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Road vehicles — Ergonomic aspects of transport information and control systems (TICS) — Procedures for determining priority of on-board messages presented to drivers

Véhicules routiers — Aspects ergonomiques des systèmes de commande et d'information du transport (TICS) — Modes opératoires pour la détermination de la priorité des messages embarqués présentés aux conducteurs

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Foreword

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

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Introduction

When multiple in-vehicle information systems are present, including both transport information and control systems (TICS) and non-TICS, various kinds of messages will be presented to drivers from these systems and displayed at various times. If these messages are not managed properly, drivers could fail to obtain critical information, which may degrade safety. This Technical Specification establishes two prioritization methods for TICS and other system-initiated or driver-requested messages presented to drivers while driving. Other prioritization methods are possible. The primary method given in this Technical Specification takes criticality and urgency ratings of such messages into consideration when calculating a priority index. An alternative method involving paired comparisons of all possible messages to form a priority matrix is presented in Annex A and its relative advantages and disadvantages are discussed.

Priority is one of the parameters to consider in determining when, where and how system messages are to be displayed. As TICS applications are deployed, the number and frequency of TICS messages presented to drivers can be expected to increase. This Technical Specification will provide road vehicle manufacturers and TICS suppliers with a consistent basis for the management of messages competing for the driver's limited information processing capability. This, in turn, will reduce the driver's workload and help ensure that the most important messages reach the driver. This Technical Specification complements ISO 15005 [3], a dialogue management standard.

This Technical Specification is intended for those involved in the design of message management systems that integrate in-vehicle messages. It describes how to establish message priorities. It also specifies criteria for message prioritization and, therefore, serves as an evaluation tool for TICS installed in vehicles as standard equipment and for after-market TICS devices.

Road vehicles — Ergonomic aspects of transport information and control systems (TICS) — Procedures for determining priority of on-board messages presented to drivers

1 Scope

This Technical Specification provides formal procedures and two, alternative, methods (users are advised to choose whichever of the two suits their individual requirements) for determining the priority of on-board messages presented to drivers of road vehicles by transport information and control systems (TICS) and other systems. It is applicable to the whole range of TICS in-vehicle messages, including traveller information, navigation, travel and traffic advisories, “yellow pages” information, warnings, systems status, emergency calling system information, and electronic toll/fee collection, as well as to messages from non-TICS sources such as telephone, warnings and telltales. Although applicable to systems that allow the free generation of messages, it neither provides guidance on how to use the messages deriving from its procedures nor is it applicable to mandatory or legally required messages.

2 Terms and definitions

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

2.1
contents of message
information presented to a user by the TICS or other on-board system

EXAMPLE A message containing system status information, warnings or alarms presented using characters, symbols, figures, audible tones, voices or other means.

2.2
criticality
severity of the impact of the most likely accident or malfunction that can occur when the message is not received or is ignored by the driver

2.3
display
device that allows the presentation of visual, auditory, or haptic dynamic information to a driver

2.4
driving
activities undertaken by the driver to navigate, manœuvre and handle the vehicle to achieve lateral and longitudinal control

2.5
evaluator
person who judges the contents of a message from the point of view of criticality and urgency to the driver

2.6
examiner
person who manages and conducts the use of this Technical Specification for determining priority

2.7
k_c
weighting of criticality used to calculate the priority index

2.8
k_u
weighting of urgency used to calculate the priority index

2.9
message management system
system that controls and evaluates a wide range of information and presents it ergonomically to drivers, allowing them to cope with the information while driving and assisting them in driving safely and comfortably

2.10
priority
relative importance of two or more messages which determines their ranking in a time sequence or emphasis of presentation

NOTE The message with the highest priority is assigned first place (larger priority ratings correspond to higher priority items).

2.11
priority index
index used to determine which messages should be given precedence when two or more messages are available for presentation

2.12
scenario
explanation of the driving context and situation for the message presented to evaluators

2.13
system-initiated message
message provided by a TICS or conventional system (both inside and outside of the vehicle) without a specific request from the driver

2.14
transport information and control system
TICS
system comprised of an advanced information and telecommunications network for users, roads and vehicles that contributes to solving problems such as traffic accidents and congestion

NOTE See ISO/TR 14813-1 for a list of TICS services [4].

2.15
urgency
time within which driver action or decision has to be taken if the benefit intended by the system is to be derived from the message

3 Data collection for the priority index procedure

This clause presents the steps for collecting the data used to calculate a priority index for each message. See the example outputs given in Annex E and Annex H.

3.1 Appoint an examiner

The priority index procedure requires an examiner to coordinate the data preparation, analysis, and reporting. The role of the examiner is detailed in 3.6.

The examiner shall be familiar with the prioritization process, knowledgeable on message management, and have automotive experience.

If the examiner has similar qualifications to that of the evaluators, the examiner may participate as both an examiner and evaluator.

3.2 Identify and assemble messages

It is necessary for the examiner to identify in advance messages that are to be presented to drivers. Generally speaking, the messages represent the aggregate output given by the TICS and non-TICS connected to a message management system. The examiner shall collect these messages and prepare them for presentation to the evaluators.

3.3 Define driving context and situation

For each message, the examiner shall define, or assist in defining, a driving context and situation in terms of the road environment and the traffic condition in which the message is likely to be presented.

The contextual and situational factors should be defined at the moment when the message is presented because the priority (assignment of criticality and urgency ratings) depends heavily on the driving context. Particular attention should be given to the presentation of messages in potentially hazardous situations. All hazardous situations should be considered, except for highly unlikely possibilities. Based on these situations the examiner may define one or more (normally not more than four) scenarios for a particular message.

The same message in two different scenarios shall be regarded as two different information items to be evaluated. This is because messages may occur in several different driving contexts, and each context could yield a different message priority. For example, the priority given to a message pertaining to a system malfunction will be different depending on whether the driver is starting the car or is relying on the system whilst driving.

If only one scenario is used for a given message, that scenario should represent a reasonable “worst-case” situation. At minimum, a TICS or non-TICS expert and the examiner should agree on the worst-case driving scenario. A traffic safety expert may also be consulted.

3.3.1 Consider the sensing capability of the vehicle

In practice the messages that are provided to the driver will depend on the capability of the vehicle to sense or detect various relevant situations. For example, if the vehicle can detect the driver’s state of arousal, then the driver’s state can be considered in describing the driving scenario.

For situations in which the vehicle is incapable of sensing, the message priority should be determined for a scenario representing a “reasonable” worst-case situation for the factors listed in 3.3.2.

3.3.2 Factors to consider in developing the driving scenarios (see Table 1)

Table 1 is provided to assist the examiner in developing driving context and relevant situations. A sample of situation and context factors is given in the rightmost column. The examiner may use these or other factors to define driving scenarios. If the context cannot be categorized into one of the candidate factors listed in Table 1, it should be clearly described within the “Other” parentheses. If neither the context nor situation is defined for one of the factors, select “not defined (N-D)” from the list of the candidates.

