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Road vehicles — Ergonomic aspects of transport information and control systems — Procedure for assessing suitability for use while driving

Véhicules routiers — Aspects ergonomiques des systèmes de commande et d'information du transport — Procédure d'évaluation de leur adéquation pour une utilisation pendant la conduite

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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

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

ISO 17287 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 13, *Ergonomics applicable to road vehicles*.

0 Introduction

0.1 General

This International Standard arises from the increasing availability of transport information and control systems (TICS) to support the driver in the primary driving tasks and in other secondary tasks. Drivers require ease of use and high functionality and do not expect this to lead to unsafe driving situations (in use as intended by the manufacturer, or during malfunction).

0.2 Assessment of suitability of TICS

The suitability of TICS is assessed on the basis of compatibility with the primary driving task and is concerned with those aspects of usability which relate most closely to the driver's performance. In particular, suitability focuses on

— interference (with the driving task),

— controllability,

— efficiency, and

— ease of use while learning about the system.

The first three aspects (which are not necessarily mutually exclusive) relate closely to the primary driving task. The fourth is also important, as some features of TICS may be used infrequently, or by drivers who are initially unfamiliar with the systems. Other aspects of usability, such as satisfaction, are less important in assessing the suitability of TICS for use while driving as they are more specific to individual manufacturers and their product profiles, and do not relate so closely to the driver's performance in undertaking the primary driving task.

The importance of the four identified components in an overall assessment of suitability will vary between TICS.

Suitability is a property of TICS and not of their components. It is assessed on the basis of the interaction between the driver and the TICS within the driving environment, and suitability needs to take into account driver's behavioural adaptation induced by the TICS.

This International Standard concerns the process of assessment of a specific TICS product and is intended to ensure that its suitability is considered, assessed and documented as part of the design and development process. It does not attempt to prescribe all the actions that should be taken to assess or ensure suitability. The scope and detail of an assessment is a matter for users of this document. Informative annexes provide examples of aspects of the suitability assessment process.

0.3 Application

This International Standard is intended to assist the assessment of the suitability of TICS in advance of widespread system deployment. It can be used when components from different suppliers are proposed or assembled for use in the in-vehicle environment. The trend of integration of in-vehicle systems is likely to increase the need to consider the impact of multiple and integrated in-vehicle systems and this document could also be applicable to non-TICS functions.

This International Standard is intended for use by manufacturers or by others concerned with assessing the suitability of TICS for use while driving. It is assumed that the users will have some knowledge of automotive human factors.

This International Standard can be used by manufacturers as part of their own quality processes. The design and implementation of procedures to ensure that TICS suitability is assessed and documented will be influenced by the varying needs of an organization, its objectives, the products and services supplied and existing processes and practices employed.

It is not the purpose of this International Standard to enforce uniformity of TICS. It is independent of the type of vehicle, complexity of TICS, level of integration within a vehicle or the specific TICS application or implementation. It is applicable to all TICS, including, for example, those intended for use by drivers with special needs.

Road vehicles — Ergonomic aspects of transport information and control systems — Procedure for assessing suitability for use while driving

1 Scope

This International Standard specifies a procedure for assessing whether specific TICS (transport information and control systems), or a combination of TICS with other in-vehicle systems, are suitable for use by drivers while driving. It addresses

— user-oriented TICS description and context of use,

— TICS task description and analysis,

— the assessment process, and

— documentation.

The TICS description and context of use includes consideration of improper use, reasonably foreseeable misuse and TICS failure. The TICS description, analysis and assessment include a process for identifying and addressing suitability issues.

This International Standard does not recommend specific variables for assessing suitability nor does it define criteria for establishing the suitability of use of a TICS table while driving.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15005, *Road vehicles — Ergonomic aspects of transport information and control systems — Dialogue management principles and compliance procedures*

ISO 15008, *Road vehicles — Ergonomic aspects of transport information and control systems — Specifications and compliance procedures for in-vehicle visual presentation*

3 Terms and definitions

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

3.1 Terms and definitions related to suitability

3.1.1
suitability
degree to which TICS use is appropriate in the context of the driving environment based on compatibility with the primary driving task

NOTE Suitability focuses on a subset of usability comprising

— interference (with the driving task),

— controllability,

— efficiency, and

— ease of use while learning about the TICS.

3.1.2
interference
adverse influence on the driver's ability to deal with the vehicle and the environment

NOTE In this context, interference from the TICS is the opposite of driver support provided by the TICS.

3.1.3
controllability
manner and degree to which drivers can influence TICS function and pace of interaction

NOTE Control elements include initiation, termination, repetition, overriding, resuming, regulation (e.g. of level or brightness) and adaptation.

3.1.4
efficiency
resources expended in relation to the accuracy and completeness with which drivers achieve intended objectives

NOTE 1 Efficiency relates to situational awareness, mental effort, physical effort, sensory effort and stress.

NOTE 2 Resources include physical, mental and sensory capacities.

NOTE 3 Adapted from ISO 9241-11:1998, definition 3.3.

3.1.5
learning
acquiring knowledge and developing skills

3.2 Other terms and definitions

3.2.1
assessment
judgement of the actual and potential effect of a TICS in a "prospective" way, usually before widespread deployment

3.2.2
behavioural adaptation
behaviour which may occur in response to changes to the road-vehicle–user system

3.2.3
context of use
description of drivers, goals, tasks, equipment (hardware, software, materials) and the physical and social environments in which the TICS are used

3.2.4
criterion
threshold or range of values of a variable to be met

3.2.5
workload
degree of mental, physical and perceptual effort required by a driver to undertake a particular task

3.2.6
environment
physical surroundings in which data is captured

EXAMPLE Real road, test track, simulator, laboratory.

3.2.7
failure
system state which results in TICS non-performance or TICS impaired performance (relative to the TICS specification)

NOTE This is usually as a result of a hardware or software malfunction.

3.2.8
failure modes and effects analysis
FMEA
formal technique for listing ways in which a system can fail and estimating the probabilities and consequences associated with each failure

3.2.9
HMI component
element or subsystem of a TICS with which the driver can interact while driving

EXAMPLE Visual display, control knob.

3.2.10
improper use
use of TICS functions while driving that are not intended by the manufacturer to be used while driving

3.2.11
intended use
TICS use while driving in accordance with specifications, instructions and information provided by the manufacturer

3.2.12
manufacturer
organization or person designing, developing, integrating or supplying a TICS product

NOTE For original equipment supplied with a vehicle, the manufacturer is the vehicle manufacturer. For after-market products, the manufacturer is the after-market supplier.

