is the probability that the horizontal Velocity error exceeds the horizontal Velocity Protection Level.
	East	East Velocity Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of East Velocity Protection Levels computed for that target integrity risk.	The East Velocity Integrity Risk is the probability that the East Velocity error exceeds the East Velocity Protection Level.
	North	North Velocity Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of North Velocity Protection Levels computed for that target integrity risk.	The North Velocity Integrity Risk is the probability that the North Velocity error exceeds the North Velocity Protection Level.
	Along track	Along Track Velocity Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of Along Track Velocity Protection Levels computed for that target integrity risk.	The Along Track Velocity Integrity Risk is the probability that the Along Track Velocity error exceeds the Along Track Velocity Protection Level.
	Cross track	Cross Track Velocity Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of Cross Track Velocity Protection Levels computed for that target integrity risk.	The Cross Track Velocity Integrity Risk is the probability that the Cross Track Velocity error exceeds the Cross Track Velocity Protection Level.
	Vertical	Vertical Velocity Protection Level Performance for a given (e.g. 1E-6) target integrity risk is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of Vertical Velocity Protection Levels computed for that target integrity risk.	The Vertical Velocity Integrity Risk is the probability that the Vertical Velocity error exceeds the Vertical Velocity Protection Level.

Table 3 — Availability metrics summary

Output	**Availability Metric**
Position	Position Availability (T) is the percentage of operating time intervals of length T[a] during which the positioning terminal provides at least one position output
Velocity / Speed	Velocity /Speed Availability (T) is the percentage of operating time intervals of length T during which the positioning terminal provides at least one velocity/speed output
[a] The length of time interval T should be defined according to each application specific needs.	

Table 4 — Timing metrics summary

Variable	**Type**	**Timing Metric**
Timestamp Resolution	N/A	Timestamp resolution is the size of the smallest time lapse which would result in different consecutive timestamps. It can be understood as the value of the least significant bit within the word used to encode the timestamp.
Output Latency Stability	N/A	Output latency stability is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of output latency errors.
Output Rate Stability	N/A	Output rate stability is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of output rate errors.
Time To First Fix (TTFF)	Cold	Cold TTFF is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the elapsed time from positioning terminal switch-on in cold conditions until a valid position solution is outputted.
	Warm	Warm TTFF is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the elapsed time from positioning terminal switch-on in warm conditions until a valid position solution is outputted.
	Hot	Hot TTFF is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the elapsed time from positioning terminal switch-on in hot conditions until a valid position solution is outputted.

- **Cold start**: The receiver is switched on when no information is available in it and therefore the receiver entails a full search of the sky for all satellites.

- **Warm start**: The receiver is switched on and has a valid almanac (either stored from a navigation message recently decoded or obtained via other means, e.g. through *Assisted GNSS*) and a rough position with approximate information on frequency offset.

- **Hot start**: The receiver is switched on and has both accurate ephemeris and information on frequency offset as well as an accurate initial solution.

5 Operational scenarios

5.1 Definition

5.1.1 Composition

In this document, the *Operational scenario* represents the conditions in which the *GBPT* is placed when it is operating for the benefit of the *Road ITS system* and that may have a great influence upon its performances, especially on the GNSS receiver's performances. When a performance target or requirement is expressed, either for the *GBPT* or for the whole *Road ITS system*, the *Operational scenario* in which the performance is expected shall be precisely described.

This *Operational scenario* is threefold. It **shall** be composed of:

- the set-up conditions of the terminal, and particularly of the antenna of the GNSS receiver;
- the trajectory of the mobile vehicle (more precisely of the antenna);
- the environmental conditions.

5.1.2 Set-up conditions

The set-up conditions are those which have an influence on the GBPT performances, in particular the location of the antenna, on the roof of the vehicle or behind the windshield, and in this last case, the transparency of the windshield to the radio waves.

For a terminal hybridizing other sensors, the location and configuration of these sensors **shall** also be defined.

5.1.3 Trajectory

A trajectory is a series of time-stamped positions describing the path of the vehicle (positions only) and possibly its dynamic behaviour (the position derivatives such as speed and acceleration can be derived from the series of positions).

The trajectory described in an *Operational scenario* **shall** be described in such a way that it is possible to follow it with a test vehicle.

Its accuracy depends on the application and can be quite poor for a majority of cases. A description of the roads or streets to be taken with a general requirement in terms of maximum or minimum speed can be sufficient.

5.1.4 Environmental conditions

The environmental conditions are complex and encompass:

1) the geometry of the GNSS satellite constellations;
2) the latitude of the test location (affecting the relative position of the satellite constellation with respect to the receiver);
3) the geometry of the various semi-static obstacles surrounding the vehicle (buildings, mountains, trees with or without foliage, etc.);
4) the geometry of the various dynamic obstacles surrounding the vehicle, mainly the other vehicles;
5) the physical properties of the obstacles, affecting the interactions between them and the GNSS radio signals (reflection, diffraction, etc.);

6) the general electromagnetic environment (other sources of radio waves that may affect the behaviour of the GNSS receiver, unintentionally or intentionally produced);

7) the weather conditions, like deep fog, heavy rain or snow that can affect the electromagnetic waves propagation;

8) the ionosphere conditions.

Upon all these conditions, the third category, called hereafter *Geometrical environment*, is of the upmost importance since it mostly affects the GNSS performances, up to a complete unavailability of the signal.

The merging of all these environmental conditions is called "*GNSS environment*" in this EN.

To characterize the *Geometrical environment*, the visibility of the sky above the antenna, called "sky-plot", is often used. The figure indicates in polar coordinates (elevation-azimuth) oriented in the forward direction of the mobile:

- the presence of solid obstacles supposed to totally block the satellite signals,
- the presence of zones affected by a partial masking in which the GNSS signals are supposed to be attenuated.

NOTE 1 The sky visibility condition is not sufficient to represent the reality of the phenomena that affect the signals propagation. For example a narrow street with medium high buildings and a large avenue with high buildings can be characterized by the same sky plot but the additional paths of the signals reflecting on the buildings facades, especially those coming from masked satellites (NLOS or Nonline-Of-Sight signals), will be totally different in terms of length, creating significantly different errors in terms of position.

NOTE 2 The sky visibility conditions cannot represent the physical properties of the building materials, or the variability of the buildings in a city, in terms of height, width, etc.

