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PART III

Recommendations E.800 to E.880

QUALITY OF SERVICE; CONCEPTS, MODELS,

OBJECTIVES, DEPENDABILITY PLANNING

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SECTION 1

TERMS AND DEFINITIONS RELATED TO THE QUALITY OF TELECOMMUNICATION SERVICES

Recommendation E.800

QUALITY OF SERVICE AND DEPENDABILITY VOCABULARY

CONTENTS

1 Introduction

Formerly part of Recommendation G.106, *Red Book* , Fascicle III.1

Terms printed in italics in the text may be found with their related definitions in Supplement No. 6 or in Recommendation E.600.

A consistent set of terms and definitions is necessary for the development of Recommendations in the important areas of *quality of service* and *network performance* by the numerous Study Groups responsible for the Recommendations. Terminology standardization is also necessary to align the work of the various groups and to avoid confusing the users of Recommendations by the introduction of conflicting terms and definitions. Therefore, this Recommendation sets forth a simple set of terms and definitions relating to the concept of the quality of telecommunications services and *network performance* . These terms and definitions apply to all telecommunications services and all network arrangements used to provide the services.

The diagram in Figure 1/E.800 is intended to provide an overview of the factors which contribute collectively to the overall *quality of service* as perceived by the *user* of a telecommunication service. The terms in the diagram can be thought of as generally applying either to the quality of service levels actually achieved in practice, to objectives which represent *quality of service* goals to be achieved, or to requirements which reflect design specifications.

The diagram in Figure 1/E.800 is also structured to show that one quality of service factor can depend on a number of others. It is important to note — although it is not explicitly stated in each of the definitions to follow — that the value of a characteristic measure of a particular factor may depend directly on corresponding values of other factors which contribute to it. This necessitates, whenever the value of a measure is given, that all of the conditions having an impact on that value be clearly stated.

An essential aspect of the global evaluation of a service is the opinion of the users of the service. The result of this evaluation expresses the users' degrees of satisfaction. This Recommendation establishes:

1) a general framework for the *quality of service* concept

2) the relationship between *quality of service* and *network performance*

3) a set of measures for these performances.

It is obvious that a service can be used only if it is provided, and it is desirable that the provider have a detailed knowledge about the quality of the offered service. From the provider's viewpoint, *network*

performance is a concept by which network characteristics can be defined, measured and controlled to achieve a satisfactory level of service quality. The interests and the viewpoints of users and providers are different, and usually require a compromise between quality and economics.

In the utilization of a *service* the *user* identifies two <<bodies>>:

1) the ‘‘Organization(s)’’, i.e., the telecommunication Administration, operating company, etc. providing the means and facilities for the access to and the utilization of the *service* ;

2) the <<network>>, i.e., the necessary means (terminals , lines, switches, etc.) actually used.

The contribution of the Organization to the *quality of service* is characterized by one performance concept, *service support performance* , as shown in Figure 1/E.800.

The contribution of the network to the *quality of service* is characterized by three performance concepts, which are:

— *service operability performance* , i.e., the ease by which the *service* can be used, including the characteristics of terminal equipment, the intelligibility of tones and messages, etc.;

— *serveability performance* , the ability of a *service* to be obtained — within specified tolerances and other given conditions — when requested by the *user* and continue to be provided for the requested duration. Thus, *serveability performance* describes the response of the network during the establishment, retention and *release* of a service connection;

— *service integrity* , the degree to which a *service* is provided without excessive impairments, once obtained. Thus, *service integrity* is primarily concerned with the level of reproduction of the transmitted signal at the receiving end.

The *serveability performance* is further subdivided into two terms:

— *service accessibility performance* , the ability of a *service* to be obtained — within specified tolerances and other given conditions — when requested by the *user* , further subdivided into (1) *network accessibility* , which is the ability of the *user* to obtain access to the network for a service request, and (2) *connection accessibility* , which is the ability of the network to provide the *user* with a satisfactory connection to the intended *destination* ;

In some countries' terminals are not part of the network and are or may be customer-provided

— *service retainability performance* , which is the ability of the *service* , once obtained, to continue to be provided under given conditions for a requested period of time. That is, *service retainability performance* covers the proper retention of *connections* and the *release* (disengagement) when requested by the *user* .

Serveability performance is divided into *trafficability performance* , *dependability* and *propagation performance* as shown in Figure 1/E.800. The *trafficability performance* is described in purely teletraffic engineering terms (see Recommendation E.600). The *measures* are expressed in terms of losses and delay times. *Dependability* is the combined aspects of availability, reliability, maintainability and maintenance support

performances and relates to the ability of an *item* to be in a state to perform a *required function* (see Supplement No. 6). *Propagation performance* refers to the ability of the transmitting medium to transmit the signal within intended tolerances.

Figure 1/E.800

Measures for all of the above performances may be related to an instant of time (instantaneous, etc.) or expressed as a mean value over a time interval. These and other recommended qualifiers (measure modifiers) are found in Supplement No. 6.

Supplement No. 6 further provides recommended statistical terms and definitions for use in the application of measures related to all performances.

While dependability is used only for a general description in non-quantitative terms, the actual quantification is done under the heading of availability performance, reliability performance, maintainability performance and maintenance support performance.

The most important of these dependability-related measures are found in Supplement No. 6, Part I. The properties expressed by these measures impact the measures related to quality of service and network performance and are thus implicitly characterizations of these performances.

Measures are connected to events (failure, restoration, etc.), states (fault, up state, down state, outage, etc.) or activities (e.g. maintenance), with their time durations.

Part I of Supplement No. 6 provides necessary identification of times, events, states and maintenance activities.

2 Related Recommendations and Supplements

Recommendation E.600: Terms and definitions of traffic engineering

Supplement No. 6: Terms and definitions for quality of service, network performance, dependability and trafficability studies.

3 Performances

3.1 *Service related performances*

3101 **quality of service**

F: qualit´e de service

S: calidad de servicio

The collective effect of service performances which determine the degree of satisfaction of a *user* of the *service* .

Note 1 — The *quality of service* | s characterized by the combined aspects of *service support performance* , *service operability performance* , *serveability performance* , *service integrity* and other factors specific to each *service* .

Note 2 — The term ‘‘quality of service’’ is not used to express a degree of excellence in a comparative sense nor is it used in a quantitative sense for technical evaluations. In these cases a qualifying adjective (modifier) shall be used.

3102 **serveability performance**

F: servibilit´e (d’un service)

S: servibilidad (de un servicio)

The ability of a *service* | o be obtained — within specified

tolerances and other given conditions — when requested by the *user* and continue to be provided for a requested *duration* .

Note — *Serveability performance* | ay be subdivided into the *service accessibility performance* | nd the *service retainability performance* .

3103 **service accessibility performance**

F: accessibilit´e (d’un service)

S: accesibilidad (de un servicio)

The ability of a *service* | o be obtained, within specified tolerances and other given conditions, when requested by the *user* .

Note — This takes into account the transmission tolerance and the combined aspects of *propagation performance* , *trafficability performance* and *availability performance* of the related systems.

3104 **service retainability performance**

F: continuabilit´e (d’un service)

S: retenibilidad (de un servicio)

The ability of a *service* , once obtained, to continue to be provided under given conditions for a requested duration.

Note — Generally this depends on the transmission tolerances, the *propagation performance* and *reliability performance* of the related systems. For some services, for example packet switching, this also depends on the *trafficability performance* and the *availability performance* of the related systems.

3105 **service support performance**

F: logistique de service

S: log´istica del servicio

The ability of an organization to provide a *service* | nd assist in its utilization.

Note — An example of *service support performance* | s the ability to provide assistance in commissioning a basic service, or a supplementary service such as the call waiting service or directory enquiries service.

3106 **service operability performance**

F: facilit´e d'utilisation (d'un service)

S: facilidad de utilizaci´on (de un servicio)

The ability of a *service* | o be successfully and easily operated by a *user* .

3107 **service integrity**

F: integrit´e de service

S: integridad del servicio

The degree to which a *service* | s provided without excessive
| mpairments, once obtained.

Note — This *service* is characterized by the *transmission performance* | f the system.

3108 **transmission performance**

F: qualit´e de transmission

S: calidad de transmisi´on

The level of reproduction of a signal offered to a telecommunications system, under given conditions, when this system is in an *up state* .

3.2 *Item related performances*

3201 **network performance**

F: qualit´e technique du r´eseau

S: calidad de funcionamiento de la red

The ability of a network or network portion to provide the functions related to *communications* between *users* .

Note 1 — Network performance contributes to *serveability performance* and *service integrity* (see Figure 2/E.800).

Note 2 — Network performance measures are meaningful to network providers and are quantifiable at boundaries of network portions to which they apply. Quality of service measures are only quantifiable at a service access point.

Figure 2/E.800

3202 **trafficability performance**

F: traficabilit´e; capacit´e d'´ecoulement du trafic

S: aptitud para cursar tr´afico

The ability of an *item* | o meet a traffic demand of a given size and other characteristics, under given internal conditions.

Note — Given internal conditions refer, for example, to any combination of *faulty* and not *faulty* sub-items.

3203 **capability**

F: capacit´e; capabilit´e (d'une entit´e)

S: capacidad

The ability of an *item* | o meet a demand of a given size under given internal conditions.

Note 1 — Internal conditions refer, for example, to any given combination of *faulty* and not *faulty* sub-items.

Note 2 — This is also called *trafficability performance* .

3204 **propagation performance**

F: caract´eristiques de propagation

S: caracter´istica de propagaci´on

The ability of a propagation medium, in which a wave propagates without artificial guide, to transmit a signal within the given tolerances.

Note — The given tolerances may apply to variations in signal level, noise, interference levels, etc.

3205 **effectiveness (performance)**

F: efficacit´e

S: efectividad

The ability of an *item* | o meet a service demand of a given size.

Note — This ability depends on the combined aspects of the *capability* | nd the *availability performance* of the *item* .

4 Interruptions

4101 **interruption; break (of service)**

F: interruption; coupure (d'un service)

S: interrupci´on (de un servicio); corte (de un servicio)

Temporary inability of a *service* | o be provided persisting for more than a given *time duration* , characterized by a change beyond given limits in at least one parameter essential for the *service* .

Note 1 — An *interruption* | f a *service* | ay be caused by *disabled states* | f the *items* | sed for the *service* or by external reasons such as high service demand.

Note 2 — An *interruption* | f a *service* | s generally an *interruption* | f the transmission, which may be characterized by an abnormal value of power level, noise level, signal distortion, *error* rate, etc.

4102 **time between interruptions**

F: *temps entre interruptions*

S: *tiempo entre interrupciones*

The *time duration* | etween the end of one *interruption* | nd the beginning of the next.