3.2.13
method
high-level approach to assessment, based on theory, which implies an underlying rationale in the choice of assessment techniques

EXAMPLE Behavioural analysis, workload assessment, analysis of psycho-physiological responses.

3.2.14
misuse
use of TICS functions intended by the manufacturer to be used while driving in a way or manner not intended by the manufacturer and which may lead to adverse consequences

3.2.15
mode
specified sub-set of functions or behaviour pattern of a TICS

EXAMPLE Processing, data entry.

3.2.16
performance
skill demonstrated by the driver in a driving task or TICS-related task

3.2.17
primary driving task
those activities that the driver has to undertake to maintain longitudinal and lateral vehicle control within the traffic environment

3.2.18
satisfaction
comfort and acceptability of use

3.2.19
task analysis
formal method used to describe and study the performance demands made on the human elements of a system

3.2.20
technique
component of the method used to directly gather data

EXAMPLE Eye movement registration, subjective assessment, heart rate monitoring.

NOTE Use of a technique will provide one or more variables.

3.2.21
transport information and control system
TICS
single function, such as route guidance, or number of functions designed to work together as a system

[ISO 15005:2002, definition 3.25]

See ISO/TR 14813-1[1] for TICS services.

3.2.22
tool
means for obtaining one or more variables

NOTE Although a tool is often an item of equipment such as a video camera or accelerometer it can also be a questionnaire or checklist.

3.2.23
usability
concept comprising the effectiveness, efficiency and satisfaction with which specified users can achieve specified goals in a particular environment

NOTE Adapted from ISO 9241-11:1998, definition 3.1.

NOTE As well as effectiveness (see ISO 9241-11[2]), efficiency and satisfaction, usability involves learnability, controllability, interference and adaptability.

3.2.24
variable
metric or indicator giving a quantitative measure of driver behaviour

EXAMPLE Eye glance duration, vehicle speed.

NOTE A variable is independent of the tool used to measure it.

4 Requirements and recommendations

4.1 Summary of requirements

The assessed TICS shall be described in accordance with the following requirements (see Annex A).

a) The intended use of the TICS and the context of use shall be defined (see 4.2.2 to 4.2.4).

b) TICS functions that are not intended to be used while driving shall be identified (see 4.2.5.1).

c) Steps taken to prevent the use of functions not intended to be used while driving shall be described (see 4.2.5.2).

d) Steps taken to prevent reasonably foreseeable misuse shall be described (see 4.2.5.3).

e) The way in which TICS failures will be apparent to the driver shall be described (see 4.2.6).

f) Suitability assessment shall take account of the intended use and context of use of the TICS (see 4.4.2).

g) Information concerning suitability, including assessment results, shall be recorded and documented (see 4.5).

4.2 User-oriented TICS description and context of use

4.2.1 Introduction

The intended use of the TICS and the context of use shall be defined. This subclause provides a recommended structure along with an explanation of the elements. An outline example is given in Annex A.

4.2.2 General description

Table 1 gives those elements that should be included in the general description of the TICS.

Table 1 — General TICS description

Aspect of description	Explanation
Market	A brief introductory description of the market for which the product is intended.
General function	A brief “headline” description of the function performed by the system.
Technical context	A brief *résumé* of current developments in the field including, particularly, comparisons with existing systems.
Benefits	A summary of the intended goals and benefits of system use. Where appropriate, reference should be made to the three levels of the driving task (navigating, manoeuvring and handling).

4.2.3 Identification

Table 2 gives those elements that should be included in the identification of the TICS.

Table 2 — TICS identification

Aspect of description	Explanation
Product name and version	A one line description for identification purposes.
Manufacturer	The name, address and contact points.
Subsystems	A brief description of the subsystems to an appropriate level. HMI (human–machine interface) components should receive greatest attention.
Build status	A brief description of the state of development of the TICS for reference purposes.
Documentation	A list of technical and user documentation included within the suitability assessment.

4.2.4 Context and restrictions for intended use

The context and restrictions can be regarded as “envelope of use”. Restrictions or limitations may be particularly important for certain TICS functions. In these cases, the restrictions and limitations should be given particular emphasis. A consideration of the driver’s needs, including his or her training needs, could be helpful. Table 3 presents aspects of the context that should be considered.

Table 3 — Context and restrictions for intended TICS use

Aspect of description	Explanation
Vehicle	A description of the TICS requirements of a vehicle (e.g. physical devices, sensor signals or other information). Also, any exclusions or restrictions on the vehicle within which the TICS is intended to be used.
Driver	If any restrictions or special driver skill requirements are defined by the manufacturer, these should determine the intended user group considered within assessments.
Road	A definition of the road context in which the TICS is, and is not, intended to be operated. This includes the road category and physical requirements of road markings, gradients, curvatures, widths, etc.
Traffic	A description of the traffic context within which the TICS is, and is not, intended to be operated (e.g. traffic mix and density).
Other environmental	Additional requirements or restrictions could include weather and lighting specifications.
Infrastructure	A general description of any infrastructure or information which is external to the vehicle and required for the intended TICS operation.

4.2.5 Improper use and misuse

4.2.5.1 TICS functions that are not intended to be used while driving shall be identified. According to the definition of *intended use*, this is the responsibility of the manufacturer of the TICS. The result should be a clear distinction between functions intended to be used while driving and those not intended for use while driving.

4.2.5.2 Steps taken to prevent the use of functions not intended to be used while driving shall be described. Such *improper use* occurs when a function not intended to be used while driving is used by the driver. As an example, suppose a mobile phone is not intended to be used without a hands-free car-adapter kit. Steps taken to prevent the use of functions could include physical lock-outs or descriptions in the operating manuals of the intended scope of TICS use and suitable warnings.

4.2.5.3 Steps taken to prevent reasonably foreseeable *misuse* shall be described. Misuse occurs when a function intended to be used while driving is used by the driver in a way or manner not intended by the manufacturer and which may lead to adverse consequences. Examples are using an ACC system as a collision warning system and using a large-scale map as a driving aid in fog. Steps taken to prevent reasonably foreseeable misuse could include advice and warnings in the operating manual or warning reminders placed inside the vehicle.

4.2.6 Failures

TICS failures should be identified. The way in which TICS failures will be apparent to the driver shall be described. The consequences of failures on TICS operation should be considered. More detailed descriptions may also be undertaken using techniques such as failure modes and effects analysis (FMEA).

4.2.7 Additional information

More detailed system descriptions may also be undertaken (e.g. state diagrams, transition diagrams). Descriptions of interactions between the TICS and other vehicle systems may be generated (e.g. where there are common or related HMI components).