For these reasons, the characterization of an environment for field tests purposes cannot be done in a satisfactory way by only sky visibility conditions and this EN proposes a way to characterize a *GNSS environment* which is more suitable to field tests.

The best way to characterize globally a *GNSS environment* with respect to the impact it can have on a GNSS receiver performances, is to use precisely the result of the measurement of these performances of a *Benchmark GNSS receiver* as characteristic. The performances at the pseudo-ranges level being more representative of the impact of the environment than the performances at the position level, a *Benchmark GNSS receiver* capable of delivering pseudo-ranges **shall** be used. Since it is not feasible to specify a unique type of receiver that shall be used by all the parties wishing to characterize finely an environment, this characterization can only be **relative** and not absolute. The exact procedure for comparing *GNSS environment* using a *Benchmark GNSS receiver* will be given in 5.2.3.

5.2 GNSS environments classification and characterization

5.2.1 Rationale

GNSS reference environments **shall** be used to interpret test results and to compare results of tests which are similar but executed at different places. This is valid either for tests done on the *GBPT* or on the whole system itself.

Two levels of characterization of *GNSS environments* **shall** be used, the second one being relative and not absolute, and consequently **shall** be used only for comparison:

- Coarse absolute characterization: classification in a high-level category of *GNSS reference environment* (defined hereafter);

- Fine comparison of several environments: using the Environment fine characterization metric and a Benchmark GNSS receiver.

5.2.2 Definition of the high-level categories of GNSS reference environments

The coarse characterization of a GNSS environment **shall** correspond to its classification into one of the six following categories.

1) "**Flat Rural**", or "clear sky": rural roads in a flat countryside with masking angles smaller than 10°, no mountains nor high hills;

2) "**Tree-lined Rural**": rural roads, with lines of trees with foliage on each side and a significant effect on signal reception due to the foliage;

3) "**Mountainous**": roads with sharp curves and high mountains around, generally on one side of a valley, with numerous tunnels and sometimes trees, masking angles between 10° and 80°;

4) "**European Peri-urban**": suburb or medium cities ring roads, with relatively large streets and small to medium height buildings, masking angles up to 30 °;

5) "**European Urban**": standard European "old" big cities with relatively narrow streets, but sometimes large avenues or ring roads, with buildings from medium height to tall, masking angles up to 60 ° generating frequent multipath and Nonline-Of-Sight phenomena;

6) "**Modern Urban Canyon**": business centres with very high modern buildings mainly of glass and metal, generally large avenues and many tunnels, masking angles often greater than 60° generating frequent Nonline-Of-Sight phenomena.

5.2.3 Fine characterization of a GNSS environment

5.2.3.1 General

The fine characterization **shall** be used to compare several environments and to assess that they belong to the same high-level category.

5.2.3.2 Description of the fine characterization procedure

The *GNSS environment* fine characterization test **shall** use:

- a test vehicle equipped with a *Reference Trajectory Measurement System* (*RTMeS*) capable of providing a *Reference trajectory* in any type of environment, with an availability equal to 100 % and an accuracy better of at least one order of magnitude than the accuracy of the *Benchmark GNSS receiver*;

- a *Benchmark GNSS receiver*;

- a data acquisition system capable of recording the outputs from the *RTMeS* and those from the *Benchmark GNSS receiver* and to synchronize them within the same time reference;

- a data processing software capable of computing the errors on the pseudo-ranges provided by the *Benchmark GNSS receiver*.

The *GNSS environment* fine characterization test **shall** be preceded by the provision of a test design specification describing the following steps:

1) definition of a pre-defined path inside the area where the characterization is to be done, this path being as representative as possible of all the different situations likely to be met in the environment;

2) installation, set-up and initialisation of the *Benchmark GNSS receiver* and the *RTMeS* on-board of the vehicle, their antennas being installed on the roof, distant from each other of at least 20 cm to avoid cross masking phenomena, the height from the ground being between 1,5 m and 2,25 m;

3) travel of the pre-defined path, at a standard speed[3], the duration of the test being greater than 2 h (see step 7) and the output rate of the two positioning systems equal or higher than 1 Hz, in order to gather a sufficient amount of data;

4) at least two repetitions of the test using the same path with a time interval between the 3 tests of approximately 2 h, in order to be representative as much as possible of the different satellite constellations;

5) processing of the true ranges of the satellites whose signals have been received and processed by the *Benchmark GNSS receiver* and computation of the pseudo-range errors;

6) application of the *Fine environment characterization metric* to the pseudo-range errors database;

7) when the traffic conditions are bad during tests in cities, the length of the tests **shall** be extended, with the objective of gathering at least 2 h of data corresponding to a speed greater than 2 km/h

NOTE Since the positioning errors output by a GNSS receiver can be significantly different when the mobile is moving and when it is stationary, especially in constrained environments where multipath are frequent, it is important to use samples containing very few measurements obtained at a speed below 2 km/h

5.2.3.3 Choice of the Benchmark GNSS receiver

The *Benchmark GNSS receiver* **shall** be an off-the-shelf and widely used high sensitivity GNSS receiver, offering a good availability and a good sensitivity to the multipath and NLOS phenomena and capable of providing pseudo-ranges measurements.

5.2.3.4 Definition of the Fine environment characterization metric

The fine characterization of a *GNSS environment* using a *GNSS benchmark receiver* **shall** use the metric composed of the 95th percentile of the CDF of the absolute values of the pseudo-range errors, computed for the whole set of data acquired during the test, at a speed greater than 2 km/h

5.2.3.5 Definition of the comparison test

When proceeding to a comparison between several environments located at different places and supposed to belong to the same category, the following procedure **shall** be used:

1) fine characterization tests shall be executed in all the environments to be compared, using the same *GNSS benchmark receiver* and following the procedure described in 5.2.3.2,

2) the metric defined in 5.2.3.4 shall be applied to the data acquired in the different environments,

3) the environments **shall** be declared belonging to the same category if the absolute value of maximum deviation between all the metrics and the mean value of them do not exceed 20 % of the mean value.

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[3] Standard speed means: respecting the legal speed limits, the traffic signs and the safety conditions.

6 Sensitivity Analysis

6.1 General

Performance tests on the *Road ITS application* can be carried out in field conditions, using the real *GBPT* and the real *Road ITS application*, that is to say the full real system, or in laboratory by simulating the *GBPT* to feed the real *Road ITS application* with simulated *PVT* data.