4103 **interruption duration**

F: dur´ee d'interruption

S: duraci´on de interrupci´on

The *time duration* | f an *interruption* .

4104 **mean time between interruptions (MTBI)**

F: dur´ee moyenne entre interruptions (DMEI)

S: tiempo medio entre interrupciones

The *expectation* | f the *time between interruptions* .

4105 **mean interruption duration (MID)**

F: dur´ee moyenne d'une interruption (DMI)

S: duraci´on media de una interrupci´on

The *expectation* | f the *interruption duration* .

5 Measures of performances

5.1 *Service support performance*

5101 **mean service provisioning time**

F: d´elai moyen pour la fourniture d'un service

S: tiempo medio de espera (para la prestaci´on de un servicio)

The *expectation* | f the *duration* | etween the *instant of time* | potential *user* requests that an organization provides the necessary means for a *service* , and the *instant of time* when these means are furnished.

5102 **billing error probability**

F: probabilit´e d'erreur de facturation

S: probabilidad de error de facturaci´on

The *probability* | f an *error* | hen billing a *user* of a *service* .

5103 **incorrect charging or accounting probability**

F: probabilit´e de taxation erron´ee

S: *probabilidad de tarificación o de contabilidad incorrectas*

The *probability* | f a *call attempt* receiving incorrect charging or accounting treatment.

5104 **undercharging probability**

F: *probabilité de sous-taxation*

S: *probabilidad de subtarificación*

The *probability* | hat an effective *call* will be undercharged for any reason.

5105 **overcharging probability**

F: *probabilité de surtaxation*

S: *probabilidad de sobretarificación*

The *probability* | hat an effective *call* will be overcharged for any reason.

5106 **billing integrity** (probability)

F: (probabilit´e de) justesse de facturation

S: integridad de la facturaci´on (probabilidad de)

The *probability* | hat the billing information presented to a *user* correctly reflects the type, destination and duration of the *call* .

5.2 *Service operability performance*

5201 **service user mistake probability**

F: probabilit´e d'erreur d'un usager

S: probabilidad de error de un usuario (de un servicio)

Probability | f a *mistake* | ade by a *user* in his attempt to utilize a *service* .

5202 **dialling mistake probability**

F: probabilit´e d'erreur de num´erotation

S: probabilidad de error de marcaci´on

The *probability* | hat the *user* of a telecommunication network makes dialling *mistakes* during his *call attempts* .

5203 **service user abandonment probability**

F: probabilit´e d'abandon (d'acc`es à un service par un usager)

S: probabilidad de abandono de un servicio por un usuario

The *probability* | hat a *user* abandons the attempt to use a *service* .

Note — Abandonments may be caused by excessive *user* mistake rates, by excessive service access delays, etc.

5204 **call abandonment probability**

F: probabilit´e d'abandon (d'une tentative d'appel)

S: probabilidad de abandono de una tentativa de llamada

The *probability* | hat a *user* abandons the *call attempt* to a telecommunication network.

5.3 *Service accessibility performance*

5301 **service accessibility; service access probability**

F: accessibilit´e (d'un service)

S: accesibilidad de un servicio; probabilidad de acceso a un servicio

The *probability* | hat a *service* | an be obtained within specified tolerances and other given operating conditions when requested by the *user* .

5302 **mean service access delay**

F: dur´ee moyenne d'acc`es

S: retardo medio de acceso a un servicio; demora media de acceso a un servicio

The *expectation* | f the *time duration* | etween an initial *bid* by the *user* for the acquisition of a *service* and the *instant of time* the user has access to the *service* , the *service* being obtained within specified tolerances and other given operating conditions.

5303 **network accessibility**

F: accessibilit´e (d'un r´eseau)

S: accesibilidad (de una red)

The *probability* | hat the *user* of a *service* after a request receives the proceed-to-select signal within specified conditions.

Note — The proceed-to-select signal is that signal inviting the *user* to select the desired *destination* .

5304 **connection accessibility**

F: accessibilit´e

S: accesibilidad de una conexi´on

The *probability* | hat a *connection* can be established within specified tolerances and other given conditions following receipt by the exchange of a valid code.

5305 **mean access delay**

F: dur´ee moyenne d'acc`es

S: retardo medio de acceso; demora media de acceso

The *expectation* | f the *time duration* | etween the first *call attempt* made by a *user* of a telecommunication network to reach another *user* or a *service* and the *instant of time* the *user* reaches the wanted other *user* or *service* , within specified tolerances and under given operational conditions.

5306 **p-fractile access delay**

F: quantile-p de la dur´ee d'acc`es

S: cuantil-p del retardo de acceso; cuantil-p de la demora de acceso

The *p-fractile* | alue of the *duration* | etween the *first call attempt* made by a *user* of a telecommunication network to reach another *user* or a *service* and the *instant of time* the *user* reaches the wanted other *user* or *service* , within specified tolerances and under given operational conditions.

5307 **accessibility of a connection to be established**

F: accessibilit´e d'une communication à ´etablir

S: accesibilidad de una conexi´on por establecer

The *probability* | hat a switched *connection* can be established, within specified transmission tolerances, to the correct *destination* , within a given *time interval* , when requested by the *user*

Note 1 — For user-originated calls, it could express the *probability* | f a successful call establishment on the first attempt. For operator-handled calls, it could represent the *probability* of having a satisfactory *connection* established within a given *time duration* .

Note 2 — In general, the tolerances should correspond to a level of *transmission performance* which makes the connection unsatisfactory for *service* such that, for example, a substantial percentage of *users* would abandon the *connection* .

5308 **unacceptable transmission probability**

F: *probabilit´e d'une transmission inacceptable*

S: *probabilidad de transmisi´on inaceptable*

The *probability* | f a *connection* being established with an unacceptable speech path transmission quality.

5309 **no tone probability**

F: *probabilit´e de non tonalit´e*

S: *probabilidad de ausencia de tono*

The *probability* | f a *call attempt* encountering no tone following receipt of a valid code by the exchange.

5310 **misrouting probability**

F: probabilit´e d'acheminement errone

S: probabilidad de encaminamiento err´oneo

The *probability* | f a *call attempt* being misrouted following receipt by the exchange of a valid code.

5.4 *Service retainability performance*

5401 **service retainability**

F: continuabilit´e (d'un service)

S: retenibilidad (de un servicio)

The *probability* | hat a *service* , once obtained, will continue to be provided under given conditions for a given *time duration* .

5402 **connection retainability**

F: continuabilit´e (d'une cha | ne de connexion)

S: retenibilidad (de una conexi´on)

The *probability* | hat a *connection* , once obtained, will continue to be provided for a *communication* under given conditions for a given *time duration* .

5403 **retainability of an established connection**

F: continuabilit´e d'une communication ´etablie

S: retenibilidad de una conexi´on establecida

The *probability* | hat a switched *connection* , once established, will operate within specified transmission tolerances without *interruption* for a given *time interval* .

5404 **premature release probability; cut-off call probability**

F: probabilit´e de lib´eration pr´ematur´ee

S: probabilidad de liberaci´on prematura; probabilidad de corte de una llamada

The *probability* | hat an established *connection* will be released for a reason other than intentionally by any of the parties involved in the call.

5405 **release failure probability**

F: probabilit´e de non-lib´eration

S: *probabilidad de fallo de liberaci´on*

The *probability* | hat the required *release* of a *connection* will not take place.

5.5 *Serveability performance*

5501 **probability of successful service completion**

F: *probabilit´e d'ex´ecution correcte du service*

S: *probabilidad de prestaci´on satisfactoria de un servicio*

The *probability* | hat a *connection* can be established, under satisfactory operating conditions, and retained for a given *time interval* .

5.6 *Transmission performance*

5601 **bit error ratio (BER)**

F: taux d’erreur sur les bits (TEB)

S: tasa de errores en los bits; tasa de error en los bits (TEB)

The ratio of the number of bit errors to the total number of bits transmitted in a given *time interval* .

5602 **error free seconds (EFS)**

F: secondes sans erreur (SSE)

S: segundos sin error (SSE)

The ratio of the number of one-second intervals during which no bits are received in error to the total number of one-second intervals in the *time interval* .

Note 1 — The length of the *time interval* | eeds to be specified.

Note 2 — This ratio is usually expressed as a percentage.

6 Common concepts

The following concepts are used in the definitions of this Recommendation. Others used, such as probability, measure, up state, disabled state, time duration, user and connection may be found in Recommendation E.600 and in Supplement No. 6.

6001 **service**

F: service

S: servicio

A set of functions offered to a *user* by an organization.

6002 **item; entity**

F: entit´e; individu

S: elemento; entidad; ´item

Any part, device, subsystem, functional unit, equipment or system that can be individually considered.

Note 1 — An *item* | ay consist of hardware, software or both, and may also include people, e.g. operators in a telephone operator system.

Note 2 — In French, the term *entit´e* | eplaces the term *dispositif* | reviously used in this meaning, because the term *dispositif* is also the common equivalent for the English term ‘‘device’’.

Note 3 — In French, the term *individu* | s used mainly in statistics.

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ANNEX A
(to Recommendation E.800)

Alphabetical list of definitions contained in this Recommendation

2 col 5307 accessibility of a connection to be established

5102 billing error probability

5106 billing integrity (probability)

5601 bit error ratio

5204 call abandonment probability

3203 capability

5304 connection accessibility

4101 break (of service)

5402 connection retainability

5404 cut-off call probability

5202 dialling mistake probability

3205 effectiveness (performance)

6002 entity

5602 error free seconds (EFS)

5103 incorrect charging or accounting probability

4103 interruption duration

4101 interruption

6002 item

5305 mean access delay

4105 mean interruption duration

5302 mean service access delay

5101 mean service provisioning time

4104 mean time between interruptions

5310 misrouting probability

5303 network accessibility

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SECTION 2

MODELS FOR TELECOMMUNICATION SERVICES

Recommendation E.810

MODEL FOR THE SERVEABILITY PERFORMANCE ON A BASIC CALL IN THE TELEPHONE NETWORK

Introduction

This Recommendation is one of a set of closely related Recommendations concerned with the accessibility and retainability of telephone services, as listed below.

The CCITT,

considering

(a) that there is a desire to establish overall objectives for the quality of service as perceived by the users;

(b) that such objectives can then be used as a basis for the design, planning, operation and maintenance of telecommunication networks and their component parts;

(c) that Recommendation E.800 contains terms and definitions for the quality of service, the reliability and availability performances and related characteristics of services and networks,

recommends

that the telephone call model given in this Recommendation shall be used by Administrations to design, plan, operate and maintain their networks taking into account the objectives given in Recommendations:

E.830 Models for the allocation of international telephone connection retainability, accessibility and integrity;

E.845 Connection accessibility objective for the international telephone service;

E.850 Connection retainability objective for the international telephone service.

