INTERNATIONAL TELECOMMUNICATION UNION

# CCITT

THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

**RED BOOK**

**VOLUME II – FASCICLE II.3**

# INTERNATIONAL TELEPHONE SERVICE
# NETWORK MANAGEMENT, TRAFFIC ENGINEERING

**RECOMMENDATIONS E.401-E.600**

**VIII[TH] PLENARY ASSEMBLY**
MALAGA-TORREMOLINOS, 8-19 OCTOBER 1984

Geneva 1985

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ISBN 92-61-02011-9

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### Part I – Recommendations E.401 to E.427

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# MODIFICATIONS TO THE SERIES E RECOMMENDATIONS

## 1 *Fascicle II.2*

1.1 The following new Recommendations did not appear in Fascicle II.2 of the *Yellow Book*, and were developed during the Study Period 1981-1984:

*Recommendations*

| | |
|---|---|
| E.124 | E.175 |
| E.126 | E.183 |
| E.127 | E.212 |
| E.128 | E.213 |
| E.164 | E.220 |
| E.171 [1] | E.221 |

1.2 The following Recommendations in Fascicle II.2 of the *Yellow Book* were revised during the Study Period 1981-1984:

*Recommendations*

| | |
|---|---|
| E.100 | E.141 |
| E.115 | E.150 |
| E.116 | E.151 |
| E.120 | E.161 |
| E.121 | E.163 |
| E.122 | E.180 |
| E.123 | E.210 |
| E.130 | E.211 |
| E.132 | E.231 |

1.3 The following Supplement which appeared in Fascicle II.2 of the *Yellow Book* was revised during the Study Period 1981-1984:

Supplement No. 1

## 2 *Fascicle II.3*

2.1 The following new Recommendations did not appear in Fascicle II.3 of the *Yellow Book*, and were developed during the Study Period 1981-1984:

*Recommendations*

| | |
|---|---|
| E.410 [2] | E.501 |
| E.411 | E.502 [3] |
| E.412 | E.550 |
| E.413 | E.600 [4] |
| E.425 | |

[1] This Recommendation has been completely changed from the one which appears in the *Orange Book*.

[2] Previous Recommendation E.410 in the *Yellow Book* was restructured and new material was developed during the Study Period 1981-1984, which is now contained in Recommendations E.410 to E.413. Also, as a consequence, Supplement No. 6 of the *Yellow Book* has been deleted.

[3] Previous Recommendation E.502 in the *Yellow Book* was revised and renumbered as Recommendation E.506.

[4] Previous Supplement No. 7 in the *Yellow Book* was revised and has been converted to Recommendation E.600.

2.2 The following Recommendations in Fascicle II.3 of the *Yellow Book* were revised during the Study Period 1981-1984:

*Recommendations*

| | |
|---|---|
| E.420 | E.500 |
| E.421 | E.506[5)] |
| E.422 | E.522 |
| E.423 | E.543 |

2.3 The following new Supplements did not appear in Fascicle II.3 of the *Yellow Book* and were developed during the Study Period 1981-1984:

*Supplements*

No. 6

No. 7

No. 8

2.4 The following Supplements which appeared in Fascicle II.3 of the *Yellow Book* have been deleted from the *Red Book*:

*Supplements*

No. 5[6)]

No. 7[7)]

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PRELIMINARY NOTES

1 The Questions entrusted to each Study Group for the Study Period 1985-1988 can be found in Contribution No. 1 to that Study Group.

2 In this fascicle, the expression "Administration" is used for shortness to indicate both a telecommunication Administration and a recognized private operating agency.

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5) This revised Recommendation was numbered as E.502 in the *Yellow Book*.

6) The information in this Supplement can now be found in new Recommendation E.411 (and in new Recommendation E.502).

7) This Supplement was revised in the Study Period 1981-1984 and has been converted to new Recommendation E.600.

# PART I

## Recommendations E.401 to E.427

# INTERNATIONAL TELEPHONE NETWORK MANAGEMENT AND CHECKING OF SERVICE QUALITY

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## SECTION 1

## INTERNATIONAL SERVICE STATISTICS

**Recommendation E.401**

### STATISTICS FOR THE INTERNATIONAL TELEPHONE SERVICE (NUMBER OF CIRCUITS IN OPERATION AND VOLUME OF TRAFFIC)

(Statistics exchanged by Administrations)

Administrations exchange each year, *in February*, statistics showing the number of circuits used and the volume of traffic monitored in the preceding year, as well as estimates of the number of circuits which will be required three years and five years later. These statistics shall be drawn up in the form indicated below.