Since GNSS *PVT* errors depend on a high number of parameters which vary along the time and are in particular highly dependent on the local physical environment, performance assessment of the *Road ITS application* using GNSS data needs numerous tests representing the multiplicity of cases likely to be met during the operation of the system. Furthermore, the verification of some *E2E performances*, which are expressed by a very low probability, needs a high number of tests and cannot be carried out in real conditions on the field. Therefore, simulated *PVT* data **shall** be used.

There are 2 ways to generate a high number of simulated *PVT* data from a given *GBPT* operating in a given *Operational scenario*:

- to use a GNSS constellation simulator as input to the *GBPT*, as for laboratory *GBPT* performance tests, with the limitations due to the fact that the real physical conditions of GNSS signals propagation are difficult to simulate exactly,

- to use a *PVT error model*, established thanks to a limited number of field tests, and to add the errors provided by this model to the reference trajectory used for the tests.

NOTE When the *GBPT* includes other types of sensors needing the movement of the mobile object or the usage of beacons or landmarks captured by a vision system, the generation of the *PVT* data are no more feasible in the laboratory with only a GNSS constellation simulator.

Following the second way, this EN describes a procedure combining limited field tests on the *GBPT* and extensive simulation tests on the *Road ITS application*. This procedure is called *Sensitivity analysis*.

The *Sensitivity analysis* is a method that **shall** be used to assess the performance of a *Road ITS application* when it is fed with outputs of a given *GBPT* or of a whole *Road ITS system* comprising a given *GBPT*. It is not relevant for performance assessment of the *GBPT* itself.

6.2 Presentation of the method

6.2.1 General

The method is described in Figure 5.

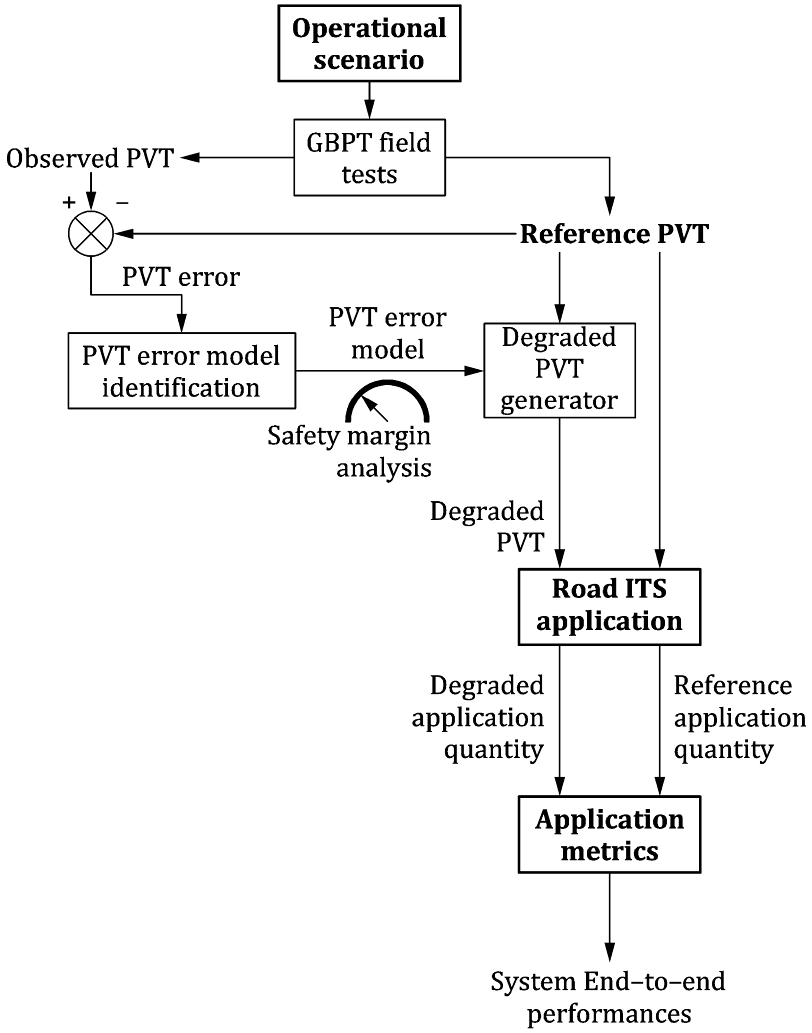


Figure 5 — Sensitivity analysis general principle

It **shall** consist in 6 main steps:

1) Definition of the *Operational scenario* and of the test protocol;

2) *GBPT* field tests execution;

3) *PVT error model* identification;

4) Generation of degraded trajectories;

5) *End-to-end performances* assessment;

6) *Safety margin analysis*.

All these steps are detailed below.

6.2.2 Definition of the Operational scenario and of the test protocol

The *Operational scenario* and the test protocol, in particular the design of the tests using degraded simulated *PVT*, **shall** derive directly from the *E2E performances* of the whole system that need to be assessed.

The *Operational scenario* used for the *Sensitivity analysis* **shall** represent the conditions in which the application or the whole system has to be tested. It **shall** be composed (see Clause 5) of the description of the set-up conditions of the *GPBT*, of the trajectory and of the environment.

Since tests can be costly, the definition of the *Operational scenario* **should** be very carefully done. The result of the analysis **should** be a trade-off between the representativeness of the scenario with respect to the real operational conditions of the system in test and the cost.

Four scenarios can be distinguished, depending on the type of *Road ITS system* and the environments where it is deployed:

- If the *Road ITS system* is deployed on a small number of specific locations, the trajectories that will be chosen for the tests **shall** be defined at these precise locations.
- If the *Road ITS system* is deployed on a high number of specific locations, like for instance a highway charging system with hundreds of charging points, all the locations **shall** be classified into distinct categories with respect to the GNSS environment, the trajectories **shall** be defined at locations representative of the worst case in each category and the global performance of the system **shall** be a weighted mean of the scores realized for each category.
- If the *Road ITS system* is deployed anywhere in a unique kind of environment (see 5.2.2), like for instance an urban charging system supposed to operate in the centre of a big city, the trajectory for the tests **shall** be defined randomly in this kind of environment.
- If the *Road ITS system* is deployed anywhere in different kinds of environment, the tests **shall** be carried out in different environments representative of these different kinds and, if a global performance is expected, it **shall** be a weighted mean of the performances measured individually in the different representative environments.