The following factors should be considered in developing the driving contexts and situations for evaluators to consider when making their ratings.

3.3.2.1 Trip context

The trip context is a factor that considers the aim of the trip (e.g. commuting, leisure), the timing or position along the route (e.g. relative position between start and destination), and the preparatory distance to the next manœuvre.

EXAMPLE “Close (e.g. 20 m) to turn (or merge)”.

3.3.2.2 Road environment

The road environment is a static factor related to road structure that affects driving. Considerations shall include the road type (e.g. highway, urban road, country road), the speed limit, the number of lanes, and the road width. Consideration shall also be given to the effect on driving of the surrounding environment, including weather conditions and time of day (e.g. morning, daytime, night time, raining).

3.3.2.3 Traffic situation

The traffic situation is a dynamically changing factor related to traffic or obstacles on the road that affect driving. Considerations here include the relationship to other vehicles, such as headway distance and speed difference to the lead vehicle.

EXAMPLE 1 “Headway distance”.

EXAMPLE 2 “Lateral vehicle exists”.

EXAMPLE 3 “Speed difference to the lead vehicle”.

3.3.2.4 Vehicle condition

This factor originates from the vehicle itself and derives from the relationship between the vehicle and the road. Vehicle condition can be separated into “vehicle type” and “vehicle state”.

EXAMPLE 1 Vehicle type: “passenger vehicle”, “heavy vehicle”.

EXAMPLE 2 Vehicle state: “driving speed”; “driving in left [right] lane”; “negotiating curve [intersection]”; position of the vehicle within a lane.

3.3.3 Document the driving context and situation

The defined driving context, situation, appropriate driver behaviours and/or cognitive demands associated with each message shall be documented. An example for a specific configuration is given in Annex E.

Table 1 — Factors to consider in developing driving scenarios

Driving context/situation		Candidate situational or contextual factors
Trip context		Close to turn (or merge, or diverge) Other (……) N-D
Road environment:	Road	Highway / urban / country / curve / icy / wet Speed limit (…) Number of lanes (…) Other (……) N-D
	Weather	Rain / fog Time of day (morning / daytime / night-time) Other (……) N-D
Traffic situation		Headway distance is approx. (…) m or (…) s Lateral vehicle(s) exists (yes or no) Speed difference to the lead vehicle is approx. (…) km / h N-D
Vehicle condition	Type	Passenger vehicle / heavy vehicle Other (……) N-D
	Status on roadway / manœuvre	Driving speed (…) km/h (mph) Driving in left (or right) lane Curve (intersection) negotiation Other (……) N-D
	Status of vehicle subsystem(s)	Systems check after start-up shows all systems are normal Malfunction of system (……) — provide relevant details Other (……) N-D
Miscellaneous		Driver's state of arousal N-D
N-D Not defined.		

3.4 Select the evaluators

The examiner shall select a minimum of 5 evaluators (see 4.1 and Annex C).

Evaluators should include experienced human factors and road safety practitioners and others who possess a good understanding of the functions of the subject TICS system. They must be well-informed of the traffic environment and road environment of the subject country/region and have the ability to evaluate and take into account the safe presentation of messages. Actual use of the system is recommended for all evaluators.

The profile of each evaluator should be recorded. Profiles should include field of expertise, knowledge of road safety, human factors, and knowledge of the systems producing messages that are prioritized (see Annex D).

3.5 Evaluate criticality and urgency of a message

The contents of messages and the driving scenarios shall be explained by the examiner so that the evaluators have a common understanding of the scenario, the functions of the system, and the contents of messages being examined.

Examiners shall ensure that evaluators understand the definitions of criticality and urgency, the two evaluation criteria composing the priority index. For this, evaluators must understand the four-category ordinal evaluation scales used to assign criticality and urgency values (see Tables 2 and 3).

Each evaluator shall assign a criticality and urgency rating for each message assuming he/she is the driver.

In general, urgency will be time dependent. Controllability is one of the important factors that must be considered in determining urgency. If the situation is uncontrollable, no action shall be expected from drivers. However, if there is a possibility of controlling the situation, then urgency shall be determined depending on when the system expects drivers to take an action to handle it [2].

If the examiner has not fully defined the driving context and situation, evaluators shall be instructed to consider all hazardous situations, except for highly unlikely possibilities. They should assume a reasonable worst-case scenario when determining their criticality and urgency ratings.

3.6 Instructions for the examiner

The role of the examiner is to

a) record information about each evaluator in the evaluator profile (see Annex D),

b) create the questionnaire according to Annex E for the vehicle and system to be evaluated, and distribute the questionnaire and Tables 2 and 3 to each evaluator (definitions of criticality and urgency should be provided with the questionnaire),

c) explain the evaluation items and the contents of the message(s) in the questionnaire, while providing a means for evaluators to record the driving context and situation they used in making their evaluations, whenever the examiner's description was not clear or sufficient,

d) explain the classification of criticality and urgency according to Tables 2 and 3,

e) explain how to record the rating for criticality and urgency in the appropriate column of the questionnaire,

f) collect the questionnaire, and

g) analyse the data and report the results.

Table 2 — Criticality rating scale

Rating	Risk to vehicle, occupants and/or pedestrians	Examples
3	**Severe or fatal injury**	Ignoring speed warning when driving significantly above the speed limit. Collision as a result of loss of braking due to ignoring the brake failure warning. Departing roadway due to ignoring lane departure warning. Collision at high speed. Leaving the roadway, head-on collision and collision with structures at intermediate speed. Following vehicle ahead too closely at high speed.
2	**Injury or possible injury**	Risk of collision due to following a vehicle ahead too closely at intermediate speed. Vehicle(side)-to-vehicle(side) collision due to ignoring collision warning at intermediate or low speed, vehicle leaving the road, head-on collision and collision with structures at intermediate or low speed.
1	**No injury (vehicle damaged)**	Vehicle-to-vehicle collision except head-on collision at low speed. Following vehicle ahead too closely at low speed. Collision with structures at low speed.
0	**No injury (no vehicle damage)**	Vehicle-to-vehicle contact at very low speed. Collision with structures at very low speed.

NOTE 1 Initially, three ratings scales were used in calculating a priority index. See Annex F for the reason for reducing the number of rating scales to two.

NOTE 2 Only a few examples are shown above. These can be expected to vary in criticality from region to region depending on the road environment and other situational and contextual factors. Therefore, examiners are able to alter them at their discretion.

NOTE 3 The examples shown here illustrate that a warning message can be assigned a high criticality rating, even if failure to respond to the warning does not result in a crash.

NOTE 4 Driving speeds vary by country. The speed values (km/h) for "very low", "low," "intermediate", and "high" speed will depend on the country and on elements of the driving scenario such as urban, suburban, or expressway roads.