A copy of the statistics shall be sent to the CCITT Secretariat for information.

### ANNEX A

(to Recommendation E.401)

**How to fill in the table on international telephone traffic statistics**

Column 1 — Designation of the connection by giving the name of the outgoing exchange first and then the name of the incoming exchange. Two-way connections will be shown in alphabetical order.

Columns 2 and 3 — Number of circuits in operation as on *31 December* of the year of the statistics.
The number will be shown in column 2 when it refers to outgoing circuits and in column 3 when it refers to both-way circuits.

Columns 4 and 5 — Number of circuits which would have been required during the year of the statistics.

Column 6 — Method of operation.

The following abbreviations will be used:

A for automatic,

SA for semiautomatic,

M for manual,

A + SA for automatic and semiautomatic.

Column 7 — Destination of traffic.

Each relation will be shown in this column on a separate line.

In the example given, the traffic routed over the Zürich-København circuits is destined for Denmark (terminal), Sweden, Norway and Finland (transit). In this case, the data for each destination will be shown in columns, 8, 9, 10 and 11. The total traffic figure, however, should not be omitted. These data will be bracketed together. If the connection handles traffic only to the country in which the incoming exchange is situated, only the word "terminal" will appear in column 7.

Columns 8 and 9 Busy-hour traffic, expressed in *erlangs.* (See Supplement No. 7 at the end of this fascicle.)

The traffic measured during the busiest month of the year of the statistics is given in column 9. For two-way circuit groups the total amount of incoming and outgoing traffic should be given. In column 8 the month of the year during which the traffic was measured should be indicated in roman numerals.

Column 10 Busy hour (UTC).

This refers to the busy hour as defined in Supplement No. 7 at the end of this fascicle.

Column 11 Annual increase, in %. Each Administration should insert in this column the annual traffic increase rate with respect to the previous year.

Columns 12 and 13 Columns 12 and 13 should show the estimated number of circuits required to route traffic in three and five years' time, respectively. For example, if the statistics relating to 1982 are drawn up in February 1983, column 12 will give the estimated number of circuits required in 1986 and column 13 those required in 1988.

**International telephone traffic statistics**

Year: ................................................

| Circuits | Number of circuits in service | | Number of circuits required | | Method of operation | Destination of traffic | Busy-hour traffic | | Start of busy-hour (UTC) | Annual traffic increase | Estimated number of circuits | | Observations |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Outgoing | Both-way | Outgoing | Both-way | | | Month | Erlangs | | | In three years | In five years | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| *(Examples)* | | | | | | | | | | | | | |
| Zürich-København | 24 | — | 20 | — | SA | Terminal | X | 8 | 10.00 | 15% | | | |
| | | | | | | Sweden [a] | X | 4 | 10.15 | 12% | | | |
| | | | | | | Norway | X | 2 | 09.45 | 13% | | | [a] Overflow traffic on Zürich-Stockholm connection |
| | | | | | | Finland | X | 1 | 10.30 | 7% | | | |
| | | | | | | *Total* | X | 15 | 10.00 | 14% | 28 | 32 | |
| Zürich-Stockholm | 12 | — | 11 | — | SA | Terminal | IX | 5.5 | 10.15 | 12% | 13 | 15 | |

## SECTION 2

## INTERNATIONAL NETWORK MANAGEMENT

**Recommendation E.410**

### INTERNATIONAL NETWORK MANAGEMENT – GENERAL INFORMATION

### 1 Introduction

The demand for international telephone service continues to increase substantially. This increasing demand has been met by advances in both technology and operational techniques. The growth of traffic has also required the development of larger international transmission systems and switching centres to provide the capacity to meet the required grade of service. This has resulted in an international telephone network which is highly interconnected and interactive.