Before starting the *Sensitivity analysis*, once the *Operational scenario* has been agreed, a test protocol recapitulating all the conditions of the tests and of the data processing **shall** be established.

6.2.3 GBPT field tests execution

The field tests which are necessary to execute on the *GBPT* do not aim at assessing the performances of the *GBPT* itself, but only at building the *PVT error models* representative of the behaviour of the *GBPT* in the chosen environment(s) in order to be able to assess the performances of the whole system by simulation. The test procedure is very similar to the one described in 5.2.3, dedicated to the fine characterization of an environment, except that the tests are performed with the *GBPT* and not with the *Benchmark GNSS receiver*.

The tests necessitate:

- a test vehicle equipped with a Reference Trajectory Measurement System (RTMeS),
- the chosen GBPT, bound to be installed on-board of the test vehicle;
- a data acquisition system capable of recording the outputs from the RTMeS and those from the chosen GBPT and to synchronize them within the same time reference;
- a data processing software suite capable of computing the errors on the positions delivered by the chosen GBPT, and on the velocities if necessary.

The *GBPT* field test procedure necessary for the *PVT error model* identification **shall** be composed of the following steps:

- installation, set-up and initialisation of the chosen *GBPT* and the *RTMeS* on-board of the test vehicle, following the set-up conditions indicated by the *Road ITS system* provider;
- travel of the trajectories as defined in the test protocol implementing the *Operational scenario* and record of the *GBPT* and *RTMeS* outputs;
- processing of the data in order to compute the errors on the output of interest (generally the components of the horizontal position), using the reference *PVT* produced by the *RTMeS*.

6.2.4 PVT error model identification

Once the error database is established, the correct error model, statistically and timely representative of the observed errors, **shall** be identified (see Clause 7).

6.2.5 Generation of simulated degraded trajectories

To simulate the degraded trajectories representing the real trajectories that the *Road ITS application* will have to process, a specific piece of software, called *Degraded PVT generator*, **shall** be developed and used. This software generator **shall** use one or several of the reference trajectories recorded during the tests and **shall** add, at each epoch of time, a simulated error coming from the *PVT error model* to the considered *PVT* component.

If the considered *PVT* components are the Longitude and the Latitude (for a *Road ITS application* considering only the horizontal position, the *Degraded trajectory generator* **shall** build a degraded trajectory by a series of coordinates of the form: (Longitude + error on Longitude, Latitude + error on Latitude), for each epoch of measurement.

At each simulation, the errors will be different, since they come from different draws of the random parameters of the *PVT error model*.

The number of simulated degraded trajectories to be generated during a *Sensitivity analysis* **shall** depend on the system *E2E performance* that needs to be assessed and on the associated confidence interval when the *E2E performance* is expressed by a very low probability of occurrence of a certain type of events.

6.2.6 End-to-end performances assessment

The *E2E performances* of the *Road ITS system* are defined by the metrics of the system. They can be expressed very differently, depending of the system.

The metric is always a function of an error, or a deviation, with respect to the “true” value of a quantity. This “true” *Application quantity* is the value of the *Application quantity* output by the *Road ITS application* when the *PVT* processed is the “true” one, or is considered as errorless like a reference trajectory produced by an *RTMeS*.

6.2.7 Safety margin analysis

Even if the system *E2E performances* are met, as in any engineering work, the safety margin existing on the performance fulfilment **should** be estimated.

Since the *PVT error model* contains several parameters describing the size of the noise and the biases, by applying different multiplying coefficients to these parameters, different simulated trajectories with amplified errors compared to the observed errors can be generated. The safety margin analysis **shall** consist in repeating the procedure described above with amplified errors, step by step, until the concerned *E2E performance* is no longer satisfied. The safety margin will be the value of the multiplying coefficient corresponding to the failure of the test.

7 PVT error models

7.1 General

This section describes the principle and utility of *PVT error models* for the application of the *Sensitivity analysis* method that have been detailed in Clause 6.

The basic idea is to be able to simulate a realistic behaviour of a *Positioning terminal* used in a *Positioning-based Road ITS system* when proceeding to laboratory tests with the *Road ITS application*.

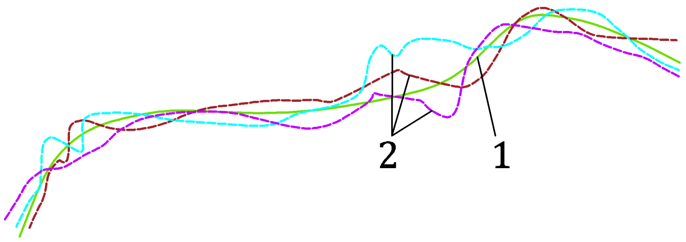
The *PVT error model* is used to draw pseudo-random trajectories representative of real trajectories.

Figure 6 illustrates schematically 3 degraded trajectories randomly distributed around the true trajectory.

Figure 5 explains how the *PVT error models* are produced and how they are used in the *Sensitivity analysis*:

- they are produced by an identification process fed by results of field tests on the *GBPT* which have been performed following the *Operational scenario*;
- they are used by a *Degraded PVT generator* which produces the *Degraded trajectories* (or *Degraded PVT*) necessary for the tests.

PVT error models **shall** be parametric models with some parameters being random variables (following given probabilistic laws) determined by an identification process fed by field test data. To each draw of those random parameters corresponds a given trajectory respecting the model, but different from the other draws. These trajectories **shall** be drawn as many times as necessary for the *Road ITS application* test purposes.



Key

1 true trajectory

2 degraded trajectories

Figure 6 — Illustration of randomly generated degraded trajectories

PVT error models **shall** be established for homogeneous GNSS environments that is to say for environments classified in the same high-level category (see 5.2.2).

When the *Operational scenario* of the application comprises several environments significantly different in terms of GNSS signals perturbations, for each of them, different *PVT error models* or different sets of parameters of the same model **shall** be used.

7.2 Different types of error models

Error models can be built on the different outputs (*PVT* components) of the *GBPT*, depending on the output that will be used by the *Road ITS application* to perform its tasks. Depending on the application, it can be on the 2 components of the horizontal position, on the 3 components of the 3D position, on components of the velocity, on the speed, etc.

NOTE Most of the time, *Road ITS applications* use the position components to perform their tasks, i.e. the Longitude and Latitude of the position, sometimes the Altitude. Some applications can use the speed or velocity components, but they are relatively rare compared to those which use the position components.