4.3 Task description and analysis

The tasks that the driver is required to or likely to perform while interacting with the TICS should be defined. Operations that the TICS performs should also be defined where this aids understanding of the driver's task. Various task analysis techniques exist in the human factors literature[3]. A good starting point can be to imagine one or more typical journeys, step-by-step.

The tasks should be defined in sufficient detail so as to be useful as a basis for assessment. The number of hierarchical task levels that should be used will depend on the nature and complexity of the system. The tasks should also be related to the different modes or phases of system use (set-up, destination entry, initiate call, read email, etc.).

The list of tasks should take into account situations where there are different methods of task execution, for example, a navigation destination which can be entered by spelling a name or via a list.

The frequency and priority of tasks should be identified. Tasks that are externally time-paced rather than driver-paced should be identified.

The environment in which a specific task is likely to be performed should be identified if it differs from that specified in 4.2.4, or if it is considered to have specific safety implications in that environment.

Table 4 presents a structure that may be used for TICS task description and analysis. Examples are provided in Annex B.

Table 4 — TICS task description and analysis

Aspect of task description	Explanation
First (top) level tasks	A significant system task, such as route guidance destination entry.
Second level tasks	The individual sub-tasks that are required to complete the first level task (e.g. choice of city). Decomposition to further levels can be undertaken as required for the assessment. Methods of task execution can be included.
Typical task frequency	An indication of the frequency with which the sub-task is carried out (e.g. once per journey or every manoeuvre).
Task priority (and time pacing)	A qualitative description of the importance of the second level task for safety and whether the driver input has to be provided within a specific time interval. The time interval should also be estimated.
Exceptional environments or scenarios	A space for comments concerning where there are situations of special interest or difficulty for system related tasks to be completed, e.g. where two manoeuvres are required in close succession.

4.4 Assessment

4.4.1 When to assess

Assessment may take place at different stages of the product design life-cycle, including

— specification,

— development,

— prototype,

— manufacture, and

— deployment.

Intermediate assessment results may influence the design and development process in an iterative manner.

4.4.2 Aspects to be assessed

Suitability assessment shall take account of the intended use and context of use of the TICS. Data gathered during TICS description, context of use description, task description and task analysis should be used as a source of information (see 4.2 and 4.3). A recommended assessment process is described below, but the scope and detail of assessment is a matter for users of this International Standard.

Suitability focuses on

— interference (with the driving task),

— controllability,

— efficiency, and

— ease of use while learning about the system.

When assessing the overall suitability of a TICS for use while driving, aspects of TICS use which relate most closely to safety should be given special attention. Specific examples include

— the driver’s workload,

— the driver’s performance of the driving task,

— any behavioural adaptation induced by the TICS, and

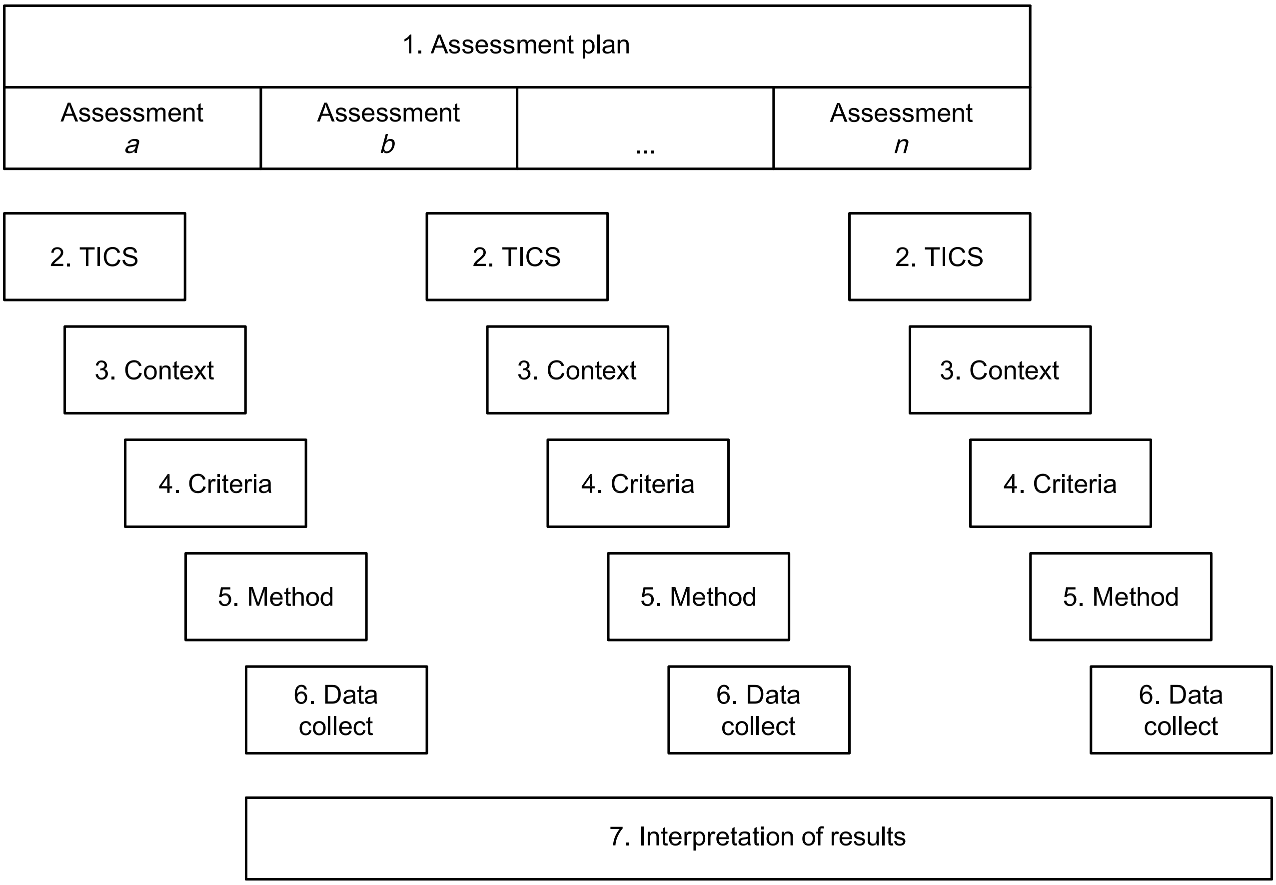
— how easily the driver learns about the system.

One approach is to identify aspects of TICS use which require high driver attention and to also identify relevant and critical situations in which the TICS is intended to be used.

4.4.3 The assessment process

4.4.3.1 Introduction

An assessment process should be established which could be developed from the following seven-stage scheme. Annex D contains examples of Stages 2 to 6.