A number of events arise which have a detrimental effect on the international telephone service. Among such events are:

- failures of international or national transmission systems;
- total or partial failures of international or national switching centres;
- planned outages of transmission systems and switching centres, which affect service;
- abnormal increases in traffic demand. The events which give rise to such traffic demand may be foreseen (e.g., national or religious holidays, international sporting events) or unforeseen (for example, natural disasters, political crises);
- difficulties in meeting the requirements of international traffic resulting, for example, from delays in the provision of additional circuits or equipment.

These events lead to congestion which, if uncontrolled, may spread and thus degrade the service in other parts of the international network. Considerable benefits can be derived for the international network as a whole if prompt action is taken to control the effect on service of such events.

With the continuing growth of the international automatic service, direct supervision and control over telephone traffic has decreased since operators are no longer involved in establishing the majority of calls. Alternative means must therefore be provided to supervise and, where necessary, control the traffic carried by the automatic telephone network.

The above considerations have led to the development of "international network management", which encompasses all the activities necessary to reduce the effect on service of any situations affecting unfavourably the international telephone network.

### 2 Definition of international network management

**International network management** is the function of supervising the international network and taking action to control the flow of traffic so as to ensure the maximum utilization of the network in all situations.

Network management requires "real-time" monitoring and measurement of network status and performance, and the ability to take prompt action to control the flow of traffic when necessary.

## 3 Objective of international network management

The objective of international network management is to enable as many calls as possible to be successfully completed. This objective is met by maximizing the use of all available equipment and facilities in any situation which may occur, for example, by the following means:

### 3.1 *Utilizing all available international circuits*

There are periods during localized situations when, due to changing traffic patterns, the demand for service cannot be met by the circuit within that part of the international network. At the same time, many circuits to other locations may be idle due to differences in calling patterns caused by time zones, local calling habits, or busy season variations. After negotiation and agreement between the Administrations concerned, some portion of the unusually heavy traffic can be redirected to this idle capacity for completion.

### 3.2 *Keeping all available international circuits filled with traffic which has a high probability of resulting in effective calls*

The international network is basically circuit limited; therefore the maximum number of effective calls is determined by the number of available circuits. Ineffective calls occupy circuit capacity which would otherwise be available for effective calls. Therefore identifying those calls which are likely to be ineffective because of an event in the network (e.g., a failure), and reducing them as far back in the network as possible, will allow circuit capacity to be available for calls which have a high probability of being effective.

### 3.3 *When all available international circuits are in use, giving priority to calls requiring a minimum number of international circuits to form a connection*

When international networks are designed using a routing hierarchy with automatic alternate routing of calls, efficient operation occurs when traffic loads are at or below planned values. However, as traffic loads increase above the planned value, the ability of the network to carry effective calls decreases since an increased number of calls require two, or more circuits to form a connection. Such calls increase the possibility of one call blocking several potential calls.

Thus automatic alternate routing should be restricted to give preference to direct routed traffic during periods of abnormally high demand.

### 3.4 *Restricting switching congestion and preventing its spread*

An increase in ineffective calls with its associated increase in repeat attempts can result in switching congestion at the international switching centre. If this switching congestion is left uncontrolled, it can spread to other switching centres and cause a further degradation of the network. Network controls should be applied which inhibit switching congestion by removing call attempts from the congested switching centre (e.g., by cancelling alternate routed traffic via the congested switching centre).

*Note* – International network management assumes that the international network is adequately engineered to meet the normal levels of traffic, the requirement for which is described in Recommendations E.171, E.510, E.520, E.522, E.540 and E.541.

## 4 Benefits derived from international network management

Among the benefits to be derived from international network management are:

4.1 Improved service to the customer. This can lead, in turn, to:

- improved customer relations;
- stimulation of customer calling rate;
- increased revenue.

4.2 More efficient use of the planned international network. This can result in:

- an improvement in the ratio of effective to ineffective calls;
- an increased return on the capital invested in the international network.

4.3 Greater awareness of the actual status and performance of the international network. Such awareness can lead to:

- a basis by which network management and maintenance priorities can be established;
- improved network planning information;
- improved information on which future capital investment in the international network can be decided.

4.4 Protection of essential services at all times and particularly during severe network situations.

## 5 Network management functions

The following are considered to be the main functions of international network management:

a) monitor the status and performance of the international network on a real-time basis;

b) collect and analyze network performance data;

c) detect abnormal network conditions;

d) investigate and identify the reasons for abnormal network conditions;

e) initiate corrective action and/or control;

f) cooperate and coordinate actions with other centres, both domestic and international, on matters concerned with international network management and service restoration;

g) issue reports of abnormal network situations, actions taken and results obtained to higher authority and other involved departments and Administrations, as required;

h) provide advance planning for known or predictable network situations.