Note — Refer also to the draft Recommendation on interruption objectives which is being studied under Question 39/II.

Although this Recommendation deals with the telephone service, in principle the model and the decomposition of serveability performance can also be applied to other telecommunication services. The elaboration of this principle is left for further study.

Some of the terms in this Recommendation, for example the noun ‘‘measure’’, are used in the sense of their definition given in Recommendation E.800.

1 Model of a basic telephone call and its serveability performance

The following simplified model illustrates the principal phases of a basic telephone call service-related performance concepts and their principal measures as well as to the main causes of failure in the establishment and retention of such a call and its subsequent billing.

The model also indicates where, in this series of phases, user actions or mistakes may influence the call.

2 Comments to the model and its applications

2.1 *Mathematical modelling*

In a simple case of statistical independence, the probabilities may be combined into the following mathematical models:

$$P = (P_{1\backslash d1} \times P_{1\backslash d2}) \times P_2 \times (P_{3\backslash d1} \times P_{3\backslash d2}) \times P_4$$

to express the probability of a correctly billed revenue-making call and,

$$P = (P_{1\backslash d1} \times P_{1\backslash d2}) \times P_2 \times (P_{3\backslash d1} \times P_{3\backslash d2})$$

to express the probability of a successfully completed call.

2.2 *Contributions to causes of call failure*

It is generally recognized that the various parts of a national or international network may be of different importance to the successful completion of the various phases of a call. For example, the network accessibility is mainly determined by the telephone set, the subscriber line and the local exchange; the connection accessibility by the exchanges, transmission network and signalling network used; the billing integrity is dependent on the charging facilities used by the network parts that constitute the connection and the equipment for processing the billing information, etc. In some Administrations, the telephone set is not considered as a part of the network and in that case it is not included in the concept of network performance.

2.3 *Time aspects of measures*

Depending on the intended application of the measures indicated in Figure 1/E.810, it may be appropriate to express these measures as instantaneous values related to a given instant of time or as a mean over a given time interval.

Advice on which variant to use should be given in each specific relevant Recommendation.

2.4 *Space aspects of averages*

The measures as indicated in Figure 1/E.810 could be applied to calls between particular destinations as traffic weighted averages over a number of destinations, etc.

Each relevant Recommendation should clearly specify which alternative(s) to use.

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FIGURE 1/E.810, p.

Recommendation E.830

MODELS FOR THE ALLOCATION OF INTERNATIONAL TELEPHONE CONNECTION RETAINABILITY, ACCESSIBILITY AND INTEGRITY

Introduction

This Recommendation is one of a set of closely related Recommendations, comprising Recommendations E.810, E.830, E.845, E.850 and E.855 concerned with the accessibility, retainability and integrity of telephone services.

The CCITT,

considering

that there is a need to establish hypothetical reference connection models to allocate overall connection retainability, accessibility and integrity objectives to the component parts of international connections,

recommends

three models for retainability (one of which is for a typical, or average, international connection), and one model for accessibility and integrity.

1 Retainability models

The models are shown respectively, in Figures 1/E.830, 2/E.830 and 3/E.830. As indicated by Fig ure 1/E.830, the typical connection has two circuits in each of the national systems, and one in the international chain. In the 90th percentile case, there would be three in the national systems and one in the international chain.

2 Number of circuits

The number of circuits in each of the models is based on Table 1/E.830. The entries of this table are based on the information contained in Table 1/G.101.

The mean and model number of national extension circuits are both equal to 2. This applies to both originating and terminating national systems. The mean number of international circuits is 2.1 and the model number is 2.

H.T. [T1.830]

TABLE 1/E.830

Probabilities of the number of circuits in the two national

systems and the international chain (expressed as percentages)

Number of circuits	Originating LE-ISC	International ISC-ISC	Terminating ISC-LE‘
1	33.8	95.1	32.9
2	38.9	4.5	39.5
3	20.2	0.3	20.4
4	6.0	—	6.1
5	1.0	—	1.0

LE Local exchange

ISC International switching centre

Note — The possibilities of 6 and 7 circuits in the originating national system are 0.005% and 0.0005% respectively. The probabilities of 4, 5 and 6 international circuits are 0.03%, 0.00007% and 0.00009% respectively.

Table 1/E.830 [T1.830], p.

Figure 1/E.830, p.

Figure 2/E.830, p.

Figure 3/E.830, p.

3 Accessibility and integrity model

The model to be used for allocation of the connection accessibility and integrity objectives found in Recommendations E.845 and E.855 respectively to the national portions and international chains of international connections is shown in Figure 4/E.830.

FIGURE 4/E.830, p.8

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SECTION 3

OBJECTIVES FOR QUALITY OF SERVICE AND RELATED CONCEPT

OF TELECOMMUNICATION SERVICES

Recommendation E.845

CONNECTION ACCESSIBILITY OBJECTIVE FOR THE

INTERNATIONAL TELEPHONE SERVICE

Introduction

This Recommendation is one of a set of closely related Recommendations, comprising Recommendations E.810, E.830, E.845, E.850 and E.855 concerned with the accessibility, retainability and integrity of telephone services.

Preamble

This Recommendation provides an overall end-to-end connection accessibility (availability) objective for *international* switched telephone service.

Connection accessibility is a component of service accessibility as defined in Recommendation E.800.

This Recommendation contains a measure of connection accessibility, an objective, and an allocation of the objective to the national systems and international chain of international connections. The Recommendation also relates the overall end-to-end performance to the reliability and availability of circuits and exchanges in a way useful for network design purposes.

The objective includes the effects of equipment faults and traffic congestion.

The CCITT,

considering

(a) that connection accessibility is defined in Recommendation E.800;

(b) that customers rank connection inaccessibility as one of the most annoying of call set-up impairments;

(c) that an objective for connection accessibility which takes into account customer opinion about the call set-up phase is consistent

with other Recommendations which have recommended an objective for service retainability based, in part, on customer opinion;

Formerly G.180, in *Red Book* , Fascicle III.1.
Some of the terms in this Recommendation, for example, the noun ‘‘measure’’, are used in the sense of their definition given in Recommendation E.800.

(d) that connection accessibility will not be constant over time, even for a particular calling and called line pair. One suitable measure is a long-term average network connection failure probability. (Other suitable measures may also be required.);

(e) that the overall objective for connection accessibility should be allocable to the national systems and the international chain of the international connection;

(f) that the objective should take into account the concerns of network planners and system designers, provide useful guidance to both and may be used by Administrations in providing a method for verifying whether or not network performance is acceptable;

(g) that the overall connection accessibility should be controlled by the accessibility performances of individual exchanges and circuits, and that to obtain this control, the overall connection accessibility must be mathematically linked to the equipment availability and reliability,

recommends

1 Measure of connection accessibility

Connection accessibility shall be measured using the long-term average network connection failure probability , which is the complement of the connection access probability as defined in Recommendation E.800.

The network connection failure probability P_{NCF} can be estimated by using the following formula:

$$P_{NCF} = \frac{Q_N}{N}$$

where Q_N is the number of unsuccessful connection access attempts and N is the total number of connection access attempts in some time period (to be determined).

A method for estimating the required call sample size is contained in Annex A.

For purposes of network design, the network connection failure probability, P_{NCF}, can also be calculated using the method outlined in Annex B. Annex C describes how the busy and non-busy hours affect the network connection failure (NCF).

Note 1 — Those unsuccessful connection access attempts reflecting failure of the *network* to work properly, from the user's perspective, are called network connection failure caller can determine and are caused by network faults and congestion. A network connection failure is any valid bid for service which receives one of the following network responses:

1) dial tone returned after dialling is completed;

2) no ring and no answer;

3) all circuits busy signal or announcement;

4) connection to the wrong number (misrouting);

5) double connection.

This list may not be exhaustive.

Note 2 — This definition of network connection failure is based on the response the caller can hear.

Note 3 — There are two generic causes of network connection failures: equipment faults and traffic congestion.

Note 4 — The averaging interval (to be determined) used for estimating the connection failure probability shall include normal and peak hour traffic periods. In the event of exceptionally high traffic demand (public holiday, natural disaster, etc.) failure rates higher than the objective may be tolerated.

Note 5 — The network connection failure probability should be estimated by Administrations in a manner consistent with obtaining, from the Administration's point of view, reasonably accurate estimates.

2 Objective for connection accessibility

Connection accessibility is acceptable if the long-term average connection failure probability, expressed as a percentage, does not exceed a value (overall average for all international calls) of *A* % to *B* % (values to be determined). Additionally, the long-term average failure probability at any single international homing exchange should never exceed *C* % (value to be determined).

Note — Possible values for *A* , *B* and *C* are in the range of 10% to 20%.

3 Allocation of the overall objective to the national systems and international chain

The network connection failure probability objective shall be apportioned as follows:

X % to the originating national system,

Y % to the international chain,

Z % to the terminating national system,

where $X + Y + Z = P$, and *P* is the overall objective stated in § 2.

Note 1 — The connection access attempt may fail in the national systems or the international chain of the connection.

Note 2 — The objective takes into account all means of ‘‘defense’’ of the network against failure to complete the connection, including alternate routing, if used.

Note 3 — The network connection failure probability of the national systems or international chain is defined as the probability that the call access attempt will fail because of some problem (equipment fault or congestion) in the systems or chain.

Note 4 — Values for *X* , *Y* and *Z* are in the range of 3% to 7%.

ANNEX A

(to Recommendation E.845)

Method for selecting the required call sample size, N

The network connection failure probability shall be estimated by Administrations in a manner consistent with obtaining reasonably accurate estimates.

The number of call access attempts sampled shall be sufficiently large to obtain a good estimate of the probability.

A method of picking a sample size *N* could be used which could produce a maximum error of measurement, *e* , (to be determined) with confidence level, α (to be determined).

Recommendation E.850 contains a method for estimating the sample size required to estimate cutoff call probability. This method should be studied for application here.

ANNEX B

(to Recommendation E.845)

Method for relating overall network connection failure

probability to the reliability and availability performance of exchanges and circuits

The following equation gives the relationship between the overall network connection failure probability, $P_{N\backslash dC\backslash dF}$, and the probabilities of connection failure in the national systems and international chain of the connection:

$$P_{N\backslash dC\backslash dF} = 1 — (1 — P_{O\backslash dE})(1$$

$$— P_I)(1 — P_{T\backslash dE})$$

where $P_{O\backslash dE}$ is the probability that the access attempt fails in the originating national system, P_I is the probability of failure in the international chain and $P_{T\backslash dE}$ is the probability of failure in the terminating national system.

Hypothetical reference connections for the three parts of an international connection are shown in Figure B-1/E.845. The proportion of calls (F_n) which are routed over the parts are also given in the figure. The values are taken from Table 1/G.101.