NOTE Numbers 1 to 7 correspond to the stages described in 4.4.3.2 to 4.4.3.8.

Figure 1 — Suitability assessment process

4.4.3.2 Stage 1 — Definition of assessment plan

The assessment plan should concern the overall suitability assessment of the TICS, which may be composed of a series of individual assessments (*a*...*n*), involving different

— TICS representations (see 4.4.3.3),

— contexts of use (see 4.4.3.4),

— criteria for assessing suitability (see 4.4.3.5), and

— methods (see 4.4.3.6).

The assessment plan should consider resource allocation to the individual assessment tasks (Stages 2 to 6 and Stage 7) and contain an assessment schedule.

Inexperienced users or other safety concerns may necessitate conducting preliminary tests of the TICS under controlled conditions. This could identify aspects of TICS performance needing improvement before the undertaking of more detailed assessments.

4.4.3.3 Stage 2 — Selection of TICS representation

This refers to two main choices, described in Table 5.

Table 5 — Aspects of TICS representation

Selection	Explanation
Design cycle stage	When in the TICS product design cycle (e.g. concept, prototype, post-launch).
TICS component(s)	The TICS or those of its subsystem(s), function(s) or mode(s) being investigated.

4.4.3.4 Stage 3 — Definition of assessment context

With reference to the intended context of use, the context for an individual assessment should be defined. For assessments based on calculation or modelling, the context is not relevant. For field trials, aspects of the context could include

— user population and sample profile,

— vehicle, traffic and road characteristics,

— ambient conditions (e.g. weather, day/night), and

— specific or critical driving situations to be studied (e.g. approaching traffic congestion or approaching traffic lights).

4.4.3.5 Stage 4 — Definition of assessment criteria

In this stage, the individual assessment should be "operationalized" by identifying specific variables (also called metrics or indicators) to be measured as well as the criteria for success. See ISO 15008 for presentation of visual information and ISO 15005 for dialogue management. The variables can provide evidence concerning one or more aspects of suitability (e.g. controllability, learnability) and it could be useful to specifically identify these.

4.4.3.6 Stage 5 — Selection of assessment method

The choice of assessment method (and the techniques and tools used) will depend on the variables identified during Stage 4 (e.g. whether qualitative or quantitative data are required). Important factors for any method will be its validity, reliability and sensitivity. The choice may also be influenced by a number of practical factors, including equipment cost and availability, ease of use and time required. More information on this stage is provided in Annex C.

4.4.3.7 Stage 6 — Performing assessment and analysing data

In this stage the actual assessment, data collection and preliminary data analysis should be performed. Apart from the technical data collected or calculated, additional information as to when the assessment was performed and who was involved in the process (e.g. whether the assessment was performed in-house or externally, the qualifications and affiliations of the assessors) should also be provided.

4.4.3.8 Stage 7 — Interpretation of results

In this stage the results obtained from the individual assessment should be studied and compared with the criteria identified in Stage 4.

Results of an individual assessment should also be studied in context using results from other assessments of the TICS. Repetition or redesign of tests, iteration through TICS design or reassessment of the assessment plan could be required before an overall assessment of suitability can be made.

4.5 Documentation

Information concerning suitability, including assessment results, shall be recorded and documented. The level of detail, content and format of the documentation is a matter for the party or parties using this International Standard.

Annex A
(informative)

User-oriented TICS description — Examples

A.1 Introduction

This annex is intended to provide additional information and illustrations. Inferences should not be drawn about “good” or “bad” TICS products. Examples are not intended to represent a single TICS product, but provide aspects of description drawn from different TICS.

The ellipsis (...) indicates where more detail could be provided.

A.2 General description

See Table A.1.

Table A.1 — General TICS description

Aspect of description	Example
Market	A low-cost system to be sold through motorist accessory stores designed to appeal particularly to independent professional minicab drivers.
General function	Route guidance to user-defined destinations using real-time updates of local traffic conditions from radio broadcasts ...
State of the art	Car radios with RDS-TMC functionality are widely available ... Navigation products which operate autonomously are commercially available from ... This product is a development of the previous product Nav-Screen which incorporates ... The system is operated in the same way as the Nav-Screen but ...
Benefits	To assist drivers in re-routing using traffic information. To make driving decisions easier and more reliable. To reduce travel times.

A.3 TICS Identification

See Table A.2.

Table A.2 — TICS identification

Aspect of description	Example
Product name and version	Trav-Nav 2000
Manufacturer	Car-Pleasure Corporation ... address ... Marketing Manager: J.T. Preview. Phone: ..., Fax: ...
Subsystems	Telephone handset: Manufacturer ABC Code 346 LCD display: Grund 400 ...
Build status	Prototype IV. Serial No. 00203
Documentation	Packaging, video tape and user manual

A.4 Context and restrictions for intended TICS use

See Table A.3.

Table A.3 — Context and restrictions for intended TICS use

Aspect of description	Example
Vehicle	Saloon cars or delivery trucks. Not suitable for use with metalled windscreens. Not designed for vehicle speeds less than 60 km/h. ...
Driver	— All able-bodied drivers — Professional taxi driver — Requires knowledge of ... computer system
Road	Inter-urban roads of carriageway width > 3,2 m. Road curvature not less than 500 m.
Traffic	All mixed traffic but not intended in traffic of speed less than 60 km/h. Cyclists are not detected by the TICS.
Other environmental	— Does not work in rain (precipitation > ... /hour) — Intended for use only when visibility < 50 m — Requires daylight or ambient illumination > ...
Provider infrastructure	— Requires GPS signals and RDS-TMC service over FM — Requires roadside beacons ... — Requires leaky coax of specification ...

A.5 Improper use and misuse

See Tables A.4 and A.5.

Table A.4 — TICS improper use and prevention

Function not intended for use while driving	Example of prevention
Handheld telephone use while driving	Vehicle motion sensor disconnects handset (and switches to hands-free speaking option).
Complex destination entry by individual character selection	This is inoperable when the vehicle is moving and is detected by a wheel rotation sensor.

Table A.5 — TICS misuse and prevention

Potential misuse	Example of prevention
Excessive visual attention to in-vehicle screen	Road safety advice warning displayed when system is first switched on. Also warning in driver's manual.
ACC engaged by driver above design speed	Vehicle decelerates to ACC design speed maximum of 160 km/h.

A.6 Failures

See Table A.6.