## 6 Further guidance on network management

6.1 Recommendation E.411 provides operational guidance for network management including:

- status and performance parameters;
- expansive and protective traffic controls;
- criteria for application of controls.

6.2 Recommendation E.412 provides guidance on planning for events such as:

- peak days;
- failures and planned outages;
- traffic surges resulting from disasters.

6.3 Recommendation E.413 provides guidance on the functional elements of a network management organization which need to be identified internationally as contact points. These comprise:

- planning and liaison;
- implementation and control;
- development.

6.4 It is stressed that in order to achieve some benefit from the application of network management techniques, it is not necessary to meet the full scope of these Recommendations. However the Recommendations do provide detailed information over a wide range of techniques, some of which can be implemented readily, whilst others may require considerable planning and design effort.

# INTERNATIONAL NETWORK MANAGEMENT – OPERATIONAL GUIDANCE

## 1 Introduction

Network management requires "real-time" monitoring of network status and performance and the ability to take prompt actions to control the flow of traffic when necessary (see Recommendation E.410). Operational guidance to meet these requirements, including a description of status and performance parameters, traffic controls and the criteria for their application are included in this Recommendation. It should be noted that the complete range of parameters and traffic controls are not necessary for the introduction of a limited network management capability, however a comprehensive selection will bring substantial benefit (see Recommendation E.410, § 4).

## 2 Information requirements

2.1 Network management requires information of where and why difficulties are occurring or are likely to occur in the network. This information is essential to identify the source and effect of a difficulty at the earliest possible time, and will form the basis for any network management action which is taken.

2.2 The information relating to current difficulties can be obtained from:

a) real-time surveillance of the status and performance of the network;

b) information from telephone operators as to where they are experiencing difficulties, or where they are receiving customer complaints of difficulties;

c) transmission system failure and planned outage reports (these reports need not relate only to the network local to one Administration, but should reflect the whole international network);

d) international or national switching centre failure and planned outage reports;

e) news media reports detailing unforeseen events which stimulate traffic (for example, natural disasters).

2.3 The information relating to difficulties which are likely to occur in the future will be obtained from:

a) reports of future planned outages of transmission systems;

b) reports of future planned outages of international or national switching centres;

c) knowledge of special events (for example, international sporting events, political elections);

d) knowledge of national holidays and festivals (e.g., Christmas Day, New Year's Day).

2.4 The system availability information point, defined in Recommendation M.721, will provide a ready source for much of the information indicated above.

## 3 Network status and performance data

3.1 In order to identify where and when difficulties are occurring in the network, or are likely to occur, data will be required which will indicate the status and measure the performance of the network. Such data will require real-time collection and processing.

3.2 Data may be collected using various devices which range from electromechanical counters which are read manually when required (e.g., during periods of heavy traffic or special events), to computerized systems which provide processed data automatically.

3.3 Network status information includes information on the status of switching centres, circuit groups and common channel signalling systems. This status information can be provided by one or more types of displays. These include data printers, cathode ray tube devices, visual indicators on a display board or network management console.

3.3.1 Switching centre status information relates to the following:

*Load measurements* – These are provided by attempt counts, usage or occupancy data, data on the percent of real-time capacity available (or in use), blocking rates, percentage of equipment in use, counts of second trials, etc.

*Congestion measurements* – These are provided by measurements of the delay in serving incoming calls, holding times of equipment, average call processing and set-up time, queue lengths for common control equipment (or software queues), and counts of equipment time-outs, etc.

*Service availability of switching centre equipment* – This information could highlight a cause of difficulty or give advance warning that difficulties could arise if demand increases. Information can be provided which shows when major items of equipment are made busy to traffic.

*Congestion indicators* – In addition to the above, indicators can be provided by SPC exchanges which show levels of congestion. These indicators can show:

- no congestion Level 0 (clearing signal);
- moderate congestion Level 1;
- serious congestion Level 2;
- unable to process calls Level 3.