The probability that a connection access attempt fails in either of the parts is given by the following equations:

P
QE = 1 —
[Formula Deleted]
(1 n— *P*
c)
n (1 — *P*
s)
n

P
I = 1 —
[Formula Deleted]
F
n (1 — *P* $$Ei: ‘:*c* _
)
n (1 —
P $$Ei: ‘:*s* _
)
n +1

P
TE = 1 —
[Formula Deleted]
F
n (1 — *P* $$Ei:":*c* _
)
n (1 —
P $$Ei:":*s* _
)
n

where *n* | is the number of circuits in a selected part. F_n is the call frequency for an *n* -circuit system or chain (from Figure B-1/E.845).

Figure B-1/E.845, p.

P_c, P'_c and P''_c are the probabilities that the connection access fails in the originating system, international chain or terminating system circuits, respectively. (It is assumed here for simplicity that all circuits in a system or chain have the same probability of failure. However, this is not a requirement.)

P_s, P'_s and P''_s are the probabilities that the connection access attempt fails in the originating system, international chain (note that ISC is assumed part of the international chain) or terminating system exchanges, respectively. (For simplicity, all exchanges are assumed to have the same failure probability, but this is not a requirement.)

A circuit or exchange can cause a network connection failure for one of three reasons:

1) The call is blocked because of congestion. The probability of blockage is $P_{C\backslash dB}$ and $P_{S\backslash dB}$ for circuits and exchanges, respectively.

2) The circuit or exchange fails during the call set-up time. The probability of such a failure is $P_{C\backslash dF}$ and $P_{S\backslash dF}$ for circuits and exchanges, respectively.

3) The circuit or exchange is unavailable to arriving calls, so all calls arriving during the downtime fail to be completed. These probabilities are $P_{C\backslash dD}$ and $P_{S\backslash dD}$ for circuits and exchanges, respectively.

The probability that a circuit or exchange causes a network connection failure is given by the following equations, respectively:

$$P_C = 1 - (1 - P_{C\backslash dB})(1 - P_{C\backslash dF})(1 - P_{C\backslash dD})$$

$$P_S = 1 - (1 - P_{S\backslash dB})(1 - P_{S\backslash dF})(1 - P_{S\backslash dD})$$

The failure probabilities $P_{C\backslash dF}$ and $P_{S\backslash dF}$ can be expressed in terms of the long-term mean failure intensities Z_c and Z_s of circuits and exchanges, respectively, by the following equations:

$$P_{C\backslash dF} = Z_c T_s$$

$$P_{S\backslash dF} = Z_s T_s,$$

where T_s is the long-term average call set-up time.

Similarly, the failure probabilities $P_{C\backslash dD}$ and $P_{S\backslash dD}$ can be expressed in terms of the long-term mean accumulated downtime $(MADT)_c$ and $(MADT)_s$ of circuits and exchanges, respectively, by the following equations:

$$P_{CD} = \frac{(MADT)_c \times \alpha_c}{N}$$

$$P_{SD} = \frac{(MADT)_s \times \alpha_s}{N}$$

α_c and α_s are the long-term average call arrival rates for circuits and exchanges, respectively, and N is the long-term average number of call attempts (in some interval, such as one year).

K is a constant equal to the number of units of time (minutes or seconds) used to express the downtime in the long-term averaging interval selected (such as a year).

For example, if the downtime is expressed in minutes and the averaging interval is one year, then K = 525 600 min./year.

ANNEX C

(to Recommendation E.845)

Effects of busy hours and non-busy hours on the network connection failure

The two major components of network connection failure (NCF) are the blocking rate due to congestion and connection access attempt failures due to equipment faults. Equipment faults are further divided into major and minor faults. These components affect NCF differently.

C.1 *Influences of faults*

Faults of subsystems in a telephone network may be divided into two categories, according to their influence on network performance. Table C-1/E.845 shows two fault categories: major and minor.

H.T. [T1.845]

TABLE C-1/E.845

Failure category	Definition	Network components
Subscriber line	subscriber terminal | ub)	exchange

a) Intermittent fault is excluded and its treatment is an unresolved problem.

b) In some Administrations the subscriber terminal is not considered a network component.

Table C-1/E.845 [T1.845], p.

C.2 *Relationship between NCF, congestion and fault*

Congestion-related NCF depends on the traffic offered to a system being considered (a switching system, a network, etc.).

The effects of a minor fault will be considered as so-called white noise where the absolute value is small and fluctuates at random.

The effects of a major (complete) fault depend on the offered traffic volume at the time of fault. If a major fault occurred during busy hours, there would be an extremely high value for NCF. Conversely, a major fault during non-busy hours will merely yield a small NCF, no matter how large the affected system is. This is because the traffic load itself is small. Since it is usually expected that major faults will be very rare, NCF characteristics under major fault conditions are different from those under minor fault conditions which may be daily occurrences.

C.3 *Long-term NCF (averaged throughout a year)*

The long-term NCF concerned with traffic congestion during non-busy hours will be much smaller than that during busy hours. Since both cumulative call failures N_f and total calls offered N_o during non-busy hours are much smaller than those during busy hours, the averaged 24-hour NCF including non-busy and busy hours effects will not be much different from the busy hour NCF.

A major fault can be identified but a minor fault cannot be specified correctly when network operators maintain network equipment. By measuring long-term NCF during non-busy hours, the effect of minor faults can be estimated because NCF during non-busy hours is attributed not to traffic congestion but to minor faults.

C.4 *NCF and busy hour pattern*

In a country (international region) with several standard time zones, there will be several busy hours. In such cases, a connection in the network may include busy and non-busy network components. Thus, an averaged 24-hour NCF would be helpful to administer a network with different time zones.

However, the averaged 24-hour NCF does not seem to be appropriate to administer a network having only one standard time zone because its fault-related term is too small to affect the total NCF, and it might be too late by the time an extraordinary NCF value has been detected. The NCF averaged during non-busy hours would be one measure for monitoring the effect of equipment faults (minor faults) on subscribers, since this will become a major factor during non-busy hours.

Recommendation E.850

CONNECTION RETAINABILITY OBJECTIVE FOR THE INTERNATIONAL TELEPHONE SERVICE

Introduction

This Recommendation is one of a set of Recommendations, comprising Recommendations E.810, E.830, E.845, E.850 and E.855 concerned with the accessibility, retainability and integrity of telephone services.

The CCITT,

considering

(a) that ‘‘premature release’’ is defined in Recommendation E.800 as the event that an established connection will be released for a reason other than intentionally by any of the parties involved in the call;

(b) that premature release is a measure of connection retainability;

(c) that a prematurely released connection is considered high in annoyance as perceived by telephone users;

(d) that the probability of a premature release is a function of network component failure intensity and call holding time;

(e) that the objective should take account of the expectations and tolerances of users to the premature release impairment as well as the capabilities of current technology;

(f) that the objective might not be met at the present time but should be viewed as a long-term goal;

(g) that the objective should take into account the concerns of network planners and system designers, provide useful guidance to each, and it can be used by Administrations in a consistent way to measure connection retainability performance;

(h) that connection retainability is defined in Recommendation E.800,

recommends

1 Definitions

A **prematurely released telephone connection** is known as a cutoff call when the connection is completely broken, or

Formerly G.181, in *Red Book* , Fascicle III.1.

Some of the terms in this Recommendation, for example, the noun ‘‘measure’’, are used in the sense of their definition given in Recommendation E.800.

1) when a single interruption occurs lasting for longer than ten seconds which causes the transmission quality of the connection to be unsuitable for voice communications;

2) when a succession of interruptions occur lasting less than ten seconds where the product of the average duration of each interruption and the frequency of occurrence (i.e., average number of interruptions/seconds) exceeds 0.005.

2 A measure to quantify telephone connection retainability performance

The measure to be used shall be the complement of connection retainability, namely the probability of a prematurely released telephone connection when normalized to a call holding time of one minute (P_r). The estimator of the premature release probability is the premature release call ratio ($P_{r\backslash de}$) which is defined as:

$$P_{r\backslash de} = 1 - \left(\frac{R_N}{N} \right)^{1/T}$$

where N is the number of telephone calls successfully established in some period of time, T is the mean call holding time in minutes and R_N is the number of telephone calls successfully completed out of such N calls (see Annex A and Annex B).

3 Overall objective for premature release probability

The provisional objective for the normalized premature release probability (P_r) shall be such that the performance is better than the values given below:

for typical international connections:

$$2 \times 10^{-4} \le P_r \le 4 \times 10^{-4},$$

for 90th percentile international connections:

$$4 \times 10^{-4} \le P'_r \le 8 \times 10^{-4}$$

for worst case international connections:

$$8 \times 10^{-4} \le P''_r \le 1.6 \times 10^{-3}.$$

Note 1 — It is intended to establish a single value for P_r, P'_r or P''_r in the future.

Note 2 — The typical 90th percentile and worst case connections mentioned above shall be assumed to be those hypothetical reference connections (HRXs) given in Recommendation E.830.

Note 3 — See Annex B.

4 Allocation of the overall objective

It is desirable, for planning purposes, to allocate the overall objective for a typical connection to the national systems and the international chain of the HRX. The overall objective is given by:

$$P_r = P$$

$$_{rn1} + P_{rn2} + P_{ri}$$

where P_{rn1} and P_{rn2} are the premature release probabilities for originating and terminating national systems respectively and P_{ri} is the premature release probability of the international chain. The allocation of the overall objective to national systems and international chain shall be as follows:

$$P_{rn1} = P_{rn2} = \alpha P_{ri} .$$

Note 1 — α is provisionally recommended as being equal to 2. Thus, for example, if:

$$P_r = 3 \times 10^{-4}$$

then

$$P_{r\,n=1} = P_{r\,n=2} = 1.2 \times 10^{-4}$$

and

$$P_{rl} = 0.6 \times 10^{-4}.$$

Note 2 — Further allocation of the overall objective to the circuits and exchanges used in a connection might also be desirable.

Note 3 — Objectives for the permissible probability of premature release of an established telephone connection in Integrated Digital Networks (IDNs) and mixed (analogue/digital) networks, due to transit digital or local and combined local/transit exchange malfunctions, are specified in the Recommendations Q.504 or Q.514.