Table 3 — Urgency rating scale

Rating	Description	Examples
3	**Respond immediately** Take immediate action or decision (within zero to three seconds) according to the displayed information.	Obstacle immediately in the vehicle path. Brake immediately. Steer to avoid dangerous situations. ACC malfunctioning.
2	**Respond within a few seconds** Take action or decision according to the information within 3 to 10 seconds [1].	Obstacle within a few seconds in the vehicle path. Brake in a few seconds. Steer away from danger as required.
1	**Response preparation** Prepare to take action or decision according to the information within 10 seconds to 2 minutes.	Onset of detection of an obstacle.
0	**Information only** No direct action or decision required by driver	System on.

3.7 Alternative method for determining message priority

An alternative method for determining message priority, the *priority matrix method*, is given in Annex A. This method determines priority subjectively by having subject matter experts make pair-wise comparisons of all messages. It involves neither the steps of rating criticality and urgency based on Tables 2 and 3 nor the calculation of a priority index according to Clause 4.

4 Data analysis for priority index

4.1 General

This clause provides a method for calculating the message priority index based on evaluator ratings of criticality (c_i) and urgency (u_i).

Since the priority index for each message is obtained by averaging the priority indexes of each evaluator, the number of evaluators affects the reliability of the overall index. Therefore, ten or more evaluators are recommended in order to make the priority index reliable (See Annex C). However, fewer than ten evaluators are acceptable if the standard deviation across evaluators is small enough [1)]. Annex I contains an example procedure for determining acceptable standard deviations. In all cases, the minimum number of evaluators should be five, to avoid bias by the selection of evaluators.

4.2 Select weights

In order to use this Technical Specification, those involved in the design of the message management system need numerical values of k_c and k_u as the first step. When there is no established rule to determine k_c and k_u, one way is to assign 1,0 to k_c and k_u, making criticality and urgency equally important. Another way is to obtain k_u and k_c based on empirical data. An example of the method is shown in Annex G. This example indicates that $k_u = k_c = 1$ can be used as rounded values for the weight factors. The evaluator's ratings of criticality (c_i) and urgency (u_i) given in Clause 3 are used to calculate priority index P_j in 4.4 [see Equation (2)]. As the ratings range between 0 and 3 for both criticality and urgency (see Tables 2 and 3), $k_c = k_u = 1$ means that the contribution of criticality and urgency to the priority index would be the same.

4.3 Calculate priority p_{ij}

Priority p_{ij} indicates the relative importance of the ith evaluator and jth message and is calculated according to the following Equation (1).

$$p_{ij} = k_c c_{ij} + k_u u_{ij} \quad (1)$$

where

p_{ij} is the individual value for priority index;

c_{ij}, u_{ij} are the individual scores, respectively, of criticality and urgency;

k_c, k_u are weight factors respectively of criticality and urgency against p_i (see 4.2).

1) The definition of "small enough" variance is still being investigated.

4.4 Calculate arithmetic mean and standard deviation of priority index across evaluators for each message

The arithmetic mean P_j, given by Equation (2), is the priority index, which indicates the relative importance of the jth message:

$$\begin{aligned} P_j &= \sum_{i=1}^{n} p_{ij} \Big/ n \\ &= \sum_{i=1}^{n} \left(k_c c_{ij} + k_u u_{ij} \right) \Big/ n \\ &= k_c C_j + k_u U_j \end{aligned} \qquad (2)$$

where

P_j is the priority index of the jth message;

C_j, U_j are the mean score across evaluators, respectively, of criticality and urgency of the jth message;

n is the number of evaluators.

Standard deviation σ_j, given by Equation (3), indicates the relative confidence of the priority index of the jth message.

$$\begin{aligned} \sigma_j = \sqrt{V_j} &= \sqrt{\sum_{i=1}^{n} \left(p_{ij} - P_j \right)^2 \Big/ n} \\ &= \sqrt{\sum_{i=1}^{n} \left(p_{ij} - \sum_{i=1}^{n} p_{ij} \Big/ n \right)^2 \Bigg/ n} \\ &= \sqrt{\sum_{i=1}^{n} \left[\left(k_c c_{ij} + k_u u_{ij} \right) - \sum_{i=1}^{n} \left(k_c c_{ij} + k_u u_{ij} \right) \Big/ n^2 \right] \Bigg/ n} \end{aligned} \qquad (3)$$

where

σ_j is the standard deviation of the jth message;

V_j is the variance of the priority index of the jth message.

4.5 Calculate P_j and σ_j

Repeat Equations (2) and (3), calculating P_j and σ_j for each of the j messages.

4.6 Determine priority order

Rank the messages in terms of their P_j values; then list the messages in descending order (larger values correspond to higher priority items). When items have the same numerical P_j values, priority should go to the message whose mean criticality score C_i is higher.

Prepare a priority order table that lists the numerical values C_j and U_j, and P_j and σ_j, for each message evaluated.

An empty table for displaying an example of a priority index calculated by assigning 1,0 to k_u and k_c is shown in Annex H.

4.7 Evaluate data quality

For the evaluators' priority ratings of each message, verify that a sufficient level of agreement among evaluators was achieved to ensure sufficiently high data quality. This can be done using either of two different methods. The agreement is sufficient if:

a) more than half the number of evaluators agree on the criticality and urgency ratings of a message, or

b) the standard deviation of priority index is less than 1,0 (see Annex I).

If neither was the case, the examiners shall interview the evaluators to ask if the explanation of message context was ambiguous. If so, the examiners shall clarify or provide additional details of the driving context and situation to the evaluators, and the evaluators shall re-evaluate the messages.

NOTE In cases where re-evaluation takes place, messages that in the first evaluation achieved an average criticality of less than 0,5 and an average urgency of less than 1,5 need not be considered in the re-evaluation.

5 Application of results

5.1 Prioritization of priority ranking

As a general principle, designers should use the priority rankings to avoid the simultaneous presentation of messages. This is particularly important with auditory messages. If two or more in-vehicle messages need to be displayed to the driver at the same time, those with larger priority rankings should be emphasized. After the message(s) has been presented to the driver, the driver should be in control of selecting, deactivating, and cancelling messages, independent of priority, except for messages regulated by law.

Even if the process for determining a priority index is performed adequately in accordance with Clauses 3 to 5, it can sometimes happen that the standard deviation of one message is extremely large compared with those of other messages. This might be caused by differences in evaluators' understanding of the criticality and urgency of messages. Therefore, due attention should be paid to handling such messages by, for example, devising special means of message presentation.

5.2 How to deal with additional messages

When new TICS systems or messages are developed, it is necessary to establish the priority for such new messages. If any evaluator is replaced with a new evaluator, he/she should be selected from a similar discipline as the previous evaluator (see 3.3).

The procedures according to 3.2 to 4.5 shall be performed only when additional messages are added. The values obtained by these procedures shall be put into the appropriate position of the priority order table already obtained according to 4.6 to determine the priority orders of the new messages.

5.3 Documentation

The examiner shall issue a report containing the following topics:

a) evaluators' profiles (see Annex D);

b) list of messages with driving situations (see Annex E) and consequences if a message is ignored;

c) priority index of each message (see Annex H).

5.4 Other

The installed priority ranking should be communicated to the driver by appropriate means (e.g. operator's manual).