The availability of specific switching centre status information will depend on the switching technology employed by each Administration.

3.3.2 Circuit group status information relates to the following:

- status of all routes available to a destination;
- status of circuits on each route.

Status indicators should be provided to show:

a) when the available network is fully utilized by indicating:
   - when all circuits in a route are busy;
   - when all routes available to a destination are busy.

   This would indicate that congestion is imminent.

b) the availability of the network for service, by indicating the number or percentage of circuits on each route that are made busy or are available for traffic.

This information could identify the cause of difficulty or give advance warning that difficulties may arise as the demand increases.

3.3.3 Common channel signalling system status provides information that will indicate failure or signalling congestion within the system. It includes such items as:

- receipt of a transfer prohibited signal (Signalling Systems Nos. 6 and 7),
- initiation of an emergency restart procedure (Signalling System No. 6),
- presence of a signalling terminal buffer overflow condition (Signalling System No. 6),
- signal link unavailability (Signalling System No. 7),
- signal route unavailability (Signalling System No. 7),
- destination inaccessible (Signalling System No. 7).

This information may identify the cause of difficulty in the network.

3.4 Network performance data should relate to the following:

- traffic performance on each route;
- traffic performance to each destination;
- effectiveness of network management actions.

It is also desirable to assemble performance data for each direction of traffic flow in terms of route and destination combinations and traffic class (for example, operator dialled, subscriber dialled, transit).

Data for network management purposes are derived from bids, seizures, answer signals, clears and the times of their occurrence. (See Annex A for the definition of these terms.)

Data collection should be based on a system of measurement which is either continuous or of sufficiently rapid sampling rate to give the required information. For example, for common control switching equipment, the sampling rate may need to be as frequent as every second.

Data reports may be provided on a 5 minute, 15 minute, 30 minute or hourly basis.

3.5 The network performance data is generally expressed in parameters which assist the identification of difficulties in the network. Among these parameters are:

3.5.1 **percentage overflow (% OFL)**

% OFL indicates the relationship between the total bids offered to a route or destination, in a specified period of time, and the quantity of bids not finding a free circuit. It will, therefore, give an indication of the overflow from one route to another, or the bids which fail because all routes to a destination are busy.

$$\% \text{ OFL} = \frac{\text{Overflow bids (to another route or to circuit busy signal)}}{\text{Total bids for the route (or all routes)}} \times 100$$

3.5.2 **bids per circuit per hour (BCH)**

BCH is an indication of the average number of bids per circuit, in a specified time interval. It will therefore identify the demand and, when measured at each end of a both-way operated route, will identify the direction of greater demand.

$$\text{BCH} = \frac{\text{Bids per hour}}{\text{Quantity of circuits available for service}}$$

It is not necessary to accumulate data for an hour to compute BCH.

3.5.3 **answer seizure ratio (ASR)**

ASR gives the relationship between the number of seizures that result in an answer signal and the total number of seizures. This is a direct measure of the effectiveness of the service being offered from the point of measurement and is usually expressed as a percentage as follows:

$$\text{ASR} = \frac{\text{Seizures resulting in answer signal}}{\text{Total seizures}} \times 100$$

Measurement of ASR may be made on a route or on a destination basis.

3.5.4 **answer bid ratio (ABR)**

ABR gives the relationship between the number of bids that result in an answer signal and the total number of bids. ABR is measured on a destination basis.

$$\text{ABR} = \frac{\text{Bids resulting in answer signal}}{\text{Total bids}} \times 100$$

ABR is expressed as a percentage and is a direct measure of the effectiveness of traffic from the point of measurement. It is similar to ASR except that it includes bids that do not result in a seizure.

3.5.5 **seizures per circuit per hour (SCH)**

SCH is an indication of the average number of times, in a specified time interval, that each circuit in a route is seized. When related to the expected values of average call holding times and effective call/seizure rate for the route, it will give an indication of the effectiveness of the service being offered.

$$\text{SCH} = \frac{\text{Seizures per hour}}{\text{Quantity of circuits available for service}}$$

It is not necessary to accumulate data for an hour to compute SCH.

3.5.6 *Occupancy*

Occupancy can be represented in units (for example, erlangs, hundred-call-seconds (CCS)) or as a percentage. It can be measured as a total for a destination or for a route and as an average per circuit on a route. Its use for network management purposes is to show usage and to identify unusual traffic levels.