ANNEX A

(to Recommendation E.850)

Relationship between the premature release probability and its estimator

The following relationship exists between the premature release probability normalized to a 1-minute holding time (P_r) and its estimator P_{re}:

$$\lim_{N \to \infty} P_{re} = \lim_{N \to \infty} \left\{ 2 \left(1 - \frac{R}{N}\right) \ldots \frac{R}{N} \ldots \frac{1}{T} \ldots \right\} = P_r, \text{ if such limit exists.}$$

On the other hand, for the purpose of network design, the probability of a premature release with a mean call holding time of T minutes, $P(Z, T)$, can be expressed using the formula:

$$P(Z, T) = \frac{Z}{Z + T} \ldots$$

where

$$Z = \sum_{i=1}^{\text{f IL}} Z_i$$

and Z_i | is the average number of failures per minute of an i | omponent in the hypothetical connection between two users as shown in Figure A-1/E.850. The connection holding time and the time between failures for the individual components are assumed to be exponentially distributed.

Figure A-1/E.850, p.

In practice, $Z << T$ DlF261[1] and therefore P_r can be approximated as follows:

$P_r = P (Z , T)$

$T \equiv 1$

$$\frac{\text{f IZ}}{f IZ + 1} = \frac{\text{f IP} (Z , T)}{f IT} .$$

Also, the following relationship exists:

BOCIJ 1.LA 90 lim

$$\lim_{N \to \infty} \left(1 — \frac{\text{f IR}}{f IN} \right) = P (Z , T).$$

ANNEX B

(to Recommendation E.850)

A method to estimate the premature release probability

for an international telephone connection

In this annex, a method is described which can be used to estimate the premature release probability for an international telephone connection.

The method is based on placing end-to-end test calls, whose mean holding time is T | n minutes, and observing those which are prematurely released due either to transmission or switching failures, or transmission interruptions lasting longer than ten seconds.

From the results of Annex A, it follows that the simple estimator of P_r | is:

$P_{r \backslash de} =$

$$2o1 —

$$\frac{\text{f IR}}{f IN}$$

$$1uT $$1e.

If it can be reasonably assumed that the occurrence or non-occurrence of a premature release for each of the test calls constitutes independent events, then the binomial sampling theory can be used to derive confidence intervals for P_r, and to determine minimum sample sizes (N).

In particular, it would be required that N | be chosen such that:

$P_r \{ | | R_N / N) — P$ | $e P$

/100 } ≥" a /100

where e | s the estimation error in percent, and a | is the confidence level in percent. Writing $P = P_r \times T$, it follows from the central limit theorem that, for large N ,

$$\frac{eNP)}{00} \Big/ \left[NP(1 - P) \right]^{1/2} \geq Z_a \quad \text{(B-1)}$$

where Z_a | is the root of the equation:

$$(2/\pi)^{1/2} \int_0^{Z_a} \exp(-1/2\, y^2)\, dy = a/100.$$

Neglecting terms of order P^2, the inequality (B-1) becomes:

$$N \geq" (100\, Z_a / e\,)^2 / P$$

(B-2)

In this last formula, P | is generally not known. As an example, however, if we have to verify that P | s in conformity with the overall objectives of typical connections (see § 3), such that P is in the order of 3×10^{D}lF261^{4}, then a choice of a = 90% and e = 40% would lead to N ≥" 56 | 20.

Similar calculations based on varying assumptions are reproduced in Figure B-1/E.850.

Based on these results, it is proposed that for an average holding time of T = 1 min, N = 60 | 00. For other values of T (in minutes), N = 60 | 00/T .

Figure B-1/E.850, p.

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TORTORELLA (M.): The Bell System Technical Journal, *Cutoff calls and telephone equipment reliability* , Vol. 60, No. 8, pp. 1861-1890, October 1981.

Recommendation E.855

CONNECTION INTEGRITY OBJECTIVE FOR INTERNATIONAL TELEPHONE SERVICE

Introduction

This Recommendation is one of a set of closely related Recommendations comprising Recommendations E.810, E.830, E.845, E.850 and E.855 concerned with the accessibility, retainability and integrity of telecommunication services, specially telephone services.

The CCITT,

considering

(a) that users of the telephone service can perceive the speech loss due to transmission interruptions with durations shorter than 10 seconds;

Note — Transmission interruptions with durations longer than or equal to 10 seconds in a conversation phase are not tolerable by telephone users (Annex A). Such transmission interruptions are considered as a premature release of the connection as defined in Recommendation E.850.

(b) that speech loss causing transmission interruptions are caused by a change beyond given limits for a given period of time in one or more parameters, e.g. power level, noise level, signal-to-noise ratio, bit error ratio, etc.;

(c) that the objective should take into account the expectations of the users for quality of voice communications as well as the capabilities of current technologies;

(d) that the objective should take into account the concerns of network planners and system planners, provide useful guidance to each and that it can be used by Administrations in a consistent way to measure transmission interruptions;

(e) that the objective should be in conformity with other Recommendations;

(f) the definition of *interruption* as given in Recommendation E.800,

recommends

1 Definitions

1.1 **connection integrity for telephone service**

The degree to which an established telephone connection is offered without excessive transmission interruptions.

1.2 mean time between interruptions (MTBI)

The expectation of the time between interruptions.

The time between interruptions is the time duration between the end of one interruption and the beginning of the next.

1.3 mean interruption duration (MID)

The expectation of interruption duration.

1.4 transmission interruption

Temporary inability of the user-to-user transmission path to be provided persisting for less than 10 seconds (maximum duration) and more than another given time duration (or minimum duration) characterized by a reduction below a certain threshold in received signal power level. The minimum duration of transmission interruption and the minimum power threshold are for further study. Transmission interruptions caused by changes beyond certain thresholds of other parameters essential to connection integrity e.g. noise level, signal-to-distortion ratio, are for further study.

2 A measure to quantify telephone connection integrity performance

The measure to be used shall be the complement of connection integrity, namely the probability of speech loss, P_i, which is tolerable to telephone users due to transmission interruptions with durations shorter than 10 s. The estimator of the speech loss probability, $P_{i\backslash de}$, is the ratio of accumulated transmission interruption duration to the total observation period of time.

$$P_{i\backslash de} = \sum_{i=1}^{N} TD_i/T$$

where T | s the observation time and TD_i is the time duration of the i | h | ransmission interruption of N transmission interruptions measured during T (see Annex B).

Note — There are two major parameters: time between interruptions (or frequency) and duration to specify characteristics of transmission interruptions. Those parameters should be easy to observe from the practical point of view. Actually it seems very difficult to measure very short duration of transmission interruptions in analogue networks and to separate interruptions from burst errors in digital networks.

3 Overall objective for speech loss probability

The provisional objective for P_i shall be such that the performance is better than the value given below:

$P_i = x$ (to be defined with further study)

Note — A percentage of speech loss of less than 0.5% due to transmission interruptions with durations shorter than 10 s (Annex C) in a conversation phase is assumed to be tolerable to telephone users.

4 Allocation of the overall objective

From a practical point of view, instead of P_i, the value $\frac{fIP\ _i fR}{|(em\ |\ fIP\ _i fR}$ should be –v'7p' allocated to various network components.

The method to allocate this value is for further study.

ANNEX A

(to Recommendation E.855)

Tolerability of telephone user to transmission interruptions

lasting several seconds or more

A.1 *Measure*

The time interval between the start of transmission interruption occurring in the middle of a conversation and the abandoning of the disturbed call either by a calling or a called party is used as a measure to assess or evaluate the tolerability of telephone users.

A.2 *Measuring method*

Fifty intra-office calls were selected at random and deliberately interrupted by callers soon after the calls had been established, and time intervals between the start of transmission interruption and the release of calls by the called party were measured.

A.3 *Results of tests*

The distribution of the durations of interruptions which forced the telephone users to give up their established calls is depicted in Figure A-1/E.855. The distribution curve is well approximated by an exponential distribution function with the mean value of 17.26 sec.

The figure shows that 50% of users released the established calls when the interruption lasted longer than 11.96 sec.

Figure A-1/E.855, p.

ANNEX B

(to Recommendation E.855)

Relationship between speech loss probability and its estimation

The following relationship exists between the speech loss probability (P_i) and its estimator (P_{ie}):

$$\lim_{T \to \infty} P_{ie} = \lim_{T \to \infty} \frac{\sum_{k=1}^{K} TD_k}{T} = P_i$$

if such limit exists and where T is the observation period of time and TD_k is the duration of the k th transmission interruption of K transmission interruptions over T.

It should be noted that there is also the following relationship:

$$P_i = \frac{\rho}{1+\rho}, \quad \rho = \sum_{i=1}^{L} \frac{MID_i}{MTBI_i}$$

where, MID_i is the mean time duration of transmission interruption caused by the i th component of a telephone connection and $MTBI_i$ is the mean time between interruptions caused by the i th component of the connection, under the assumption that the transmission interruption duration and the time between transmission interruptions are exponentially distributed (see also Figure B-1/E.855).

Figure B-1/E.855, p.

ANNEX C

(to Recommendation E.855)

Quality of speech impaired by short interruptions

C.1 *Measure*

The subjective opinion is used as a measure to assess or evaluate speech quality impaired by short interruptions with durations shorter than 1 s.

C.2 *Measuring method*

Recommendation P.77 was applied for this subjective evaluation with five grade opinion scores (Excellent = 4, Good = 3, Satisfactory = 2, Poor = 1 and Unacceptable = 0). The test procedure was comprised of a 40-second text tape recorded in Japanese spoken by a female, which was listened to by 20 test subjects through indoor test circuits with a transmission interruption generator.

C.3 *Test results*

The relationship between frequency and duration of transmission interruptions for a given Mean Opinion Score (MOS) is depicted in Figure C-1/E.855.

The dotted line in this figure shows the locus of ‘‘frequency × duration = 0.5%’’ which is considered as a permissible limit of the freeze out rate or the percentage of speech loss for designing Digital Speech Interpolation (DSI) and Time Assignment Speech Interpolation (TASI) equipment.

Note — The product of frequency and duration of the short interruption is identical to *P* [= *MID* /(*MTBI* | | fIMID)] in Annex B.

Figure C-1/E.855, p.15

SECTION 4

USE OF QUALITY OF SERVICE OBJECTIVES FOR PLANNING OF TELECOMMUNICATION NETWORKS

Recommendation E.862

DEPENDABILITY PLANNING OF TELECOMMUNICATION NETWORKS

Introduction

This Recommendation is concerned with models and methods for dependability planning, operation and maintenance of telecommunication networks, and the application of these methods to the various services in the international network.

The CCITT,

considering

(a) that economy is often an important aspect of dependability planning;

(b) that the ability of achieving a certain level of dependability differs between network providers;

(c) that network providers often operate in a competitive environment;

(d) that Recommendations E.845, E.850 and E.855 establish objectives for serveability performance;

(e) that objectives for dependability performance are deducible from Recommendations Q.504, Q.514, and X.134 to X.140;

(f) that these objectives have been established in an intuitive manner rather than based on analysis of user needs;

(g) that there exists no unambiguous way of implementing these objectives in planning;

(h) that there is a need of establishing a method for dimensioning and allocating dependability in the telecommunication network;

(i) that terms and definitions relevant to concepts used for dependability may be found in Recommendation E.800,

recommends

that the procedures defined in this Recommendation shall be used by Administrations to plan, design, operate and maintain their networks.