Annex A
(normative)

Priority matrix method

A.1 Overview of method

The priority matrix is an alternative method for determining priority when there are competing TICS and non-TICS messages. It can be used in lieu of the method according to Clauses 3, 4 and 5. The basic idea is to avoid the mathematical formulation of an abstract criterion (index) based on criticality and urgency and instead list all the messages that will be presented to the driver in a matrix format with n (i.e. number of all the messages) columns and rows. Messages are formulated exactly as they would be displayed in the vehicle. Each message should clearly describe the behaviour or malfunction of the system. Experts then compare each pair of messages, and the message with higher priority is recorded. The procedure is repeated until all possible pairs of messages are compared.

A.2 Advantages and disadvantages of method

This method has been chosen because it fits well into the engineering process of the human-machine interface (HMI) development.

a) Main advantages

— The method can be performed with the existing experts for the respective systems, there being no need to involve persons with an in-depth knowledge of all warning messages in the car (who could be hard to find, even in an automotive company).

— Optimisation of system reaction is rather easy (see Annex B), with any necessary adjustment able to be done in the respective cell without influencing any other parts of the system.

b) Main disadvantages

— All possible pairs of messages should be evaluated, which can result in a large number of evaluations.

— System reactions based on the priority matrix require more device memory space to implement.

A.3 Requirements for examiner and evaluators

A.3.1 Examiner

The examiner shall be expert in the TICS systems being evaluated and have HMI experience, or shall be an HMI expert with a good understanding of the TICS systems being evaluated. The examiner shall also be familiar with the prioritization process, knowledgeable on message management, and have automotive experience. The role of the examiner is detailed in A.5.

A.3.2 Expert evaluators

Evaluators shall be selected from experts (specialists) of the respective TICS and non-TICS systems. HMI experts may also serve as evaluators. At minimum there should be one such expert evaluator representing each TICS.

The expert evaluator should possess a good understanding of the functions of the subject TICS or non-TICS system, be well informed of the traffic environment and road environment of the subject country/region, and have the ability to evaluate and take into account the safe presentation of messages. Actual use of the system is recommended for all expert evaluators.

The profile of each expert evaluator should be recorded. Profiles should include: age, gender, expertise, experience in terms of years in his or her field of expertise, and experience in terms of years in the study of TICS human interfaces (see Annex D).

A.3.2.1 Expert opinion

The expert evaluator determines the priority for each individual message on the basis of his or her good knowledge of the system or of all the messages that can be displayed.

Criticality and urgency are considerations to be discussed when making the priority judgment for each pair of messages. The criteria of *criticality* and *urgency* are implicitly included in every priority decision. There is no need to explicitly rate criticality and urgency in order to determine priority, as is done in the priority index method.

A.4 Procedure

A.4.1 Identify and assemble messages

The examiner shall collect in advance messages that are to be presented to drivers. Generally speaking, the messages represent the aggregate output given by the TICS and non-TICS systems connected to the message management system. The examiner shall prepare the priority matrix for presentation to the expert evaluators. All the messages that can be displayed are entered into the matrix, with each message appearing in a column and in a row (see Table A.1).

A.4.2 Define driving context and situation

For each message, the examiner shall define, or assist in defining, a driving context and situation in terms of the road environment and the traffic condition in which the message is likely to be presented. This definition serves two purposes. It clarifies the driving context and it distinguishes between different situations, when those situations could influence the message priority and/or the system reaction.

A.4.2.1 Clarify driving context

Driving context and situation can be classified into “trip context”, “road environment”, “traffic situation”, and “vehicle condition” (see 3.3.2). For each message, these contextual and situational factors should be defined at the moment when the message is presented because the priority depends heavily on the driving context. Particular attention should be given to the presentation of messages in potentially hazardous situations. All hazardous situations should be considered, except for highly unlikely possibilities. Based on these situations the examiner may define one or more (normally not more than four) scenarios for a particular message.

If only one scenario is used for a given message, that scenario should represent a reasonable “worst-case” situation. At minimum, a TICS or non-TICS expert and the examiner should agree on the worst-case driving scenario. A traffic safety expert may also be consulted.

A.4.2.2 Differentiate between situations

Messages occur in several different driving contexts, and in some cases each context yields a different message priority. For example, the priority given to a message pertaining to a system malfunction will be different depending on whether the driver is starting the car or is relying on the system whilst driving. This requires that the different scenarios be distinguishable by in-vehicle sensors.

In those situations, the same message in two different scenarios shall be regarded as two different information items to be evaluated. Each scenario will have a separate row and column in the priority matrix.

A.4.2.3 Document the driving context and situation

The defined driving context, situation, appropriate driver behaviours, consequences if the message is ignored and/or cognitive demands associated with each message shall be documented (see 3.3 and Table 1). An example for a specific configuration is given in Annex E.

A.4.3 Evaluate the priority of messages

The contents of messages and the driving scenarios shall be explained so that the expert evaluators have a common understanding of the scenario, the functions of the system, and the contents of messages being examined.

The expert evaluators shall understand the definitions of criticality (2.2) and urgency (2.15).

The expert evaluator assesses and records the priority of the row message compared with the column message for each cell of the matrix. (A cell is the point of intersection of two messages from a column and a row. See Table A.1.)

When determining priority for messages coming from two different TICS or non-TICS systems, the relative priority between two messages is obtained by the agreement of the expert evaluators from the respective TICS or non-TICS systems. In some cases, the same person may be responsible for, or may have in-depth knowledge of, both applications and can do the comparison alone. If no agreement is reached, the topic is discussed under the supervision of the examiner, an HMI expert. If no agreement is yet reached, the priority is decided by the vote of the two expert evaluators and the examiner.

An example of a priority matrix is shown in Table A.1. The example is intended to clarify the method, not to recommend priorities for application.

Table A.1 — Example priority matrix

Row message	Column message			
	Fasten your safety belt	**Minimum fuel level**	**Malfunction oil pressure**	**Receipt of an SMS**
Fasten your safety belt	X	+	+	0
Minimum fuel level		X	+	0
Malfunction oil pressure			X	–
Receipt of an SMS				X

\+ the column message has a higher priority than the row message
– the column message has a lower priority
0 two messages have equal priority

NOTE It is only necessary to fill in half of the matrix to assess priority for all possible pairs of messages.

A.5 Instructions for the examiner

The examiner's role is to

a) record information about the expert evaluator in the evaluator profile (see Annex D),

b) create messages together with scenarios to describe the driving context and situation,

c) create the priority matrix and distribute it to expert evaluators, explaining the scenarios.

d) collect the responses and check whether there are different opinions in some cases,

e) if differences exist, arrange a discussion and resolve differences between the expert evaluators,

f) check all results for consistency, and

g) analyse data and report results.

A.6 Documentation

The examiner shall issue a report containing the following topics:

a) evaluators' profiles,

b) list of messages with driving situations and the consequences if a message is ignored,

c) priority matrix, if this intermediate result is produced,

d) system response matrix (see Annex B), and

e) list of specific scenarios if these are important for the decision in a specific cell in the matrix (the list does not need to be complete because the situation in many cells is obvious).