3.5.7 **mean holding time per seizure**

This is the total holding time divided by the total number of seizures and can be calculated on a route basis or for switching equipment.

*Note* – International networks contain one-way and both-way operated circuits and their traffic flow characteristics are inherently different. This difference needs to be taken into account when calculating BCH and SCH either by:

i) multiplying the number of one-way circuits by 2 to derive an equivalent number of both-way circuits or;

ii) dividing the number of both-way circuits by 2 to derive an equivalent number of one-way circuits.

When BCH and SCH data are exchanged between Administrations, it is essential that the method used is understood.

3.6 The parameters that it is possible or necessary for a particular Administration to calculate will depend upon a number of factors. These will include:

a) the data available at an international switching centre;

b) the particular routing arrangements employed (for example, SCH and BCH relate to route performance only; ASR and % OFL can relate to route or destination performance; ABR relates to destination performance only);

c) the interrelationships which exist between the parameters (for example, SCH can give similar indications to ASR – see § 3.5.5 above).

## 4 Interpretation of parameters

The interpretation of parameters on which network management actions are based can most conveniently be made by considering the originating international switching centre as the reference point (see Figure 1/E.411).

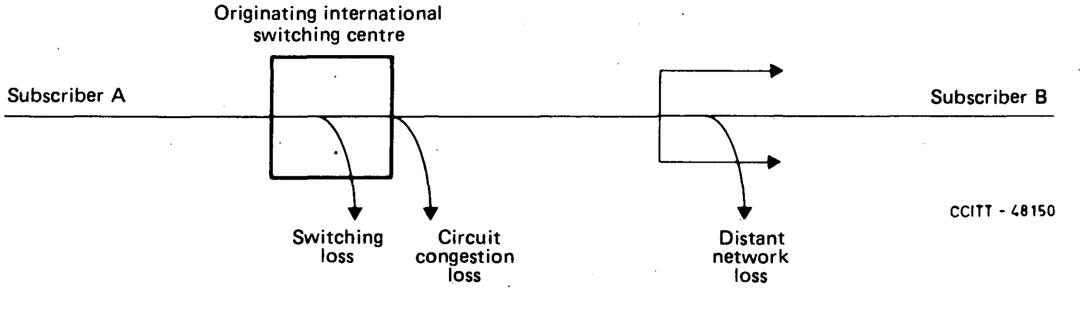


FIGURE 1/E.411

From this reference point, the factors which affect call completion can broadly be divided into three main components:

a) switching loss (near-end loss);

b) circuit congestion loss (near-end loss);

c) distant network loss (far-end loss).

4.1 *Switching loss*

Switching loss may be due to:

1) common equipment or switchblock congestion;
2) failures in incoming signalling;
3) subscriber/operator dependent errors, such as insufficient or invalid digits, premature call abandonment, etc.;
4) routing errors, such as barred transit access;
5) other technical failures.

Guidance to the identification of switching loss can be obtained from §§ 3.3.

4.2 *Circuit congestion loss*

This loss will depend on:

1) the number of circuits available for a destination, and;
2) the level of demand for that destination.

Indication that circuit congestion loss may occur can be obtained from the status information detailed in § 3.3.2 above.

Circuit congestion loss can be identified by any of the following:

– percentage overflow (see § 3.5.1),
– a difference between the "bids per circuit per hour" and "seizures per circuit per hour" measurements on the final route (see §§ 3.5.2 and 3.5.5),
– a difference between the "answer bid ratio" and the "answer seizure ratio" (see §§ 3.5.3 and 3.5.4).

It should be noted that for both-way operated routes, excessive demand in the incoming direction may also cause circuit congestion loss. This can be identified by measuring "bids per circuit per hour" or occupancy (see §§ 3.5.2 and 3.5.6) at each end of the routes.

4.3 *Distant network loss*

Distant network loss may be divided into:

1) *technical loss*: due to distant switching centre and national circuit faults.
2) *subscriber dependent loss*: due to subscriber B busy, no answer, invalid distant number, number unavailable, etc.
3) *traffic dependent loss*: these losses are due to lack of distant network capacity to meet traffic demand.