1 General

Dependability planning may be accomplished by using essentially two different methods.

Intuitive method

The level of dependability is determined by making a synthesis of objectives and procedures presently used. It is a pragmatic method in absence of an analytical method or in the case when necessary data for a thorough analysis is not available.

This method reflects the present status, but is inconsistent in achieving what Administrations actually want to attain: the most economic level of dependability taking into account customer needs and inconvenience.

Analytical method

The analytical method is based on principles defining the object of dependability planning. The principles are realized through a quantitative model. The level of dependability is deduced by applying the model, taking into account all relevant factors in each planning case.

— Basic principle: The main object of dependability planning is to find a balance between the customers' needs for dependability and their demand for low costs.

— Model: Fault consequences are expressed in terms of money and are included as additional cost factors in planning and cost-optimization. The cost factor reflects the customers' experience of faults in the network, quantified in terms of money, as well as the Administration's costs for lost traffic revenue and corrective maintenance.

— Application: The Administration is provided with a method to integrate dependability as a natural part of planning, taking local information from the actual planning case into account. This method enables the preparation of simplified planning rules.

The application of the analytical method gives, economically, the best-balanced level of dependability, seen from the customer's point of view. This reduces the risk of customer complaints and loss of business to competitors as well as the risk of unnecessary investments. It is therefore considered to be the best general way of planning dependability for the Administration, as well as for the customers.

Recommendations for operational dependability objectives are needed in order to discover impairments and to check and compare dependability performance in the national and international network. Experience from the application of the analytical method may give reason to revise existing Recommendations.

2 Generic measures for dependability planning

The dependability is described by measures defining the availability performance, the reliability performance and the maintainability performance of the network and its constituent parts as well as the maintenance support performance (for the maintenance of the network). The recommended measures are:

Availability performance

Mean accumulated down time

Reliability performance

Mean failure intensity

Maintainability performance

Mean undetected fault time

Mean time to restoration

Mean active repair time

Maintenance support performance

Mean administrative delay

Mean logistic delay

Note — The definitions of these measures are given in Recommendation E.800 and Supplement No. 6.

3 Characteristics of network faults

The faults occurring in the telecommunication network are characterized mainly by their impact on the service provided by the network, i.e. by the traffic disturbance they cause. Important measures determining the traffic disturbance due to a fault are:

Duration of the fault (mean down time), T in hours (h)

Mean traffic intensity affected by the fault, A in Erlangs (E)

Mean probability of congestion during the fault, P

The seriousness of a fault also depends on how the customers experience the fault, and on the Administration's loss of revenue. In order to express this fact, the value of a unit of traffic volume (*Eh*) disturbed by the fault is quantified in economic terms.

Measure: the economic valuation of affected traffic volume is c (monetary units per Eh).

A number of factors may influence this variable such as:

— the category of customers and services affected,

— the degree of congestion or transmission disturbance during the fault,

— the duration of the fault,

— the accessibility to alternative communication means for the affected customers,

— time of day, week or year when the fault is in effect,

— how often faults have occurred in the past.

Additionally, the Administration's costs for corrective maintenance also contribute to the assessment of fault consequences.

Measure: the maintenance cost per fault is c_m (monetary units per fault).

4 Planning for economic optimum

4.1 *Economic dimensioning and allocation method*

Mathematically expressed, the main principle of dependability planning is to find actions that minimize the total cost of the network:

$$\min \left\{ C_I + C_m \cdot d + C_t \cdot d \right\}$$

where

C_I is the investment costs to achieve a certain degree of dependability,

C_m is the expected annual costs for corrective maintenance,

C_t is the expected annual traffic disturbance costs,

d is the discount factor for calculating the present value of the annual cost over the lifetime of the investment.

C_t reflects the annoyance caused by faults and should be regarded as the basic service parameter which dimensions and allocates dependability in the network under given conditions.

An action is optimal if the following two conditions are met:

1) The benefit of the action (e.g. lower traffic disturbance cost) is larger than the cost, i.e. the action is profitable.

2) The action is the best in the sense that the ratio benefit/cost is maximal. There are no alternative actions that give a higher profit.

The method points out a profit seen from the customer's point of view, i.e. the actions are not necessarily profitable for the Administration in the short run. Rates and charges might therefore have to be increased to finance the actions. However, satisfying the customer's needs is recommended as the generally most profitable policy for the Administration in the long run.

This method is applicable for planning all parts of the national and international network and for dimensioning the dependability of network components and the level of the maintenance support. It may be used in short term planning as well as in long term optimization and strategic planning.

The method does not become out of date with technological advances, changes in cost structure etc. Dependability is converted to one clear-cut measure (money) which makes it easier to evaluate actions to promote dependability and to compare and choose between different alternatives.

4.2 *A model for traffic disturbance costs*

The annual traffic disturbance cost is obtained by multiplying the disturbed traffic volume (lost, delayed or affected by transmission impairments) by the monetary valuation of disturbed traffic volume c and the mean failure intensity z which gives:

$$C_t = P\,A\,z\,T\,c$$

where

T is the duration of the state of increased congestion or transmission disturbance due to the fault, mainly the down time. Congestion due to traffic overload after the fault has been repaired might however also have to be included.

A is the intensity of offered traffic.

P is the portion of the offered traffic volume over the time T, delayed or lost.

z is the mean failure intensity.

c is the monetary valuation of disturbed traffic volume. c may be dependent on any number of factors, i.e. $c = c(P, T, A, \ldots)$.

Assuming traffic variations, $A(t)$, and consequently variations of congestion, $P[A(t)] = P(t)$, then A and P are calculated as follows:

$$P = \frac{\int_0^T A(t)\,P(t)\,dt}{\int_0^T A(t)\,dt}$$

A = [Formula Deleted] $\int_0^T A(t)\,dt$

Normally it is not possible to predict the instant of time when a failure will occur. In this case A is a long time average incorporating yearly variations and long time trends. P is calculated by using an average traffic profile. Recommendations E.506, E.510 and E.520 to E.523 deal with methods for traffic calculations.

4.3 *Economic assessment of disturbed traffic volume, c*

The factor c reflects the level of ambition of an Administration or Operating Company in dependability planning. A high valuation of c will give a high level of dependability and vice versa. The values used by an Administration are related to the society's dependence on telecommunications which in turn might be dependent on standard of living, national economy, price level, etc. The establishment of c on the national level is therefore a national matter.

However, it is recommended that c should reflect the combined experience of the Administration and the customer, i.e. it should consist of:

1) the Administration's loss of revenue due to traffic not recurring after the fault,

2) an assessment of the average customer's economic loss due to a unit of traffic volume (*Eh*) being affected by a fault,

3) a symbolic price tag reflecting the annoyance experienced by the average customer.

The sum of 2) and 3) should reflect the price the average customer is willing to pay to avoid one Erlang-hour of offered traffic, delayed or lost due to a fault. The result will then be a level of dependability the customers are satisfied with and prepared to pay for.

Administrations are recommended to make their own investigations among their customers in order to determine the values to be used for planning. Annex B gives an example of such an investigation.

If this is not possible, rough estimates may be obtained from information about actions taken in the present network. The cost of an action is compared to the amount of traffic it saves. Actions that intuitively are regarded as reasonable give a lower limit of c , actions that obviously are unreasonable give an upper limit. The values derived this way are then used in optimization under the assumption that they are valid also for planning the future network.

If c is not possible to estimate at all, the method may still be used to find an optimum allocation of a given amount of resources. The level of dependability attained in this case does however not necessarily satisfy the customers.

4.4 *Planning procedure*

Traffic disturbance costs are included as additional cost-factors in economical calculations for planning, thus integrating dependability as a natural part of planning.

The procedure of dependability planning is performed in four steps:

Step 1: Plan a network attaining functional and capacity requirements.

The starting point is a network planned and dimensioned in order to comply with the functional and capacity requirements, but without special consideration of dependability (zero-alternative). The second step is to identify what changes may be necessary to promote dependability.

Step 2: Search for actions to promote dependability.

There is a need for actions to promote dependability if traffic disturbance costs are high or if the actions can be taken at a low cost. A non-exhaustive list from which actions could be identified is given below:

— Protection of equipment in order to prevent failures

— Choice of reliable and maintainable equipment

— Modernization and reinvestment of worn out equipment

— Redundancy

— Overdimensioning

— Increase in maintenance support

— Network management actions to reduce fault effects.

Step 3: Analyse the actions.

Express improvements in terms of changes in traffic disturbance and maintenance costs (?63C_t + ?63C_m) for each action. It is only necessary to calculate costs that differ between the alternatives. Annex A gives examples of dependability models for network design, maintenance support planning and for determining requirements for network components.

Compare ?63C_t + ?63C_m to the increased investment cost (?63C_I) for each action, e.g. by the present value method.

Choose the best set of actions, i.e. which gives the lowest total cost.

Step 4: Check that minimum requirements are complied with.

A minimum service level may be stipulated by governmental regulations, by CCITT Recommendations, for commercial or for other reasons. The establishment of any minimum requirements on the national level is a national matter. For planning of the international network the Administration is recommended to check if dependability objectives deducible from existing CCITT Recommendations are met. If not, the reasons for non-compliance should be examined more closely. If it is justified, the level of dependability should be adjusted.

4.4.1 *Numerical example based on the above*

Step 1: Network planned without special consideration of dependability.

The network studied is the trunk between two exchanges.

Figure, p.

Step 2: Search for actions to promote dependability.

The action considered is to introduce a physically redundant cable. It is assumed to be dimensioned to carry the whole traffic load, i.e. a single failure will not disturb the traffic.

Figure, p.

Step 3: Analyse the action.