Annex B
(informative)

System reaction matrix for priority matrix method

B.1 System reactions to prioritized messages

The main purpose of prioritizing messages is to manage messages and ultimately determine the system reaction for displaying the message to the driver. The priority matrix is useful as an intermediate result that does not generally take into account the specific display system features. Whilst this Technical Specification is not intended to address system reactions after the message priority has been determined, an example of system reactions is provided here for information only.

The procedure for system reactions is similar to the priority matrix procedure. The rows of the matrix represent the current messages (i.e. the messages which are currently displayed), and the columns represent incoming messages that compete with the current messages. For each pair of messages the system reaction is recorded in the appropriate cell of a system reaction matrix (e.g. a time out for the present warning). The possibilities for system reactions will depend on the capabilities of the device that displays the messages.

EXAMPLE Warnings from the navigation system and from the ACC come into conflict. The experts for navigation and ACC decide the priority, if necessary under the direction of a human factors expert. By making an entry in the cell, both the priority and the system performance are regulated. For example, the system reaction might be to interrupt the navigation direction advice and connect in the audio source with the ACC system. This means that the overall system behaviour can be described in a very comprehensible way.

Some examples of the many possible system reactions that could be chosen by a system designer include:

— message overrules existing message,

— message is displayed after x seconds,

— messages are shown alternating,

— messages are shown simultaneously,

— message changes to auditory channel.

B.2 Examples (see Table B.1)

Examples are provided to illustrate how the system reaction matrix is used with the priority matrix method. Neither the priorities chosen in Table A.1 nor the possible system reactions in Table B.1 are recommended for future application.

EXAMPLE 1 The current message is the warning message “Fasten your safety belt”. The incoming message is the warning message “Minimal fuel level”. Regulation of priorities: the information concerning the fuel level is more important than the message concerning the safety belt and, therefore, replaces this message. In this cell the number “2” is entered.

EXAMPLE 2 The current message is the warning message “Malfunction oil pressure”. The incoming message is “Receipt of a SMS”. Regulation of priorities: the oil-pressure warning has a higher priority than the SMS-message. The SMS-message is not displayed. The number “1” is entered in the cell.

EXAMPLE 3 The current message is the message “Receipt of an SMS”. The incoming message is the message “Fasten your safety belt”. Regulation of priorities: the incoming message is displayed after a time-out of 20 s. The number “3” is entered in the cell.

EXAMPLE 4 The current message is the message “Minimum fuel level”. The incoming message is the message “Malfunction oil pressure”. It is assumed that both messages are brief, so they are displayed simultaneously. The number “0” is entered in the cell.

Table B.1 — Example system reaction matrix

Current message	Incoming message			
	Fasten your safety belt	**Minimum fuel level**	**Malfunction oil pressure**	**Receipt of an SMS**
Fasten your safety belt	X	2	2	3
Minimum fuel level	1	X	0	1
Malfunction oil pressure	1	0	X	1
Receipt of an SMS	3	1	2	X

0 messages can be relayed simultaneously
1 incoming message is not displayed
2 current message will be removed, incoming message will be displayed
3 incoming message will be displayed after a time-out of 20 s

Annex C
(informative)

Rationale for recommended number of evaluators for priority index method

C.1 Objective

A procedure is described for determining the number of evaluators, N, needed to keep the error below 5 % in falsely concluding that Message B has higher priority than Message A, when in reality the opposite is true.

C.2 Detailed explanation of the procedure

If the true variance, S, of the priority index is known, and if priority indexes for each of the messages are assumed to be normally distributed, then the distribution of the difference between any two priority indexes obtained by having N persons evaluate each message can be specified. This difference between the two priority indexes will have a normal distribution with a variance of $2\,S/N$ and a mean equal to the difference between the two means [2)].

C.2.1 Conduct pilot study

In order to determine N, a study was conducted to evaluate message priority for a variety of messages. Sixteen evaluators were asked to assign a rating for each of 22 messages. The evaluators assigned ratings in terms of criticality and urgency, and the means and variances of the priority indexes were computed for each message, using the method described in Clause 4. The evaluators also rated every pair of messages in terms of the level of importance. A judgement ratio, which is the percentage of evaluators who believed one message was more important than the other, was computed for every pair of message combinations.

See Figure C.1. The relationship between priority index difference (horizontal axis) and evaluators' judgement ratio, which indicates the ratio of evaluators who believe one message was more important than the other (vertical axis), was found for 462 pairs (22 × 21) of messages. Applying regression analysis to the data to fit a cubic expression, the following formula was obtained:

$$\text{Relative number of judgement} = 0{,}5 + 0{,}26 \times (\text{priority index difference}) - 0{,}01 \times (\text{priority index difference})^3 \qquad \text{(C.1)}$$

C.2.2 Calculate the number N

Assume that, in order to be confident, Message A truly is more important (i.e. has higher priority) than Message B, at least 70 % of a large number of evaluators should make that judgement in a pair-wise comparison of these two messages. That is, the probability that Message A has greater priority than Message B is 0,7. Call this probability P70.

---

2) Assuming that the priority index of Message A is a random variable which takes a normal distribution with mean x_1 and variance S_1/N, Message A's priority index derived by averaging the priority indices from N evaluators will have a normal distribution with mean x_1 and variance S_1/N. In the same way, Message B's average priority index obtained from N evaluators will have a normal distribution, with mean x_2 and variance S_2/N. The difference of the average values will also have a normal distribution, with mean $x_1 - x_2$ and variance $(S_1 + S_2)/N$ [standard deviation (SD) is $\sqrt{S_1 + S_2} / \sqrt{N}$]. If the variances are assumed to be homogeneous, i.e. S_1 and S_2 have the same value S for all messages, the difference of the average values will have a normal distribution, with mean $x_1 - x_2$ and variance $2S/N$ (SD is $\sqrt{2S/N}$). The assumption of a normal distribution is not necessary for this relationship.

When the priority index procedure is applied to these same two messages, the priority index of Message A, calculated by averaging the priority indexes obtained from N evaluators, should be greater than the priority index of Message B. The number of evaluators, N, needs to be large enough so that the probability of finding instead that Message B has a larger priority index than Message A is small (i.e. less that 0,05).

a) Step 1: Calculate P70

Use the results of the study to calculate the priority index difference between the two messages where 70 % of the evaluators judge that one message is more important than the other.

From Equation C.1, the priority index difference for a 70 % judgement ratio (P70) will be approximately 0,79.

b) Step 2: Calculate Variance S

Calculate the variance of the priority index for each message in accordance with 4.4. Then calculate the variance of priority indexes for all 22 messages, and average these variances to obtain the mean variance value of all the priority indexes. The mean variance for the 22 messages was 0,79.

c) Step 3: Calculate N

Find a sample size, N, so that the probability is less than 0,05 for concluding Message B has priority greater than Message A when the true priority order (P70) of two messages has a priority index difference of 0,79, with Message A having the greater priority index.