Table A.6 — TICS failures and consequences

Failure	Example of how failure is apparent to driver	Consequences for driver
ACC sensor lens dirty	1) Text message: “ACC sensor dirty” 2) Telltale 3) No ACC function	No ACC function Maintenance by the driver is possible
Subsystem failure (e.g. processor, sensor)	1) No ACC function 2) Telltale 3) Auditory message “ACC unavailable” when selected by driver	No ACC function Repair required
NOTE Additional information concerning failures can be provided.		

Annex B
(informative)

TICS task descriptions — Examples

See Tables B.1 to B. 3.

Table B.1 — Example adaptive cruise control tasks

First (top) level tasks	Second level tasks	Typical task frequency	Task priority (and time pacing)	Exceptional environments or scenarios
a) Set ACC	1) Set speed by accelerator pedal	A few times per trip	High (driver-paced)	Within ACC design limits (minimum speed, highways, weather)
	2) Set speed by control lever	A few times per trip	High (driver-paced)	
	3) Set headway	Infrequent, or not at all if function is not available	High (driver-paced)	Changing weather conditions or road conditions
	4) Resume ACC	Depending on traffic conditions(1 to 10 times/hour)	High (driver-paced)	
b) Switch off ACC	1) Driver switches off by control button	Infrequent	High (driver-paced)	End of highway or end of trip
	2) Driver brakes	Regularly	High (driver-paced)	
	3) System switch off	Infrequent	High (system-paced)	Depending on switch off condition (e.g. speed, headway)
	4) Failure mode	Rare event	High (system-paced)	Driver is to take over
c) ACC driving	1) Increase set speed	Depending on traffic conditions (1 to 10 times/hour)	Medium	Speed limits, road inclination, traffic flow, weather conditions
	2) Decrease set speed		Medium	
	3) Increase set headway	Depending on weather or driving condition (1 to 2 times/trip)	Low	
	4) Decrease set headway		Low	
	5) Override by accelerator pedal	Regularly	Medium (driver-paced)	Overtaking, gear shifting
	6) Take over by braking at max. ACC deceleration	Regularly	High (situation-paced)	Traffic conditions. Maximum deceleration of ACC systems
	7) Take over by braking at driver's discretion	Regularly, depending on driving conditions	Medium	Lane change manoeuvres Cutting in vehicles Highway intersections
	8) Gear shift	Regularly	Medium	Road inclination
	9) Info on preceding vehicle	Regularly	High (driver-paced)	Info always available, driver decides to use it to evaluate the driving situation
d) System status	1) System ON	Infrequent		Comment: No information on Control Mode (Free flow, Following, etc.) is provided to the driver.
	2) System OFF	Information on ON/OFF status is always available		

Table B.2 — Example route guidance destination entry tasks

First (top) level tasks	Second level tasks	Typical task frequency	Task priority (and time pacing)	Exceptional environments or scenarios
a) Destination entry by street name [a]	1) Enter town name	Once per journey		
	2) Enter street name			
	3) Enter building name/No.			
	4) Touch “Enter” to start guidance			
b) Destination entry via dedicated HOME function	1) Press “Home” button	Once per journey		
c) Destination entry via Point of Interest feature	1) Touch “POI” on screen	Once per journey		
	2) Touch “Destination Set” button on screen to select pre-entered point of interest.			
	3) Touch “Enter”			

[a] Not intended for use whilst driving.

Table B.3 — Example route guidance operation tasks

First (top) level tasks	Second level task	Typical task frequency	Task priority (and time pacing)	Exceptional environments or scenarios
a) Destination entry [a]	1) Enter town name	Once per journey		
	2) Enter street name			
	3) Enter building name/No.			
	4) Touch "Enter" to start guidance			
b) Setting off	1) Identify direction to drive off in	Once per journey		
c) Correctly negotiating manoeuvres	1) Obtain preview of next manoeuvre	Once for every manoeuvre		
	2) Informed that next manoeuvre is imminent	Once for every manoeuvre	Yes	Where two manoeuvres are very close together
	3) Request repeat of last instruction		Yes	
	4) Match system information to road scene information	Once for every manoeuvre	Yes	Particularly complex junctions, e.g. multiple-exit roundabouts
	5) Negotiate manoeuvre	Once for every manoeuvre		
	6) Able to confirm that correct manoeuvre has been taken.	Once for every manoeuvre		
	7) Receive preview information about next manoeuvre	Once for every manoeuvre		
d) Re-routing en-route (detour)	1) Inform system to re-route around congestion ahead	Once or more depending on congestion	Depends on distance to congestion	
	2) Inform system to change destination	Not more than once? Depending on nature of trip and driver's occupation		
	3) Inform system to now go via a waypoint	Not more than once? Depending on nature of trip and driver's occupation	Depends on distance to waypoint	
e) Reaching destination	1) Obtain information from system as to precise location of destination.	Once per journey	Yes	
f) General tasks	1) Turning the system off		Yes	
	2) Adjusting volume (or turning off sound completely)		Yes	

[a] Not intended for use whilst driving.

Annex C
(informative)

Suitability assessment methods and variables

C.1 General

The methods for assessing suitability of TICS for use while driving described in this annex are for general information only, as there are constant developments in techniques and technologies.

C.2 Assessment method characteristics

An assessment method comprises experimental procedures that use tools within environments. Data generated using tools is processed to yield variables. The principal relevant characteristics of assessment methods and the variables produced are

a) validity — the extent to which the variable is diagnostic for the concept being investigated,

b) reliability — reproducibility of measurements over time, and

c) sensitivity — the ability to measure small changes in a variable.

In addition to validity, reliability and sensitivity, the choice of an assessment method will be influenced by other practical factors, including the cost and availability of environments and tools, and the time and effort required for data gathering and processing.

C.3 Environments and tools

Assessment methods use environments within which data is captured. Example environments include

— road,

— test track,

— driving simulation,

— laboratory, and

— mathematical simulation.

Assessment methods use tools to obtain data. Example tools include

— video recorders,

— eye trackers,

— vehicle data recorders,

— questionnaires,

— TICS PC-simulators, and

— lane trackers.

C.4 Assessment method categorization

Methods for assessing suitability may be categorized into three levels, as shown in Figure C.1.