Assumptions

Failure intensity z = 0.1 failures/year

Mean down time T = 24 h

Mean offered traffic A = 100 E

Congestion P = 1 (without redundancy)

P = 0 (with redundancy)

Monetary valuation of disturbed traffic volume c = 400 monetary units/Eh

Discount factor

(lifetime 25 years, interest 5% per year) d = 14

Maintenance cost per failure c_m = 1000 monetary units/failure

Cost of redundant cable C_I = 400 | 00 monetary units

Calculations

Traffic disturbance costs for network without redundancy:

$$C_t = P \times A \times z \times T \times c = (1)(100)(0.1)(24)(400) = 96\,|\,00 \text{ per year}$$

$$\text{Present value } C_t d = (96\,|\,00)(14) = 1\,|\,44\,|\,00$$

Traffic disturbance costs for network with redundancy (the possibility of simultaneous faults is negligible):

$$C_t = 0$$

Change in traffic disturbance costs:

?63*C*
= 0 — 1 | 44 | 00 = —1 | 44 | 00

Maintenance costs without redundancy:

$$C_m = zc_m = (0.1)(1000) = 100 \text{ per year}$$

Present value *C*
= (100)(14) = 1400

Maintenance costs with redundancy:

$$C_m = 2zc_m = (2)(0.1)(1000) = 200 \text{ per year}$$

Present value *C*
= (200)(14) = 2800

Change in maintenance costs:

?63*C*
= 2800 — 1400 = 1400

Cost reduction:

?63*C*
+ ?63*C*
= —1 | 44 | 00 + 1400 = —1 | 42 | 00

Change in total cost:

?63C_I+ ?63*C*
+ ?63*C*
= 400 | 00 — 1 | 42 | 00 = —942 | 00

Conclusion

Since ?63C_I+ ?63*C* + ?63*C* < 0, the action is profitable. Whether or not it is optimal depends on whether there are alternative actions that are more profitable.

Step 4: Check minimum requirements

Any additional actions to meet governmental requirements (for defence reasons, emergency, etc.) should be taken.

5 Applications to the international network

5.1 *Value of c for international traffic (for further study)*

In order to dimension and allocate dependability to different parts of the international network a uniform way of evaluating affected traffic should be established. It is recommended that the following values (c_i) be used as a guide in the planning of the international network

$$c_i = x_i SDR \mid \mid \text{fIs} / Eh$$

(values to be determined)

The values refer to a particular reference year. Price increase due to inflation, society's increasing dependence on telecommunication etc., should be taken into account.

5.2 *Planning recommendations (for further study)*

When values of *c* have been established, it is possible to make economic dependability analyses of the international network. These studies may be done in a similar manner and using partly the same data as for cost studies of charging and accounting.

The object of the studies is to arrive at planning recommendations, e.g. for the amount of redundancy, maintenance support, etc., in different parts of the international network.

5.3 *Operational objectives for dependability (for further study)*

The result of the economical dependability analysis of the international network is presented in terms of reliability, maintainability and maintenance support performances of different parts of the network. This will help Administrations monitoring and checking their networks to discover impairments, misplanning, etc.

ANNEX A

(to Recommendation E.862)

Simplified models for dependability planning

A.1 *General*

The object of this annex is to show simple examples of how different models of dependability may be used to calculate traffic disturbance costs and how the calculations can be used in planning. A list of actions is given in § 4.4. The applications may be divided into:

— Network planning (§§ A.2 and A.3)

— Dimensioning dependability of network components (§ A.4)

— Maintenance support planning (§ A.5).

A.2 *Example: Redundancy*

The traffic disturbance cost of a redundancy consisting of two independent items as shown in Figure A-1/E.862 is:

$$C_t = P_1 z_1 T_1 Ac\,(P_1) + P_2 z_2 T_2 Ac\,(P_2) + z_1 z_2 T_1 T_2 Ac\,(1)/8760$$

where

P_1 is the average congestion when item 1 is faulty,

P_2 is the average congestion when item 2 is faulty.

Figure A-1/E.862, p.

A simple case is when the two items are identical and each can carry the whole traffic load (see Figure A-2/E.862), then:

$$C_t = z^2 T^2 Ac\ (1)/8760.$$

Figure A-2/E.862, p.

By installing a redundant item, the traffic disturbance costs are reduced by

?63$C_t = zTAc$ (1) — $z^2 T^2 Ac$
(1)/8760.

The second term is often negligible, thus ?63C_t may be approximated by ?63C_t = $zTAc$ (1).

A.3 *Example: Optimal dimensioning for diversified routes*

The problem is to determine the optimal number of channels, N_1 and N_2 respectively, for which the two redundant routes should be dimensioned, see Figure A-3/E.862.

Figure A-3/E.862, p.

Denote C_N | to be the cost per channel. The optimal allocation of channels each way is found by solving

$$6o
min
$$6u
N_1, N_2
$$6e

{ (N_1 |(mu | f IC f IN $_1$ + N_2 |(mu | f IC f IN $_2$)+(P_1 |(mu | f IA |(mu | f Iz $_1$ |(mu | f IT $_1$ |(mu | f IC (P_1) + P_2 |(mu | f IA |(mu | f Iz $_2$ |(mu

This implies an overdimensioning in the fault free condition. The benefit of this is not included in this formula. The effect of simultaneous faults does not influence the optimization.

A.4 *Example: Optimal testing time*

Assume that the failure intensity $z(t)$ after a certain operation time (t) is given by

$$z(t) = z_0 + z_t \, e^{\mathrm{D}} \mathrm{lF261}$$

where

$z_0 + z$ is the failure intensity at $t = 0$,

z_0 is the constant failure intensity after the early failure period,

b is the factor determining the decrease in failure intensity during the early failure period.

By testing, faults may be corrected before causing traffic disturbance and maintenance costs. Assume that:

$c_m + ATc$ are the maintenance and traffic disturbance costs per fault,

C is the cost per year of testing.

The optimal testing time (t ‘) is found by solving

$$6o
min
$$6u
t
$$6e

$$\left\{ tC + \frac{\mathrm{f\,Iz}}{\mathrm{f\,Ib}} e^{\mathrm{D}} \mathrm{lF}\,261^{\,f\,It} (c_{\mathrm{f\,Im}} + ATc) \right\}$$

where

$\frac{\mathrm{f\,Iz}}{f\,Ib}$ e $^{\mathrm{D}}$lF261 ^{t} is the additional number of faults occurring in operation as a function of the testing time.

Optimal test time: t ‘ = [Formula Deleted] $\frac{\mathrm{f\,Iz}\,(c_{\mathrm{f\,Im}} + ATc)}{f\,IC}$.

A.5 *Example: Optimal number of maintenance units*

Mean delay $w(N)$ as a function of the number of maintenance men (N) may in some cases be mathematically expressed by using queuing theory. The simplest case is if the times between failures and repair times are exponentially distributed (an $M/M/N$ queue model). $w(N)$ is obtained by calculating:

$w(N) =$

$$\left[\frac{z / \mu)^{f\,IN} (\mathrm{mu}\ \mu}{N - 1)!(N \mu - z)^2} \right]$$

$$2/
[Formula Deleted]

where

N is the number of maintenance units,

z is the intensity of failures,

$w(N)$ is the mean delay as a function of N,

A is the affected traffic intensity,

c is the valuation of affected traffic volume,

μ is the repair rate.

The model may be refined by taking into account classes of priority. It is also possible to let faults of a higher priority interrupt assignments with a lower priority.

If C_N is the annual cost per maintenance unit, the optimal number of maintenance units is obtained by solving:

$$\min_{N} \left\{ N C_{fIN} + z w(N) A c \right\}$$

ANNEX B
(to Recommendation E.862)

Example of an investigation to assess the monetary valuation of disturbed traffic volume, c

B.1 The aim is to arrive at cost data to assess c . Different customer groups and their monetary valuation of total and partial failures with respect to typical traffic relations and different services is studied. Investigations are carried out among residential and business customers based on the following assumptions:

a) The customers are affected by telecommunication interruptions in mainly two ways: in terms of annoyance and in terms of direct costs.

b) For residential customers, annoyance is likely to predominate. For business customers, the direct cost may be important.

c) Both costs and annoyance increase by the duration of the interruptions and the amount of traffic disturbed.

d) As a natural consequence of the great variations in dependence on telecommunications there is a great variation of costs and annoyance.

e) Residential customers are not able to quantify their annoyance in monetary terms. Faults on the home telephone mostly result in irritation, and not in direct costs (except in the case of long-time faults).

B.2 *Complete faults*

B.2.1 *Business traffic*

Companies chosen at random are asked to answer the following question: ''What is the estimated approximative cost of a total interruption of the telephone or data service in connection with down times of 5 minutes, 1 hour, 4 hours, 8 hours, 24 hours and 3 days?''

Companies with experience of a specific fault are asked the question: ''What was the estimated cost of the fault just experienced?''

An estimate of the affected traffic intensity in connection with total interruptions can be made on the basis of the number of exchange lines and the number of data terminals for communication of each company, together with information on how trunks are dimensioned and measurements on the calling intensity of various customer classes.

On the basis of a stated cost, c | s estimated according to the formula:

$$c = \frac{cost\ stated\ by\ the\ customer)}{mean\ traffic\ intensity)(down\ time)}$$

Average values of c | or telephony and data traffic are calculated for different trades by means of a market profile (distribution of workplaces by trade).

B.2.2 *Residential customers*

Group discussions on interruptions can be held in order to arrive at a reasonable valuation. If there is little willingness to pay for increased dependability a relatively low value of c is assigned.

B.3 *Partial faults*

A partial interruption of a traffic relation results in costs for the customer mainly in the form of delays to commerce. By using a calculated hourly salary this cost is estimated for business customers. On the basis of information about the amount of business and household traffic, an average value of *c* for traffic disturbed by partial faults is obtained.

B.4 *Results*

Table B-1/E.862 gives a few examples of figures derived by the Swedish Administration. The figures have been used in various planning cases. The Administration's loss of revenue is included in these figures. The cost figures and exchange rate relate to 1986-01-01 [1 SEK (Swedish Krona)
= 0.1 USD (US Dollar)].

H.T. [T1.862]

TABLE B-1/E.862

{ Economic assessment of prevented communication (*c*) }		
Field of application	Class of failure {	{
{ Business customers with a large portion of data traffic }	1000 SEK/Eh	250 SEK/Eh
{ Used in the long distance network }	400 SEK/Eh	100 SEK/Eh
{ Customers in a sparsely populated area. High cost for alternative communication }	200 SEK/Eh	50 SEK/Eh
{ An average value for areas with mostly residential customers }	100 SEK/Eh	25 SEK/Eh
{ Residential area where it is easy to reach essential services. Low costs for alternative communication }	30 SEK/Eh	10 SEK/Eh

TABLEAU B-1/E.862 [T1.862], p.21

BLANC

SECTION 5

FIELD DATA COLLECTION, ANALYSES AND EVALUATION

ON THE PERFORMANCE OF EQUIPMENT, NETWORKS AND SERVICES

Recommendation E.880

FIELD DATA COLLECTION AND EVALUATION ON THE PERFORMANCE

OF EQUIPMENT, NETWORKS AND SERVICES

1 Introduction

This Recommendation provides guidelines for the collection of field data relating to dependability. It covers general aspects with an overview of sources, measures and information that may be involved when collecting field data. It is anticipated that specific practical needs of operation, maintenance and planning staff, in applying these guidelines, will be dealt with in a handbook under preparation.