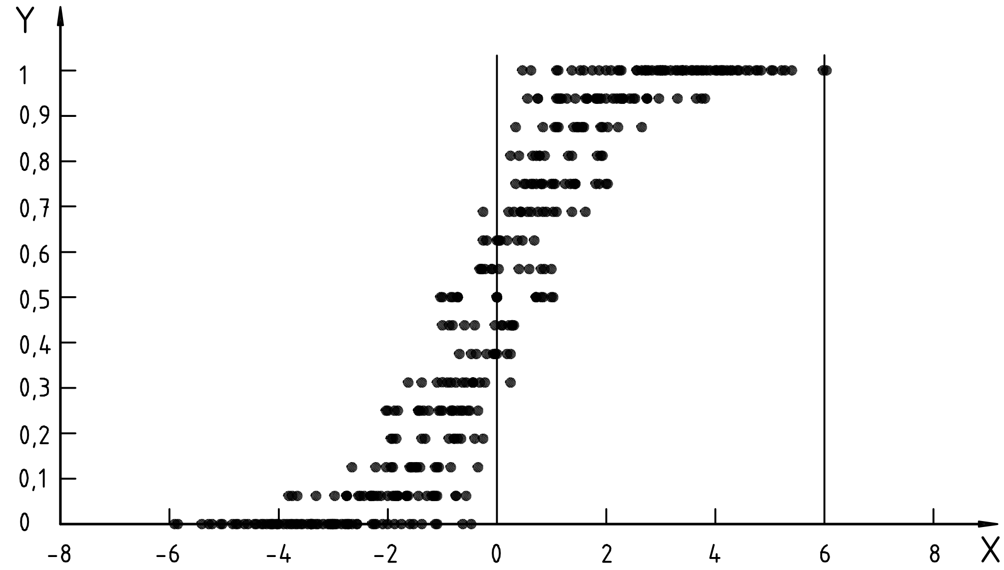
Assuming the true priority index difference between two messages follows a normal distribution, with mean 0,79 and variance $2S/N$ (= 1,58/N), calculate the number N such that the cumulative probability is less than 0,05 and the observed priority index difference is less than 0 (i.e. the observed difference between priority indexes is reversed from the true difference).

The condition that the probability of a negative difference is less than 0,05 is

$$0{,}79 \Big/ \left(\sqrt{1{,}58/N}\right) < 1{,}64$$

Solving this equation gives $N > 6{,}8$. This means that 7 or more evaluators are needed in order to keep the risk below 5 % of concluding the less important message has the higher priority.

In fact, it is probably best to have more than 7 evaluators, since the study described here only used 16 evaluators and 22 messages to estimate population mean and variance. For this reason, 10 or more evaluators are recommended.

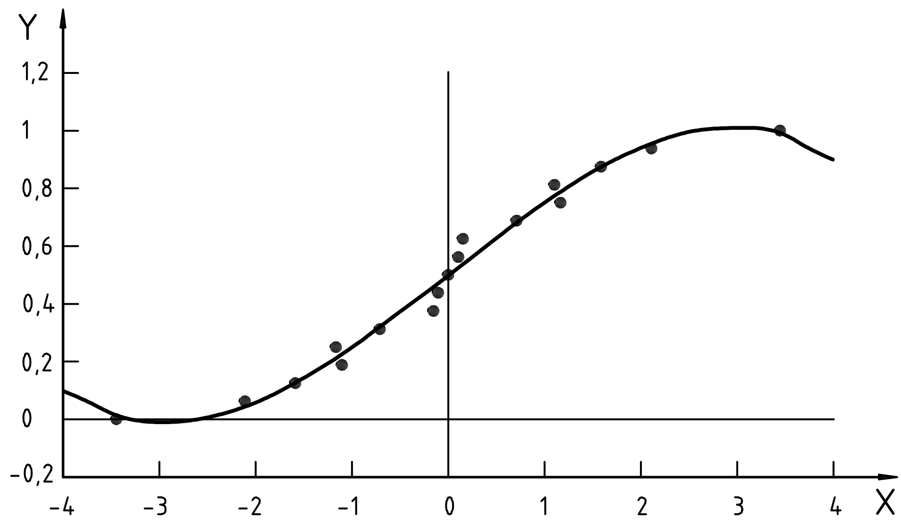


Key

X difference of priority index

Y relative number of judgement

Figure C.1 — Relationship between relative number of judgement and difference of priority index



Key

X mean of difference of priority index

Y relative number of judgement

Figure C.2 — Relationship between relative number of judgement and mean of difference of priority index

Annex D
(informative)

Example evaluator profile

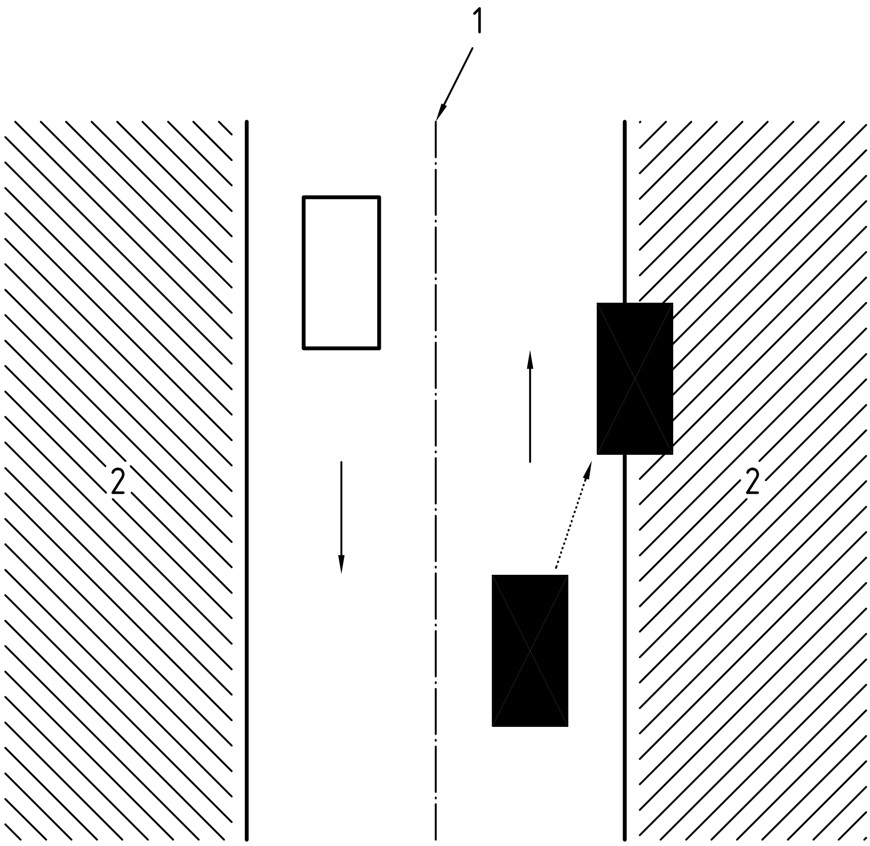
Evaluator	1	2	3	4
Name				
Date of birth	…/…/…	…/…/…	…/…/…	…/…/…
Gender				
Company/organization				
Expertise				
Systems worked on				
Experience				
Years of expertise				
Years in TICS				