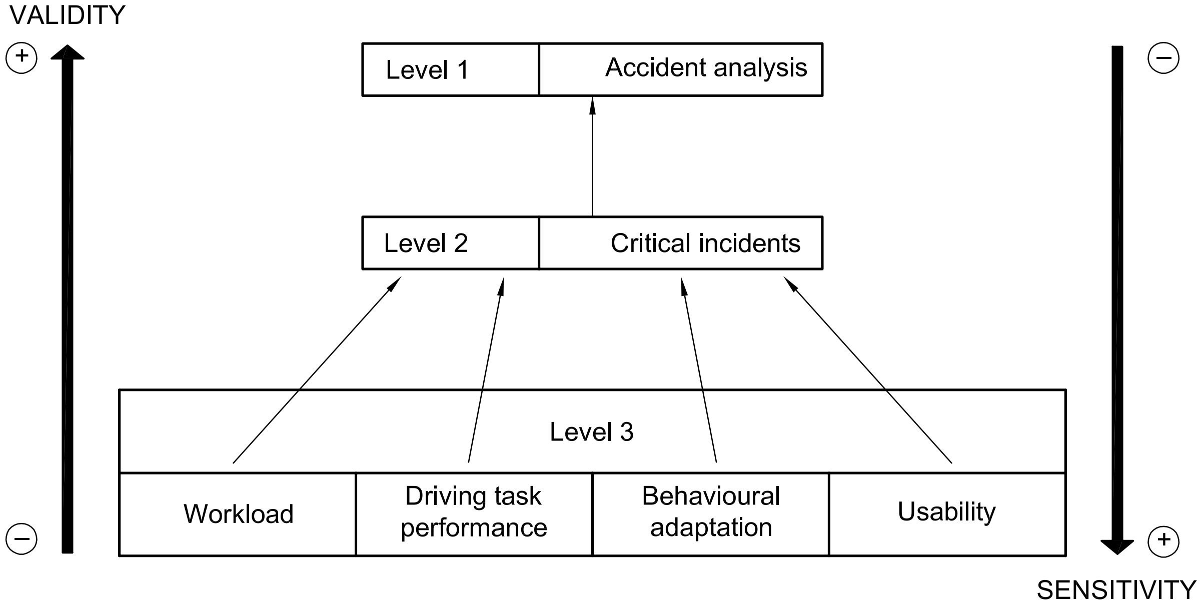


Figure C.1 — Three-level assessment method categorization

Moving from Level 1 to Level 3 is associated with an increase in sensitivity but a decrease in validity.

Level 1 methods concern accident analysis (vehicle collisions) derived from a series of years' data. Accidents per unit distance (or time) are highly valid measures of safety and should represent the ultimate criteria for evaluating TICS. However, their reliability and sensitivity are low and the data is not normally available — or at least not for many years after the TICS is in widespread use. One alternative to collecting accident data is testing a TICS in a simulator and observing accidents. However, as accidents are rare, the measure has very low reliability and sensitivity, and the validity may be questioned.

Level 2 methods concern critical incidents. The validity for accident risk of Level 2 variables is lower than those of Level 1, although measurement sensitivity should be better as the frequency of critical incidents is higher than that of actual accidents[4]. In practice, the sensitivity achieved may depend on specific test conditions and the duration of the test. The cost of simulators and instrumented vehicles, and the time and effort required make critical incident methods rather expensive.

Level 3 methods are concerned with measuring variables that are widely accepted as important when interacting with a TICS. The main factors are

— workload (under- and over-load),

— driving task performance,

— behavioural adaptation, and

— usability.

The variables generated will, in general, be interdependent. The validity of those derived from an instrumented vehicle on the road is likely to be higher than from a simulator or a laboratory test, as long as conditions between tests can be held constant. Behavioural adaptation is best measured in a field trial, whereas the other factors may be measured in the laboratory, in a simulator or in an instrumented vehicle.

In practice, Level 3 methods are likely to be used predominantly in order to assess the suitability of TICS for use while driving. Reviews of such methods and variables can be found in [5] and [6]. Specific Level 3 variables are additionally described in C.5.

C.5 Level 3 assessment variables

C.5.1 Workload

C.5.1.1 Introduction

Variables used to assess workload may be divided into three groups:

— visual attention;

— self-reported measures;

— secondary task performance.

C.5.1.2 Visual attention

C.5.1.2.1 General

In-vehicle displays with high visual attention requirements are considered to be detrimental for driver safety, because of the importance of attending to the roadside view[7]. Glance duration and frequency are often measured by off-line video analysis, which is time-consuming. Alternatively, eye-tracking equipment can be used for on-line or off-line analysis. For further information, see ISO/TS 15007-2[18].

C.5.1.2.2 Glance duration

Glance duration is the time from the moment at which the direction of gaze moves towards a target (e.g. the interior mirror) to the moment it moves away from it.

Glance duration includes the transition time to a target. There may also be some accommodation of the eyes during the transition time. Since lateral deviation of the vehicle increases with time spent looking away from the road, the validity of glance duration might be expected to be high. However, it also varies with visual load in the driving scene, so that it has limited reliability. A number of studies have indicated that glance duration is fairly constant across a number of in-car tasks with a definite upper limit the driver does not like to exceed. The sensitivity of this variable to visual load is therefore limited.

C.5.1.2.3 Glance frequency

Glance frequency is the number of glances to a target within a predefined time period, or during a predefined task, where each glance is separated by at least one glance to a different target.

Glance frequency (often described as the mean number of glances) varies strongly between different in-car tasks. Typically between one and seven glances are needed to acquire and process information. As glance frequency is related to the overall complexity of a visual task, it is a highly sensitive measure of visual attention or workload. Increased glance frequency indicates that the driver is responding to increased visual load. Since the range of the number of glances and the number of glances per task are consistent among studies, this measure can be considered as highly reliable.

C.5.1.2.4 Combined measures

Combined measures use variables incorporating both glance frequency and glance duration.

Several combined measures are reported that can have higher validity, reliability and sensitivity than the single variables. One is the total glance time (the summation of successive glance times). Others are derived from occlusion methods in which the driver controls the time spent looking at the road; the percentage of time looking at the road being an indicator of visual attention demand.

C.5.1.3 Self-reported measures

C.5.1.3.1 NASA-TLX (task load index)

The task load index is a multidimensional scale that measures subjective evaluations of six factors of workload: mental demand, physical demand, temporal demand, performance, effort and frustration level[8].

The TLX is not suitable for detecting peaks or short-lasting increases in workload, but is useful and sensitive when measuring workload over a longer period of time. Although it is a reliable method, there is no experimental evidence of a relation between NASA-TLX performance and driver behaviour or critical incidents.

C.5.1.3.2 Subjective workload assessment technique (SWAT)

The subjective workload assessment technique is a multidimensional scale that measures load on three dimensions: time stress, mental effort and psychological stress[9].

The SWAT procedure is quite time-consuming and attempts have been made to simplify it. Experimental studies have shown that a simplified version gives comparable results. Although SWAT has been shown to be sensitive, and is more sensitive than the MCH scale (see C.5.1.3.4), it is not as sensitive as NASA-TLX. Its validity still needs to be established by research. Comparative studies have shown that the SWAT is a reliable measure, although not as reliable as the NASA-TLX.