The Recommendation emphasizes that meaningful data must include the data on successes (operation without failures) as well as data on failures and faults. In other words, this Recommendation is not intended to be only a failure reporting guideline.

It is applicable, without any restriction, to different items ranging from components to systems and networks (including hardware, software and people).

Terms and definitions used are in line with Recommendation E.800.

2 Scope

It is the intention of this Recommendation to provide guidelines for setting up data collection and reporting schemes which can be applied either during monitoring of samples of items or on a more widespread basis on almost all items (of the same type) by large operational and maintenance organizations.

It is considered that, if such guidelines are followed, accuracy and completeness of reporting are enforced and the quality of the monitored items and their parts can be improved on a medium- to long-term basis. Moreover, such an effort will facilitate the inter-change of information between user and providers.

No recommendations are made on how to organize maintenance support. It is nevertheless understood that some items are repaired on site, others only replaced on site and possibly repaired at centralized facilities. Field data may be obtained at each of those stages.

In order to obtain maximum efficiency from the collection of data, it is suggested that the programmes of reporting, analysis and dissemination of results be closely co-ordinated.

The items considered may either have been designed, manufactured, or installed and may be operated by the same organization or by different organizations. This Recommendation applies to all possible cases of provider-user relations.

3 The need for data collection

Any data collection scheme must aim to provide the information required to enable the correct decisions to be taken in order to reach specified objectives; these objectives should be well defined and documented at the outset.

The specific objectives of the field data collection and presentation are as follows:

a) to provide for a survey of the actual performance level of the items monitored for information to management, operation and planning, maintenance support, training of personnel, etc.;

b) to indicate a possible need for the improvement of:

— items already installed and in operation, or

— further items to be delivered;

c) to compare the specified or predicted characteristics of the item(s) with the actual field performance;

d) to improve future designs;

e) to improve predictions (data bases and procedures);

f) to inform the provider about the performance of items on a regular or on a single occasion basis;

g) to have a common reporting basis.

4 Sources and means of data collection

In the following, the various information sources are described and the methods for systematically collecting information are outlined.

4.1 *Sources of data*

The following sources of data may generally be available:

— maintenance activities;

— repair activities (on site, repair and/or complaint centre);

— performance observation activities (e.g. anomaly reports, traffic measurements);

— existing information (e.g. stocklist, installation list, modifications, a regularly updated data base for configuration control purposes).

4.2 *Means of collecting data*

It is not intended to recommend any particular format for the recording medium (e.g. paper based or computer data base), however it should be recognized that early consideration of the format is necessary and important in setting up an effective data collection scheme and also aids subsequent successful processing.

Frequently the recording of data will be by manual means but automated and interactive data collection systems may be also considered. The advantages to be gained from holding data in a form suitable for processing by an electronic data processing system include easy and accurate updating of information and the possibility of performing new extended analyses.

Data may be collected by one or several of the following reporting means.

4.2.1 *Operation reporting*

Data reporting should be supported by information on the use of the items. Where systems are in operation for the reporting of all failures, it is necessary to collect data on the use of the whole population of items (the total number of similar items under observation).

4.2.2 *Failure reporting*

At any level, failure reporting is dependent on the fault coverage test resources used at the considered level: cases such as ‘‘fault not found’’ or ‘‘right when tested’’ should be clearly mentioned.

Failure reporting should cover all failures that have been observed. They should also contain sufficient information to identify failures. Failures considered to be attributable to any maintenance action should be so noted.

The failure reporting should be sufficiently comprehensive to cover the requirements of detailed investigation of an individual failure and the resulting fault. Where economic reasons or lack of resources make it undesirable to collect all of the failure data indicated, it may be desirable to agree upon a shortened form of report which can be used to collect limited data on all relevant failures, with an option to call for the full report in specific cases.

4.2.3 *Maintenance reporting*

The maintenance report should contain all information relevant to the manual or automatic action taken to restore the item.

When there is need to distinguish between corrective maintenance and preventive maintenance reporting, if no replacements or repairs are made, the action can be classified as a preventive maintenance report. If a preventive maintenance action results in a replacement or repair, the report may be treated as a corrective maintenance report even though the item has in fact not failed in operation.

4.3 *Storage, updating and checking procedures*

Independently of the structure chosen for the data storage, data should be checked at the time of input so as to ensure validity.

It is evident that every data bank needs an in-depth study appropriate to its specific requirements, in order to define the most suitable method of data checking, error correction, and updating.

5 List of dependability measures

The selection of the data to be collected is very dependent on the kind of performance measures to be evaluated/estimated.

Field data reporting may have to be limited by economic necessity to the minimum necessary to meet the requirement, whilst recognizing that collection systems should be capable of future expansion.

It is likely that certain data may be needed for more than one purpose, and careful consideration can therefore result in the most cost-effective data collection scheme.

The dependability measures that might be taken into consideration are listed as follows.

5.1 *Reliability performance*

Failure rate

Failure intensity

Replacement intensity

Mean operating time between failures

[.] indicates according to specific applications a mean value or a fractile.
[.] Up time.

5.2 *Maintainability performance*

5.2.1 *Time related performance*

[.] Down time

[.] Technical delay

[.] Fault localization time

[.] Fault correction time

[.] Restart time

[.] Checkout time

[.] Repair time

[.] Active corrective maintenance time.

5.2.2 *Probabilities*

Probability of fault coverage

Probability of false alarm

Probability of fault nondetection

Probability of alarm detection

Probability of a failure being localized within a given number of replaceable units.

5.3 *Maintenance support performance*

5.3.1 *Time related performance*

[.] Logistic time

[.] Administrative delay.

5.3.2 *Probabilities*

Spare parts shortage probability

Test resource shortage probability

Human resource shortage probability.

5.4 *Availability performance*

Steady state availability

[.] Accumulated down time.

6 Data required

Consideration of the foregoing objectives defines the need for a system which provides for the collection of documented data covering:

a) the identity of items or population of items under observation;

b) operational conditions;

c) maintenance support conditions;

d) performance monitoring.

For each individual item, sufficient information has to be recorded to clearly identify the item itself and its operating environment.

Depending on the item under consideration (e.g. equipment, printed circuit board, component, personnel), and on the depth and kind of analysis of collected data, the necessary item identification data shall be used, on a case by case basis.

The item identification should also allow the analysis of the relationships between the items for which data is collected.

In relation to the particular analysis to be done, some items may be considered as equivalent, therefore separate small items need not to be collected in such cases.

The following information may be needed and could be collected or will be available from existing sources:

— type of item

— manufacture/provider

— item configuration

— individual No. or serial No.

— date of manufacture

— supplier

— delivery date

— installer (company)

— installation date

— customer (name)

— site (geographic)

— system.

Consideration should be given to possible limitations due to non-completeness of collected data or possible difficulties in data collection or particular assumptions made for the collection itself.

The choice of the kinds of data to be collected and the design of the related collection procedure depend on many factors, some of which are:

— the required end-result;

— the diversity of components or systems;

— the duration of the data collection project;

— the data handling method (manual or computer based);

— a sufficient knowledge of the capability to collect the required quantity of information and the accessibility to data to be gathered.

6.1 *Number of items to be considered*

The number of items to be considered depends mainly on the characteristics to be dealt with, the statistical aspect of the evaluation to be made and the cost involved.

6.2 *Information on items being considered*

6.2.1 *Operating conditions*

6.2.1.1 *Environment classes*

a) Fixed (outdoors, indoors, underground, undersea, off-shore, etc.);

b) Portable (item specially built for easy transportation by one man only);

c) Mobile (in motor vehicle, in ship, in aircraft);

d) Other (specify).

6.2.1.2 *Specific environment data*

a) Climatic conditions

— weather-protected,

— not weather protected,

— air temperature,

— air pressure,

— humidity;

b) Electrical environment (EMC);

c) Mechanical conditions (vibration, shocks, bumps);

d) Mechanically active substances (sand, dust, etc.);

e) Chemically active substances;

f) Biological conditions.

6.2.1.3 *Mode of operation*

a) Continuous;

b) Intermittent (give cycle);

c) Stand-by;

d) Single operation (e.g. one shot devices);

e) Storage.

6.2.1.4 *Load conditions*

a) Overload;

b) Other (specified).

6.3 *Failure and fault description*

— Fault recognition: symptoms and indications, fault detected, fault not detected, false alarm.

— Item fault mode (identification of functions affected).

— Failure causes:

a) Inherent to item under observation;

b) Misuse failure;

c) Induced by maintenance or administrative action;

d) External to item under observation;

e) Secondary (caused by related item);

f) Other.

In cases where the failure immediately follows a period of transport, storage or stand-by, the relevant conditions shall be stated.

— Fault consequences

— List (identification) and physical location of faulty replaced parts:

a) quantity of suspected replaceable items;

b) quantity of replaced items.

— Fault evidence and documentation (printouts, photograph, etc.).

— Action taken: Replacement, repair, adjustment, modification, lubrication, etc.

— Active maintenance time (diagnostic + repair + tests +

— Downtime, including, where applicable:

— undetected fault time,

— fault localization time,

— reconfiguration time ,

— technical delay,

— logistic delay,

— administrative delay,

— fault correction time,

— checkout time,

— restart time.

Time required for automatic reconfiguration (if manual operations are needed, they are integrated into technical delay).

6.4 *Maintenance support data:*

— spare resources shortage,

— test resources shortage,

— resources shortage.

7 Data presentation for evaluation

When collected data is offered for subsequent evaluation by using approximate statistical methods, all conditions for their correct use and understanding should be clearly stated.

These conditions should encompass the purpose of the data gathering especially with respect to type and variation of the data chosen. Information on the circumstances should also be provided such as when (e.g. busy hour conditions), where (e.g. geographic considerations) and for how long the collection took place. Specific situations, which may limit the data application and use, should be indicated, e.g. difficulties encountered, particular assumptions made, non-completeness.

Considerations should also be given to the form of presentation: where appropriate, a condensed form (e.g. diagrams, histograms) may prevail over a detailed raw data presentation.

8 Statistical methods for data treatment

In most cases the need for data treatment appears in connection with one of the following activities:

— estimation,

— compliance evaluation,

— monitoring of performances,

— comparison of performances.

For each performance of interest, estimations, hypothesis tests, control charts and comparison techniques are used for evaluating.

The application of a given statistical procedure usually requires the fulfilment of some general conditions and assumptions which have to be carefully investigated. Some of these preliminary investigations relate directly to the properties and the characteristics of the (stochastic) process generating the collected data, some other relate to the distribution underlying the collected data.

Both preliminary investigations and data treatment may require statistical procedures not dealt with in this Recommendation. International organizations other than CCITT, e.g. IEC, have produced valuable material in this field [1].

Reference

[1] International Electrotechnical Commission — Catalogue of Publications, Ed. 1987.

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