Company/organization	Expertise	Systems worked on
University	System design (R&D)	In-vehicle message system
Public laboratory	Product design	ACC
Automotive industry	System evaluation	Navigation and RGS
OEM parts supplier	Human factors	FVCWS
Other manufacturer (pls. specify)	Traffic management	Display
Government organisation	Traffic safety	General
Other	Accident investigation	Other (pls. specify)
	Marketing	
	Other (pls. specify)	

Annex E
(informative)

Driving scenarios

TICS and Other Systems				TICS - Collision avoidance	TICS - Collision avoidance	TICS - Collision avoidance	Brake System	TICS - Lane Departure Warning	---	TICS - ACC
Information				Obstacle present	Pedestrian present	Approaching vehicle	Brake fluid	Crosswise position		Warning message
Contents of Message				Obstacle in road. Brake or steer now.	CAUTION Pedestrian walking.	Approaching vehicle. Brake immediately.	WARNING Low brake fluid level	Departing lane		Slow down: You have exceeded the ACC brake system capacity
Driving Context	Traffic Situation/ Vehicle Condition when the message is to be presented	Trip context		N-D	N-D	N-D	N-D	N-D		N-D
		Road environ-ment	Road	highway	urban road intersection	urban road	country road downhill slope	highway		highway
			Weather	Dry road	N-D	N-D	N-D	N-D		N-D
		Traffic situation		A vehicle stops about 100m ahead	Pedestrian is walking just behind and left of the lead vehicle	A vehicle is coming from a priority direction at intersection 30m ahead.	N-D	N-D		Headway distance is 1.2 sec. Lead vehicle is braking at 0.4G.
		Vehicle condition	Type	passenger vehicle	passenger vehicle	passenger vehicle	passenger vehicle	passenger vehicle		passenger vehicle
			State	100km/h	Turning left, 10km/h	Approaching stop sign for intersection at 50km/h without decelerating	60km/h	100km/h; one side of vehicle is on the shoulder of roadway (Figure E.1)		100km/h ACC is deactivated temporarily by driver's action
		Miscellaneous		N-D	N-D	N-D	N-D	N-D		N-D
	Expected driver behavior and / or cognition			To take evasive action immediately by braking or steering	To wait to turn left until the pedestrian evacuates to a place of safety	Be aware of a potential crash with vehicle. Emergency braking.	Reduce speed by shifting down or applying brake or handbrake. Park the vehicle in a safe place.	Steer vehicle back into your lane immediately		Know that ACC system cannot keep a sufficient safe distance. Take control (brake or change lane)
Rating	**Criticality**									
	Urgency									



Key

1 road centreline

2 shoulder

A picture is often helpful in describing the driving scenario to the evaluators — in this case, the lane departure scenario described in the table.

NOTE One side of the vehicle is on the shoulder of roadway; vehicle speed is 100 km/h.

Figure E.1 — Lane departure scenario

Annex F
(informative)

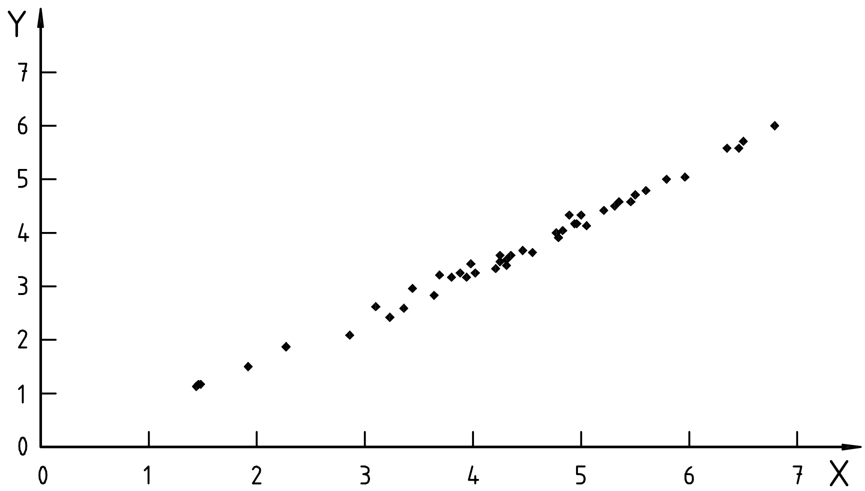
Criticality and urgency as the evaluation criteria

Reducing from three to two criteria for determining priority: Initially, three evaluation criteria were used for the priority index calculations:

- potential of damage (PD), the level of vehicle damage and/or bodily injury that may occur in an accident when the driver does not respond to the information/information messages;
- effectiveness (E), the usefulness level of the information/information messages for avoiding the accident;
- urgency (U), the time criticality of the information/information messages within which the driver must react.

Two groups — PD, E, U and PD, U — were created and compared for the study.

Figure F.1 shows the comparison of the priority indexes obtained from two evaluation criteria (PD, U) versus the priority indexes from three evaluation criteria.



Key

X three criteria (PD + E + U)

Y two criteria (PD + U)

Figure F.1 — Relationship between priority indexes derived from two evaluation criteria and from three evaluation criteria (correlation coefficient, $r = 0{,}995$)

The relationship shown in Figure F.1 indicates that the correlation coefficient is extremely close to 1,0. In addition, only a few pairs of messages with reversed priority orders were found and the differences between them were quite small.

In conclusion, PD was changed to criticality, effectiveness was deleted, and urgency remained as it was.

Thus, two evaluation criteria, criticality and urgency, were defined for calculation of the priority index.

Annex G
(informative)

Deriving weight k_c and k_u

Analyses to determine weights: The following is an example procedure that determines weights for k_c and k_u based on experimental data, instead of assuming them to be 1,0. The weights describe the relative importance of criticality and urgency via a linear equation. In this investigation evaluators subjectively ranked twenty-one messages from the highest to the lowest priority. This ranking procedure was performed separately from the evaluation procedure for rating criticality and urgency given in this Technical Specification.

A multiple regression analysis was performed using "rank" as an independent variable of the priority order (see C.2) and "criticality" and "urgency" as dependent variables. The resulting regression equation is:

$$R = -2{,}7 \times C - 3{,}0 \times U + 17{,}8$$

$$r^2 = 0{,}907$$

where

R is rank;

C is criticality;

U is urgency;

r is the correlation coefficient.

Since the ratio of the regression coefficients is 1,1 (= 3,0/2,7), the weights k_c and k_u could be made identical.