7.3 Conformity assessment of the PVT error models

Whatever the model and the generation process used to draw the trajectories, these latter **shall** comply with two main characteristics to be considered as representative of real trajectories resulting from the real terminal:

1) The statistical distribution of the errors (experimental histogram representative of the Probability Density Function (PDF) or experimental Cumulative Distribution Function (CDF)) **shall** be "*Comparable*" to the one of the real receiver.

2) The autocorrelation properties of the error signal, function of the time, which reflects the autocorrelation of certain errors at the level of the signal coming from the satellites (atmospheric errors in particular) and the filtering effect of the *PVT* computation engine of the GNSS receiver, **shall** be "*Comparable*" to the one of the real receiver.

The comparison of the statistical distributions of the errors **should** use the *Accuracy* metric defined in Clause 4, that is to say the 50th, 75th and 95th percentiles of the cumulative distribution of errors, applied respectively to the real error signals and to the simulated error signals.

EXAMPLE 1 A comparison test at the level of the errors distribution **can** be based upon the difference between the mean values of the 50th, 75th and 95th percentiles respectively of the simulated PVT errors and of the real PVT errors. A difference greater than 1 m **can** lead to the rejection of the simulated trajectory.

EXAMPLE 2 A comparison test at the level of the autocorrelation properties **can** be based upon the difference between the widths of the autocorrelation function peaks, measured at half height. A difference greater than 5 s **can** lead to the rejection of the simulated trajectory.

The general procedure to assess the conformity of a *PVT* error model is summarized in Figure 7.

The field tests from which the *PVT* error models will be identified and assessed **shall** be carried out under the same *Operational scenario* than the one that is specified for the *Sensitivity analysis* of the *Road ITS application* in which the *PVT error models* will be used.

In order to use in the *Sensitivity analysis* only simulated error signals conform to the reality, simulated PVT error signals that satisfy both tests, at the statistical level and at the autocorrelation level, **shall** be assessed as valid and kept.

It is recommended to use the *PVT* errors database obtained from the *GBPT* field tests that have been carried out for the *Sensitivity analysis method* (described in the next section) or from a subset of them, but specific field tests can also be organized for that purpose, under the condition that the *Operational scenario* for both tests are exactly the same.

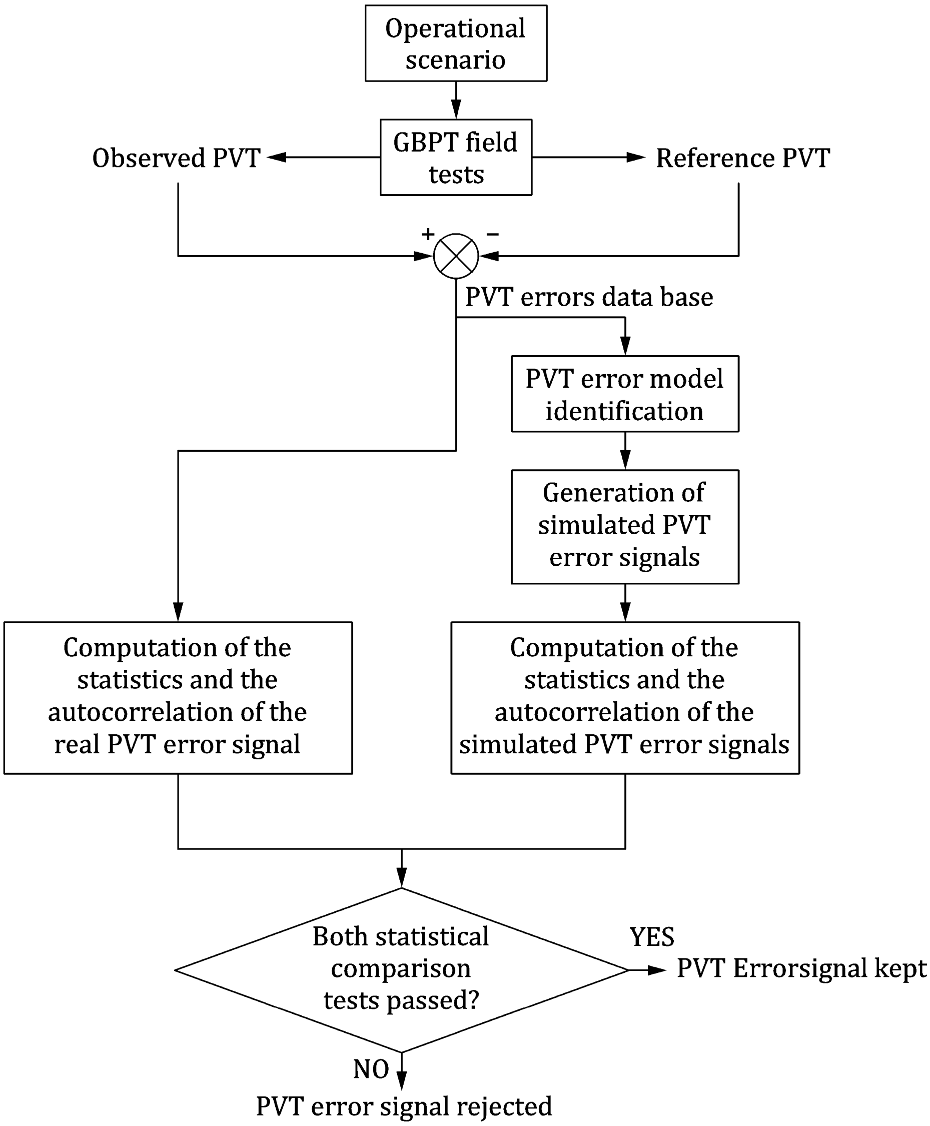


Figure 7 — Conformity assessment of PVT error models

Annex A
(informative)

positioning performance metrics rationale

A.1 General

Annex A provides:

- Background information to support the definition of positioning performance metrics provided in Clause 4;
- An example of how performance requirements can be established based on those metrics.

A.2 Performance metrics

Annex A addresses the metrics used to characterize performances of the positioning terminal. Each performance feature of those identified in Clause 4 gives rise to a number of related metrics depending on whether it refers to one or another output of the positioning terminal (e.g. horizontal position, vertical velocity…).