C.5.1.3.3 Rating scale mental effort (RSME)

This is a unidimensional scale for rating invested effort[10].

The RSME is easy to administer both during and after driving. In comparison with other techniques for measuring workload, this is one of the most sensitive measures. A higher level of invested effort is an indication of the driver's attempts to keep performance at a certain level in response to increased task demands. High levels of invested effort are considered detrimental for driver safety, but this assumed high validity still needs to be demonstrated. The technique has a high reliability since it consistently results in higher workload ratings as a function of task load.

C.5.1.3.4 Modified Cooper–Harper scale (MCH)

This is a unidimensional scale consisting of ten items that add to a single score.

MCH is not suited to measuring short-lasting variations in workload while driving. Although it has been shown to be sensitive to variations in task difficulty, it is not as sensitive as the multidimensional NASA-TLX or the unidimensional RSME. The reliability of MCH is lower compared with the other popular methods of subjective workload estimation and its validity still needs to be determined.

C.5.1.4 Secondary task performance

C.5.1.4.1 General

Secondary tasks have a few drawbacks, the most important being their intrusion on primary task performance. Since secondary tasks generally compete for attentional demands or resources with primary task execution, they may result in poorer driving performance. Another drawback is that secondary task performance may be affected by strategic resource allocation whereby the driver may choose to allocate more attention to the secondary task instead of the primary task or vice versa. These considerations suggest that, in order to be useful, the secondary task should not compete for resources with the primary task[11].

C.5.1.4.2 Visual/cognitive/manual task performance

The visual/cognitive/manual task is the measure of the driver's ability to undertake a task that is not directly connected with the primary driving task.

Tasks involving visual detection, cognitive processing and manual response are often designed with the intention that they be representative of driver information systems. In many cases the primary driving performance is actually the main variable of interest. Depending on the secondary task, the variable can be sensitive to changes in workload. The validity of the measure will depend on how well the secondary task matches that of the TICS under study. As many different secondary tasks of this type are used in different studies, the reliability is difficult to assess.

C.5.1.4.3 Peripheral detection

Peripheral detection is the measure of the driver's ability to detect visual stimuli presented towards the edge of his field of view.

The use of this variable is based on the idea that the functional field of view is reduced with increased workload or, alternatively, that attention becomes more selective with increased workload. The variable has been shown to be sensitive and its validity is assumed to be high but this has not been firmly established[12]. Similar findings have been reported in different studies under similar circumstances, so the method appears to be reliable.

C.5.2 Primary driving task performance

C.5.2.1 Introduction

Measures of primary driving performance are closely associated with driver safety. However, although the validity of such measures is high, the reliability and sensitivity is often reduced because they are strongly affected by specific driving task related factors, such as the road environment and traffic situation. These effects may be so dominant that they overshadow any effects of in-vehicle devices on driving performance. This indicates that variance induced by road and traffic-related factors needs to be controlled in order to produce the required sensitivity and reliability[13]. In practice, this calls for standardized tests under controlled circumstances, although this may reduce the ecological validity.

Variables to assess primary driving task performance may be divided into three groups:

— longitudinal vehicle control;

— lateral vehicle control;

— road scene awareness.

C.5.2.2 Longitudinal control

C.5.2.2.1 Mean vehicle speed

The mean vehicle speed is the average vehicle speed over a given test or time period.

Drivers usually reduce speed during higher task load situations in an attempt to compensate for negative effects on safety and it is the compensatory nature of this variable that makes it important. Vehicle speed is mainly determined by environmental characteristics of the driving task including local speed limits and other traffic. Due to the large number of factors involved (also including instruction to the driver), the sensitivity and reliability are very dependent on the way tests are designed. Under very controlled circumstances, speed reductions are indicative of increased in-vehicle task demands. The validity of this measure is high, in the sense that high speed or speed variability is associated with increased accident risk.

C.5.2.2.2 Standard deviation of speed

The standard deviation of speed is the variability of vehicle speed during a given test or time period.

A larger variability of speed is associated with increased accident risk, especially in situations of high traffic density. Therefore, validity is high. The sensitivity and reliability depend on the way tests are designed, as results depend not only on the driver's compensation for changes in workload or lack of attention to longitudinal control, but also on the driving task characteristics.

C.5.2.2.3 Time gap

The time gap is the time interval between two vehicles in car-following.

Time gap is computed as the bumper-to-bumper distance divided by the speed of the following vehicle. It is affected by visual circumstances and driver state, such as fatigue. Time gap has been found to be sensitive to variations in demand, and reliable. The validity for driver safety is clear. Smaller time gap is considered to be unsafe, while increased time gap under demanding circumstances is considered to be a safe response of the driver to task demands.

C.5.2.2.4 Time to collision (TTC)

Time to collision is the time required for two vehicles to collide if they continue at their present speed and on the same path.

Small TTC values can be considered as critical incidents in car-following, so the validity is very high. As they do not occur frequently, the sensitivity and reliability of small TTC is rather low. In dense traffic conditions, small TTC occur much more often and with a wider range. The distribution of these values can be used as a more sensitive and reliable measure.

C.5.2.3 Lateral control

C.5.2.3.1 Standard deviation of lateral position (SDLP)

The standard deviation of lateral position is the variability of vehicle position within a lane.

For measurement in on-road driving, a lane position tracker is required. SDLP is strongly affected by driving speed, lane width and driving manoeuvres but its reliability and sensitivity can be high if it is measured in controlled circumstances in which variance is reduced. The variable has high validity since it has been established that it is associated with the probability of exceeding lane boundaries.

C.5.2.3.2 Standard deviation of steering-wheel angle (SDST)

The standard deviation of steering-wheel angle is its variability.

Higher load often results in poorer steering performance. In contrast with SDLP, steering-wheel angle is easy to measure both in a simulator and in an instrumented vehicle. SDST is correlated with SDLP and both are indicators of the same process. Under controlled test conditions of straight road driving at similar speeds the measure is sensitive to variations in task demand. Under these circumstances it is also reliable. The validity is comparable to that of SDLP.

C.5.2.3.3 Steering amplitude

Steering amplitude is the maximum amplitude of the steering-wheel angle during a given test or time period.

It has been found that steering amplitude has high validity for measuring the effects of task load and fatigue. If workload is high or if visual requirements of other tasks (such as in-vehicle tasks or longitudinal control tasks) are high, attention to the lateral control task is reduced. The amount of research on this topic is rather limited, so results concerning sensitivity and reliability are lacking.