Under normal conditions, and for a large sample measured over a long period, distant network loss can be said to have a fixed or ambient overhead loss (this value depends on destination with some diurnal and day-by-day variations).

Under abnormal situations (heavy demand, failures, etc.) distant network losses can be significantly affected. Variations in distant network loss can be identified by any of the following:

– answer seizure ratio (see § 3.5.3). This is a direct measurement.
– seizures per circuit per hour (see § 3.5.5). This is an indirect measurement.
– mean holding time per seizure (see § 3.5.7). This is an indirect measurement.

## 5 Criteria for action

5.1 The basis for the decision on whether any network management action should be taken will depend upon real-time information on the status and performance of the network. It is advantageous if the output of this information can be initially restricted to that which is required to identify possible difficulties in the network. This can be achieved by setting threshold values for performance parameters (see § 3.5) and for the percentage of circuits and common control equipment which are in service (see § 3.3) such that when these threshold values are violated, network management action can be considered. These threshold values will represent some of the criteria by which decisions are reached.

5.2 Indications of threshold violations and of "all circuits on a route are busy" and "all routes to a destination are busy" (see § 3.3) may be used to direct attention to the particular area of the network for which detailed performance information will then be required. Considerable advantage can be achieved if these indications are prominently displayed.

5.3 The decision on whether or not to take network management action, and what action to take, is the responsibility of the network management personnel. In addition to the criteria mentioned above, this decision will be based on a number of factors, which could include:

- a knowledge of the source of the difficulty;
- detailed performance and status information;
- any predetermined plans that exist (see Recommendation E.412);
- experience and knowledge of the network;
- routing plan employed;
- local traffic patterns;
- ability to control the flow of traffic.

## 6 Network management actions

### 6.1 *General*

Network management actions fall into two broad categories:

a) "protective" actions, which are designed to remove traffic from the network which has a low probability of resulting in successful calls;

b) "expansive" actions, which are designed to make available lightly loaded parts of the network to traffic experiencing congestion on its normal route(s).

Normally, the first choice response to a network problem would be an expansive action. Protective actions would be used when expansive actions were not available or not effective.

Network management actions may be taken:

- according to plans which have been mutually agreed between involved Administrations prior to the event (see Recommendation E.412);
- according to ad hoc arrangements agreed between involved Administrations at the time of an event;
- by an individual Administration in the case of reducing its traffic entering the international network.

### 6.2 *Protective actions*

Protective actions involve removing traffic from the network which has a low probability of resulting in successful calls. Such traffic should be removed as close as possible to its origin, thus making more of the network available to traffic which had a higher probability of success.

Examples of protective actions are:

a) Temporary removal of circuits from service (circuit busying). This action may be taken when a distant part of the network is experiencing serious congestion.

   *Note* – In the case of both-way circuits, it may only be necessary to inhibit one direction of operation.

b) Special instructions to operators. For example, such instructions may require that only a limited number of attempts (or none at all) be made to set up a call via a congested route or switching centre, or to a particular destination experiencing congestion.

c) Special recorded announcements. Such announcements may be connected at an international or national switching centre and, when there is serious congestion within part of the network, would advise customers (and operators) to take appropriate action.

d) Inhibiting overflow traffic. This action prevents traffic from overflowing onto routes or into distant switching centres which are already experiencing congestion.

e) Inhibiting direct traffic. This action reduces the traffic accessing a route in order to reduce the loading on the distant network.

f) Inhibiting traffic to a particular destination (code blocking). This action may be taken when it is known that a distant part of the network is experiencing congestion.

g) Circuit reservation. This action reserves the last few idle circuits in a circuit group for a particular type of traffic such as, for example, direct routed traffic or operator originated traffic.

h) Switching system controls. These are internally provided automatic controls that are part of the exchange design. They improve switching performance during overloads by:

   - inhibiting second trials;
   - inhibiting low-priority tasks;
   - reducing the acceptance of new calls based on the availability of major components, or other load reduction actions;
   - informing connected exchanges to activate that protective controls should be activated.

6.3 *Expansive actions*

Expansive actions involve the rerouting of traffic from routes experiencing congestion to other parts of the network which are lightly loaded with traffic for example, due to differences in busy hours.