For instance, the accuracy feature splits into position accuracy, velocity accuracy, and speed accuracy. In turn, position accuracy splits into horizontal position accuracy, vertical position accuracy, cross track position accuracy, etc. So the accuracy feature gives rise to a fairly large family of metrics. However, the definitions of all these metrics are almost identical statements, and once one of them is specified, the other can be obtained straightforwardly just by changing a few words. For instance, the definition of "vertical velocity accuracy" can be obtained from the definition of "horizontal position accuracy" by just changing every occurrence of the words "horizontal" and "position" by the words "vertical" and "velocity", respectively (with the only nuance that horizontal errors are implicitly unsigned whereas for vertical ones it shall be explicitly stated that accuracy refers to errors taken in absolute value).

To avoid unnecessary and tedious repetition of almost identical definitions, only one example of each relevant family of metrics (highlighted in a box) will be presented hereafter, while paying special attention to their common conceptual aspects.

The expansion for all individual metrics is provided in the form of comprehensive Table 1 and Table 2 in 4.5.

A.2.1 Accuracy metrics

Accuracy is a statistical characterization of the error in position, velocity or speed. When it refers to position or velocity (both being vectors) it can involve one component (e.g. vertical, along-track…) or several components (as it is the case when the variable of interest is the horizontal projection, which comprises two linear components) of the corresponding error vector. Likewise, speed accuracy refers to speed errors as defined in previous section.

It is not unusual to associate accuracy to the mean and standard deviation of the error distribution it refers to. However, unless the said error distribution is known to belong to a given, well characterized family of statistical distributions (such as the Gaussian family of distributions), these two parameters may not actually capture the error characteristics of interest. For that reason, a different, more flexible and powerful approach is adopted here. In order to provide a statistical characterization of the error, the proposed **accuracy metrics** are based upon the 50th, 75th and 95th percentiles of the error cumulative distribution function (CDF)[4]. It has to be noted that these accuracy metrics are not aiming at providing an exhaustive description of the error distribution, and in particular of its tails (i.e. percentiles above 95 % or below 5 % for signed distributions) as it would imply unnecessary technical difficulties which **should** be reserved to the integrity metrics.

As stated above, accuracy metrics can be defined for a variety of output parameters and components of the positioning terminal output. What follows is an example of a formal definition of accuracy metric for a particular choice of the said parameters:

Horizontal Position Accuracy (sample definition):

Horizontal Position Accuracy is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of horizontal position errors[5].

It shall be noted that the distribution of the errors (of position, velocity or speed) considers only epochs when the output of interest is provided by the positioning terminal. This means that, if at some given epoch, for whatever reason, the positioning terminal cannot provide the output of interest (e.g. horizontal position), then the said epoch does not yield a sample with which to contribute to the corresponding error distribution (e.g. to the horizontal position error distribution), and hence has to be disregarded by the corresponding accuracy metric.

A.2.2 Integrity metrics

Integrity metrics characterize the performances of protection levels in two different ways. On the one hand there is the statistical behaviour of the protection levels themselves, that is, how large they are in a statistical sense, which is directly linked to their usability for specific applications. On the other hand there is their reliability as error bounds, that is, the probability (known as the *Integrity risk*) that a protection level fails to contain the error, which can differ from the intended one.

A.2.2.1 Integrity Risk

The *Integrity risk* (IR) associated to a position or velocity component is the probability that the error of the said component exceeds its associated *Protection level*. Here is a sample definition of an *Integrity risk* metric for a particular choice of output parameters which would be written in a totally analogous way for any other choice of parameters:

Horizontal Position Integrity Risk (sample definition):

The Horizontal Position Integrity Risk is the probability that the horizontal position error exceeds the horizontal position Protection Level.

The *Integrity risk* is not to be confused with the *Target Integrity Risk* (TIR), which is a value passed as input to the protection level computation process (generally in the form of a requirement) which represent the desired (or target) IR for the given application. A system which works according to specification should achieve IR values not higher than the TIR.

Integrity is a concept tightly linked to the reliability of the system, so whenever integrity requirements are imposed on a system, they involve extremely low TIR values (e.g. 1E-6). This implies that, in order to verify IR requirements, either very large samples shall be taken or some justified extrapolation strategy shall be adopted, what makes verification of *Integrity risk* a rather complex process.

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[4] The cumulative distribution function of a real-valued random variable X is the function given by: $F_X(x)=P(X \leq x)$.

[5] It is recalled that the horizontal position error is defined as the norm of the horizontal projection of the position error vector.

A.2.2.2 Protection Level Performance

The statistical characterization of the *Protection level* operates in a very similar way as the accuracy metrics previously discussed. The *Protection level* distribution is described by providing a few relevant percentiles of its CDF. As in the case of accuracy metrics, 50th, 75th and 95th percentiles have been chosen for this EN. As for accuracy metrics, the maximum percentile of 95th has been chosen out of the tail of the distribution in order to avoid unnecessary verification issues.

Protection levels are computed for a given *Target integrity risk*, and there is the possibility that, in certain systems, the Positioning terminal provides at once several *Protection levels* for different *Target integrity risk* values.

To each *Protection level* provided by the *Positioning terminal* (whether linked to one or more components of its associated error, whether for position or velocity) it corresponds a *Protection level* performance metric analogous to the one shown in the following example (in which the target integrity risk has been chosen to be 1E-6):

Horizontal Position Protection Level Performance (sample definition):

Horizontal position Protection level performance for a Target integrity risk of 1E-6 is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of horizontal position Protection levels computed for a Target integrity risk of 1E-6.

A remarkable difference with respect to the error percentiles involved in accuracy metrics is that *Protection level* percentiles always belong to a single-tailed distribution, as *Protection levels* are always positive real numbers. For bi-dimensional (horizontal) or three-dimensional *Protection levels*, they can be seen as the radius of a circle or a sphere respectively.

Another relevant aspect of *Protection level* performance metrics is that they consider the absence of *Protection level* as an infinite *Protection level*. So the *Protection level* distribution to which the above metric definition refers accounts for those epochs in which there is no *Protection level* in this particular manner. The logic behind this is quite natural: a protection levels is bound to the error of certain parameter, so when the said parameter is not accompanied by a *Protection level*, its error remains unbounded, what is as if the parameter was accompanied by an infinite *Protection level*. There is another reason behind this policy which has to do with the fact that the size of *Protection level* has a direct impact on the availability at system level in those applications with integrity requirements, so the availability of the *Protection level* itself has to be taken into account in the *Protection level* size statistics.