C.5.2.3.4 Steering-wheel reversal rate (SRR)

The steering-wheel reversal rate is the frequency of steering-wheel direction changes (above a threshold value) during a given test or time period.

Experimental results show that SRR is valid, sensitive and reliable only within a limited range of task loads. Recent literature has also reported increased workload associated with both increased SRR and decreased SRR.

C.5.2.3.5 Time to line crossing (TLC)

The time to line crossing is the time available until any part of the vehicle reaches one of the lane boundaries.

TLC is less affected than SDLP by road- and vehicle-related factors such as lane width, curvature and vehicle speed. However, it can usually only be measured in simulators because of the practical difficulty of measuring lateral position sufficiently accurately during on-road trials. Validity is high since small TLC values are closely associated with exceeding lane boundaries. Although the number of TLC studies is limited, the reliability and sensitivity appear to be high.

C.5.2.3.6 Lane boundary excursion (LANEX)

Lane boundary excursion is the number of excursions or percentage of time during which the lane boundary is exceeded.

LANEX is less reliable than measuring lane position with a lane tracker. On the one hand, because the frequency of actual lane boundary crossing is usually very low, the sensitivity of this measure is poor. On the other hand, the validity is very high, since exceeding the lane boundary constitutes a high accident risk. According to some studies, the reliability is acceptable.

C.5.2.4 Road scene awareness — Detection of roadside objects

The detection of roadside objects refers to the number and type of road side objects consciously detected by the driver.

The driver has to divide attention between lateral control, longitudinal control, in-vehicle tasks and detecting roadside objects, such as traffic signs, route directions or pedestrians. If load on any of these tasks increases this may result in reduced attention to one or more of the tasks. Monitoring the roadside environment is then the candidate likely to suffer first, since the consequences of driving off the road or colliding with another car are often more severe. Therefore, detection of roadside objects may be sensitive to task load. A number of studies have shown that detection performance is reliable[14]. From a traffic safety point of view detection performance has a high validity.

C.5.3 Behavioural adaptation

C.5.3.1 General

Measurement of behavioural adaptation requires the establishment of a comparative methodology, i.e. the comparison of reference data obtained before, for example, the use of a TICS with corresponding data obtained during driving with the TICS. Behavioural adaptation can be immediately apparent but could also require an extended time period for determining longer-term effects. Examples of variables are described below but it should be noted that these variables may also be highly dependent on the driver state, the driving task and other environmental factors. Thus, while all variables appear to have good validity, their reliability and sensitivity will depend on the details of the comparative methodology used. Further information on behavioural adaptation can be found in [15].

Many of the variables discussed in C.5.1 and C.5.2 can be used to measure behavioural adaptation. Additional variables include those described in C.5.3.2 to C.5.3.5.

C.5.3.2 "Ready to brake"

This variable measures the readiness of the driver to operate the brake.

The observation of this variable is a particularly good indirect indicator of how the driver becomes gradually more confident with the system as a test journey is undertaken.

C.5.3.3 Use of controls

Use of controls measures the operation of controls such as accelerator or brake or both and the evolution of the use of the controls throughout a given test journey.

C.5.3.4 Lane occupied

Lane occupied designates the traffic lane use by the driver where there are a number of lanes available during a given test journey.

C.5.3.5 Manoeuvres performed

This variable covers manoeuvres performed by the driver and their timing.

Manoeuvres include pulling out, pulling in, and turning. These aspects of driving may be measured as they develop during a given test journey, indicating changes in driving behaviour.

C.5.4 Usability

C.5.4.1 General

Usability is concerned with the ease of use and quality of interaction between the driver and the TICS. This will have an impact on the suitability of a specific TICS for use while driving. Usability can be assessed by variables such as efficiency, effectiveness, satisfaction, ease of learning, controllability, self-descriptiveness, and conformity with driver expectations. A consideration of the driver's training needs may be helpful. It is valuable to collect both performance and self-reported variables. Further information on usability assessment can be found in [16].

Many of the variables discussed in sections in C.5.1 and C.5.2 can be used to measure usability. The validity, reliability and sensitivity of the variables are highly dependent on the conditions under which experimental data are collected. In the context of suitability evaluation, validity is likely to be higher if measurements are made in realistic driving conditions, or using well-founded mathematical models. Additional variables include those described in C.5.4.2 to C.5.4.4.

C.5.4.2 Task completion time

The task completion time is the period required by the driver to successfully conclude a specific task using the TICS.

Tasks include extracting an element of information and making a control action.

C.5.4.3 Task errors

Task errors measure the number and nature of errors and problems encountered by the driver while interacting with the TICS.

C.5.4.4 TICS reaction time

The TICS reaction time is the period between driver action and TICS response.

Annex D
(informative)

Example individual assessments — Stages 2 to 6

D.1 Assessment of ease of use of “detour” function of route-guidance system

See Table D.1.

Table D.1 — Detour function assessment — Stages 2 to 6

Stage of assessment	Information
Stage 2 — TICS representation	
Design cycle stage:	Commercial product
TICS component:	“Detour” function
Stage 3 — Context	
Population:	All drivers
Sample profile:	Professional business people chosen randomly from a single organization
Characteristics:	
— vehicle, traffic, road	Vehicle [model …] moving in light urban traffic at 50 km/h
— natural conditions	Daylight
— situation studied	Approaching congestion
Stage 4 — Criteria:	Number of button presses less than four Total task completion time less than 15 s
Stage 5 — Method:	Observers within vehicle recording the driver/system interaction and using a stopwatch for timing
Stage 6 — Data collection:	The task was always accomplished with two button presses The average task time was 4,5 s Assessor’s details are contained in an accompanying document [not provided]

D.2 Assessment of the ease with which a smart card can be installed within a congestion warning system

See Table D.2.

Table D.2 — Card insertion assessment — Stages 2 to 6

Stage of assessment	Information
Stage 2 — TICS representation	
Design cycle stage:	Commercial product
TICS component:	Smartcard insertion
Stage 3 —Context	
Population:	All drivers
Sample profile:	Professional business people chosen randomly from a single organization
Characteristics:	
— vehicle, traffic, road	Vehicle moving in light urban traffic at 50 km/h
— natural conditions	Darkness
— situation studied	Card in pocket and not correctly orientated for insertion
Stage 4 — Criteria:	Task can be completed whilst always keeping one hand on the steering-wheel
Stage 5 — Method:	One Observer in vehicle. Each subject was asked to perform the operation three times.
Stage 6 — Data collection:	See Table of results [not provided]
Assessor:	J. Leblanc. Eur. Ing., Z-Dos Electronics Corporation.

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