In order to confirm this result, the following five different candidate equations with simple weights for the priority index, P, were compared (see 4.3).

$$P = C + U$$

$$P = 1{,}5 \times C + U$$

$$P = 2{,}0 \times C + U$$

$$P = C + 1{,}5 \times U$$

$$P = C + 2{,}0 \times U$$

Spearman's rank correlation coefficient (ρ) can be used as a measure to compare the equations. The average values of the this coefficient obtained from the 16 evaluators were as follows:

$\rho = 0{,}927$ for $P = C + U$

$\rho = 0{,}920$ for $P = 1{,}5 \times C + U$

$\rho = 0{,}917$ for $P = 2{,}0 \times C + U$

$\rho = 0{,}923$ for $P = C + 1{,}5 \times U$

$\rho = 0{,}920$ for $P = C + 2{,}0 \times U$

The above result indicates that "priority index $=$ criticality $+$ urgency" is a simple and effective equation for describing the ranking of messages. Therefore, it is reasonable to use weights of $k_c = 1{,}0$ and $k_u = 1{,}0$ to obtain the priority index.

Annex H
(informative)

Sample report format

The following can be used to summarize preliminary study results of the message prioritization. Each row represents one message. The column containing the priority index P_j for each message was obtained using $k_c = k_u = 1{,}0$. The weights for k_c and k_u may be changed.

TICS and other systems			**Navigation and RGS**					
Information			*Action:* turn at intersection					
Contents of message			Start turning immediately					
Priority calculation	**Priority**	Priority index P_j	2,79					
		Standard deviation σ_j	0,79					
		Order	7					
	Criticality	Priority index C_j	0,74					
		Standard deviation $\sigma(c_{ij})$	0,66					
		Max. max. (c_{ij})	1,50					
		Min. min. (c_{ij})	0,00					
	Urgency	Priority index U_j	2,06					
		Standard deviation $\sigma(u_{ij})$	0,43					
		Max. max. (u_{ij})	3,00					
		Min. min. (u_{ij})	1,00					

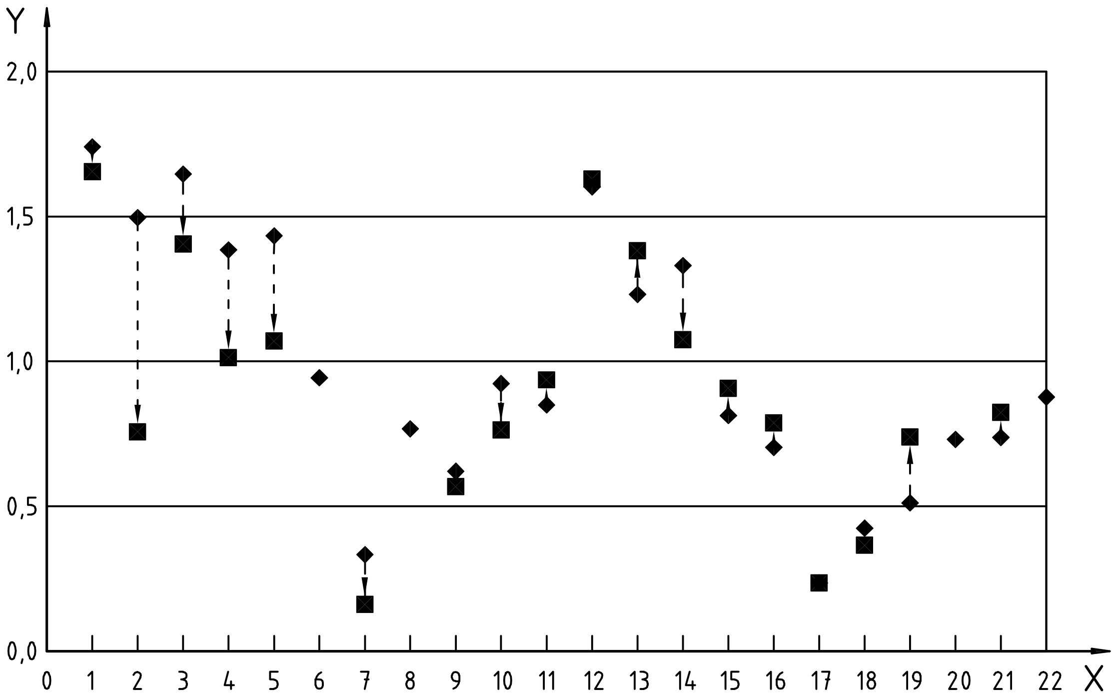
Annex I
(informative)

"Acceptable" standard deviations σ_j for priority indexes

Revision of message explanations: In the results of the preliminary study of September 1998 described in Annex C, some messages had larger standard deviations than others. For messages having large standard deviations, it was felt that the explanation given to the evaluators was insufficient. The standard deviations were divided into two classes: standard deviations that exceeded 1,0 and standard deviations that were less than 1,0.

For each message with a standard deviation larger than 1,0, the driving context and situation was revised and explained to evaluators. Then the prioritization procedure was re-performed. As a result, the standard deviations of 4 messages became approximately 1,0. (See Figure I.1, messages 2, 4, 5, and 14.)

Thus, when the message explanation was "improved", the standard deviations of the majority of messages were less than 1,0 (see Figures I.1 and I.2). This is why it is very important to clearly describe the driving context and situation for each message that is to be evaluated and prioritized.



Key

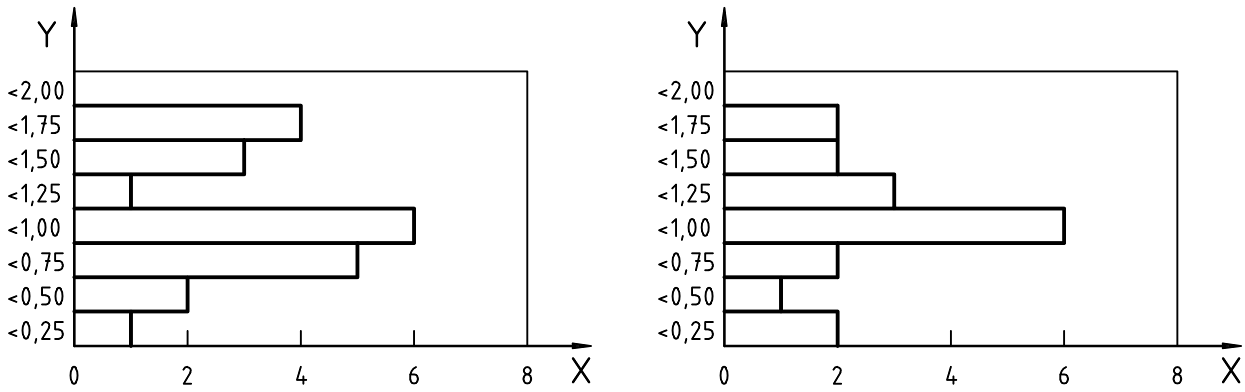
X message

Y standard deviation

◆ September 1998

■ November 1998

Figure I.1 — Standard deviations of priority index for each message before and after driving context revised (Messages 6, 8, 20, and 22 were not included in the second study)



a) **September 1998** b) **November 1998**

Key

X number of items

Y standard deviation

Figure I.2 — Distribution of standard deviation of priority indexes for all messages in each study

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