A.2.3 Availability metrics

Availability performance is defined in terms of the relative amount of time during which the output of interest (whether related to position, velocity or speed) is provided by the *Positioning terminal*. Note that this is a concept related to the *Positioning terminal*, and not to the *Road ITS application*, nor to the overall system. Application or system-level availability concepts are beyond the scope of the *Positioning terminal* performance specification. An availability metric definition for a particular parameter of interest (in this case the position) could go as follows:

Position Availability is the percentage of operating time during which the positioning terminal provides a position output.

However, in some cases it can be interesting to know not only the global percentage of time in which the position output is available or not but also how the epochs of availability / unavailability are distributed over time. For instance, consider an application which does not need to have one position output every second but just one (or a few) every now and then. To be more specific, imagine a parking pricing application whose fees are fixed on a per-minute basis. Then, one entire minute of outage followed by 59 of normal operation would result in some charging loss, whereas one isolated second of outage every minute during those same 60 min would cause no charging loss, even though the global availability figure (according to previous definition) as measured over those 60 min of operating time would be the same in both cases. In order to account for the distribution of outages over time, the above tentative definition is generalized to the following (which is the preferred one):

Position Availability(T) (sample definition):

Position Availability(T) is the percentage of time intervals of length T during which the positioning terminal provides at least one position output.

In the preceding definition, the time length T, called *Availability interval*, is to be chosen according to the specific needs of each application. For instance, in the above parking pricing example, a time length of 60 s seems to be a sensible choice. It is worth emphasizing that this definition is a generalization of the previous one as both yield the same metric when T is set to 1 (in units of the nominal time between consecutive position outputs).

This availability metric, although it is not associated to a prescribed level of performance, provides together with the accuracy metric a quite complete picture of the positioning unit performance in terms of position or velocity outputs.

A.2.4 Timing Performance metrics

Timing metrics are those related to the timing performance of the positioning terminal. The key aspects of timing performance are those related to the timestamp resolution and to the output rate and latency. Also *Time to First Fix* (TTFF) is another relevant performance metric.

First of all it is worth noting that the timestamp can hardly be inaccurate to the orders of magnitude which any *Road ITS application* may require, unless some other system malfunction occurs. Note that the timestamp error is directly linked to the error of the GNSS positioning device, so the timestamp error is in the order of magnitude of the position error divided by the speed of light. Hence, if the position error is within a few meters or tens of meters, then the timestamp error is within a few nanoseconds or tens of nanoseconds. Timestamp accuracy requirements of any conceivable *Road ITS application* can hardly go beyond the range of milliseconds or, at most, microseconds, but timestamp errors of those orders would imply position errors in an order of magnitude that ranges between kilometres and hundreds of kilometres, in which case any timestamp inaccuracy would become a secondary issue. Therefore, it does not seem to set specific requirements or metrics regarding timestamp accuracy.

What can indeed be of relevance for some applications is the timestamp sensitivity, defined as follows:

Timestamp Resolution:

Timestamp resolution is the size of the smallest time lapse which would result in different consecutive timestamps. It can be understood as the value of the least significant bit within the word used to encode the timestamp.

Regarding output latency and rate, they are defined as follows:

Output Latency: Output latency is the time elapsed between the time to which the *PVT* corresponds and the time at which the same *PVT* is made available to the *Road ITS application*. In systems which run in real time, the latency can contribute to the *PVT* errors that are effectively propagated to the *Road ITS application*.

Output Rate: Output rate is the inverse of the time elapsed between consecutive *PVT* outputs from the *Positioning terminal* (in Hz).

While *Timestamp resolution* is proposed as a metric itself the other two are interpreted as a definition that will be the basis for the definition of two additional metrics. Note that their verification does not require complicated test campaigns but just a simple test to check that the output of the positioning terminal is provided as per specifications. However, output rate and latency, which can be critical in systems with real time requirements or constraints, cannot be totally stable during operation, and their variations can have an impact on the Road ITS application performance or even on the overall system reliability.

Therefore, stability of these two parameters can need to be verified through more sophisticated and extended test campaigns, and the relevant metrics to do so would be statistical characterisations similar to those defined for accuracy or for protection levels performance, that is, they would specify some relevant percentiles of the distribution describing the possible output rate and latency variations with respect to the nominal output rate and latency values (as per positioning terminal specification). Such variations will be called hereafter output rate and latency errors, respectively, and are formally defined as follows:

- **Output latency error**: it is the difference between the true output latency and the nominal output latency stated in the positioning terminal specification. The true output latency is computed as the difference between the time at which the positioning terminal provides its output message (time of output) and the time to which the *PVT* information contained in the said output message refers (given by the message timestamp).

- **Output rate error**: it is the difference between the true output rate and the nominal output rate stated in the positioning terminal specification.

We show hereafter sample metric definitions of output rate and latency stability for a particular choice of such percentiles.

Output Latency Stability:

Output latency stability is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of output latency errors.

Output Rate Stability:

Output rate stability is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of output rate errors.

For the *Time to First Fix* two relevant aspects are to be considered in the metric definition:

- The information available in the receiver when it is switched on.

- The expected performance of the outputs.

Concerning the first point different types of TTFF (cold, warm…) conditions are defined with no universal definition. The following definitions are proposed:

- **Cold start**: The receiver is switched on when no information is available in it and therefore the receiver entails a full search of the sky for all satellites;

- **Warm start**: The receiver is switched on and has a valid almanac (either stored from a navigation message recently decoded or obtained via other means, e.g. through *Assisted GNSS*) and a rough position with approximate information on frequency offset.

- **Hot start**: The receiver is switched on and has both accurate ephemeris and information on frequency offset as well as an accurate initial solution.

Concerning the second point (the expected performance of the output) similar considerations are needed as those made for the availability definition, namely what performances, if any, are required from a *PVT* fix to be eligible as a valid first fix. The proposed definition refers only to the existence of a valid position, without further specifying what is understood by ‘valid’ as it may depend on the specific application:

Warm TTFF (sample definition):

Warm TTFF is defined as the set of three statistical values given by the 50th, 75th and 95th percentiles of the cumulative distribution of the elapsed time from positioning terminal switch-on in warm conditions until a position solution is outputted.

A.3 Introduction to Performance Requirements

The metrics previously defined are the basis for the establishment of *Positioning terminal* performance requirements that will formalize the performance expectations that the *Position terminal* has to fulfil.

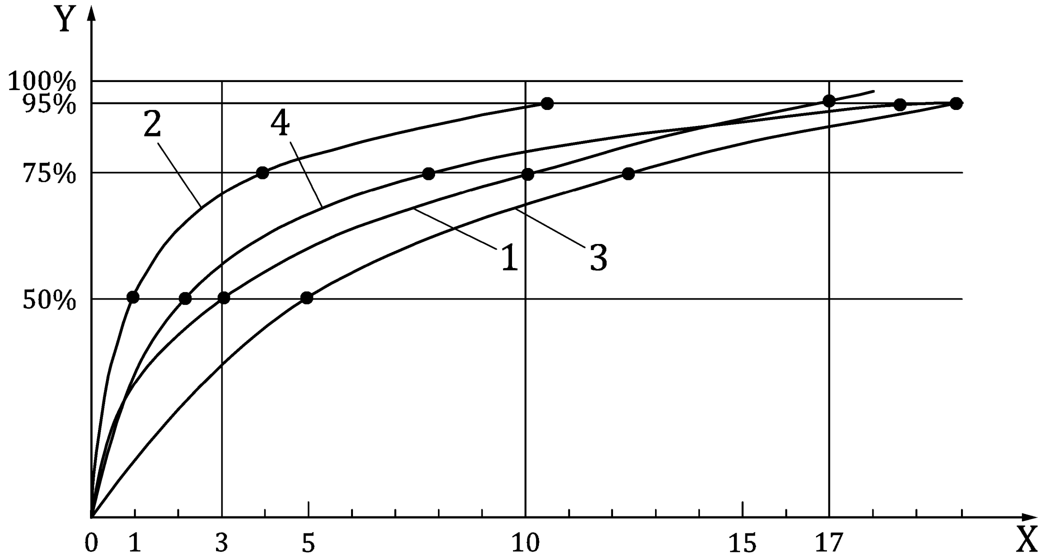
This clause presents an example on how to state unambiguous and verifiable *Positioning terminal* performance requirements in a way compatible with the metrics previously identified. This is not intended to identify the actual performances (quantitative figures) of the *Positioning terminal* but only to propose the way those performance requirements have to be established.

Although not relevant for the metrics definition, and therefore not covered along this section, performance requirements need to be defined for a certain *Operational scenario* as the resulting performances are strongly affected by this. A definition of what is intended by *Operational scenario* is given in Clause 4, together with a classification of *Reference environments* and a method for characterizing the field testing environments.

Example is provided for the Horizontal Position Accuracy.

The performances of the *Positioning terminal* shall be such that, the 50th, 75th and 95th percentiles of the cumulative distribution of horizontal position errors are smaller than 3, 10 and 17 m respectively in a certain predefined scenario.

Figure A.1 shows a graph comparing the reference performance established in the requirement (curve number 1) and examples of receivers fulfilling or not that requirement. Depicted curves represent cumulative error distributions.



Key

X horizontal position error (m)

Y cumulative percentages

1 reference

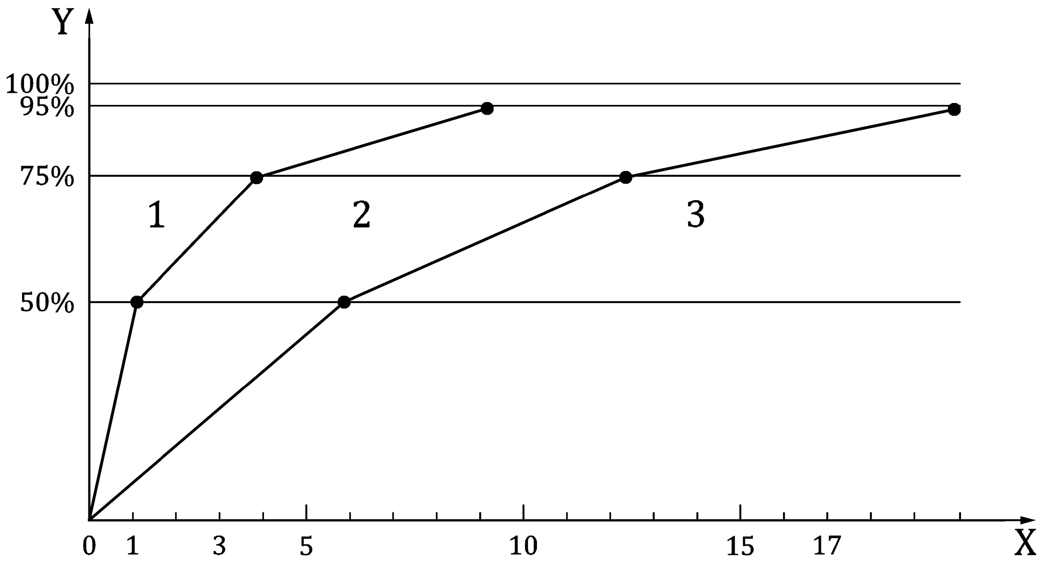
2 better accuracy

3 worse accuracy

4 unclear

Figure A.1 — Examples of Horizontal Accuracy requirements and positioning terminals fulfilling or not the requirements

This logic can also serve to identify different performance classes allowing classifying positioning terminals as shown in Figure A.2. For a given scenario a position terminal will be classified in a certain class according to the results of the measured accuracy metric.



Key

X	horizontal position error (m)
Y	cumulative percentages
1	class 1
2	class 2
3	class 3

Figure A.2 — Accuracy related performance Classes for a given scenario

Bibliography

[1] ETSI/TS 103 246-1 V1.1.1 (2015-04), *Satellite Earth Stations and Systems (SES);GNSS based location systems; Part 1: Functional requirements*

[2] ETSI/TS 103 246-2 V1.1.1 (2015-04), *Satellite Earth Stations and Systems (SES);GNSS based location systems; Part 2: Reference Architecture*

[3] ISO/TS 17444-1:2012, *Electronic fee collection — Charging performance — Part 1: Metrics*

[4] ISO/TS 17444-2:2013, *Electronic fee collection — Charging performance — Part 2: Examination Framework*

[5] Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment – DO-229D (Part 1 of 2) – RTCA/DO-229D, December 13, 2006

[6] GNSS Market Report Issue 4, March 2015: http://www.gsa.europa.eu/market/market-report

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