Examples of expansive actions are:

a) establishing temporary alternative routing arrangements in addition to those normally available;

b) in a country where there is more than one international switching centre, temporarily reorganizing the distribution of outgoing (or incoming) international traffic;

c) where circuit multiplication systems, e.g., TASI, are used, enhancing the advantage of these systems such that the number of circuits available on a congested route is increased;

d) in exceptional cases, passing traffic from operator-to-operator (manually) over circuits normally used for the semi-automatic service;

e) establishing alternative routes into the national network for incoming international traffic;

f) establishing alternative routes to an international exchange in the national network for originating international traffic.

The protective action of inhibiting one direction of operation of both-way circuits (see § 6.2) can have an expansive effect in the other direction of operation. This action is described as directionalization.

In general, expansive network management actions can be accomplished by making changes to existing route or equipment arrangements. For example, such arrangements could be provided as prewired additional routings and introduced under key control as required. In many instances, switching centres of modern design (e.g., stored program controlled) have incorporated the capability of exercising direct control over the flow of traffic, including the expansive actions mentioned above. It is desirable that these controls be activated to affect a variable percentage of traffic (for example 25%, 50%, 75% or 100%). Alternatively the number of call attempts routed in a particular period may be controlled (for example 10 calls per minute). It may also be desirable to apply controls on a destination code basis.

6.4 In general, network management actions will be invoked under manual control. However, it is possible upon receipt of appropriate network management signals to initiate certain network management actions automatically. Such automatic responses must be the subject of prior agreement between the Administrations concerned.

## 7 Exchange of information

7.1 Effective network management requires good communications between the various network management elements within an Administration and with similar elements in other Administrations (see Recommendation E.413) This includes the exchange of real-time information as to the status and performance of circuit groups, switching centres and traffic flow in distant locations.

7.2 Such information can be exchanged by voice communication (using dedicated service circuits or the public telephone network) or by network status indicators which are transmitted by special telemetry arrangements, telegraph circuits or common channel signalling systems[1]. The receiving network management location may then use this information to determine manual control actions, or to apply controls automatically. Telex or similar media can be used to transmit reports, data and to confirm verbal agreements.

7.3 Experience has indicated that the following network management signals can be useful when transmitted between international switching centres and/or network management locations. Further retransmission within the national network would be at the discretion of the Administration.

a) International switching centre congestion indicator (see § 3.3.1)

| | |
|---|---|
| – no congestion | Level 0 (clearing signal) |
| – moderate congestion | Level 1 |
| – serious congestion | Level 2 |
| – unable to process calls | Level 3 |

b) "All circuits busy" indicators (see § 3.3.2). These can be generated when all circuits in a route or to a destination are busy, or when the remaining idle circuits in a route are less than a specified threshold.

c) Destination "hard-to-reach" (HTR) indicator. A destination is said to be "hard to reach" when the answer bid ratio (ABR) is below a specified threshold (see § 3.5.4.).

Additional signals may be identified in the future based on practical experience.

When network management signals are used for automatic control of traffic at the receiving location, provision must be made to automatically identify and ignore false signals so that inappropriate control actions may be avoided. Such automatic controls should be the subject of prior agreement among the involved Administrations.

## ANNEX A

(to Recommendation E.411)

### Terminology for network management

**A.1 circuit**

A circuit connects two switching centres. A national circuit connects two switching centres in the same country. An international circuit connects two international switching centres situated in different countries. (Based on Recommendation D.150 and Recommendation F.68.)

**A.2 route**

A collection of circuits uniquely identifiable for engineering, routing or traffic purposes.

**A.3 destination**

A country in which the called subscriber is located or an area or other location that may be specified within that country. A destination can be identified by the digits used for routing the call.

**A.4 bid**

An attempt to obtain a circuit in a route or to a destination. A bid may be successful or unsuccessful in seizing a circuit in that route or to that destination.

**A.5 seizure**

A seizure is a bid for a circuit in a route which succeeds in obtaining a circuit in that route.

[1] Guidance on the exchange of network management signals using Signalling System No. 6 as a transportation system is contained in Supplement No. 6

A.6 **answer signal**

A signal sent in the backward direction indicating that the call is answered. (Based on Recommendation Q.254.)

A.7 **holding time**

The time interval between seizure and release of a circuit or switching equipment.

**Recommendation E.412**

## INTERNATIONAL NETWORK MANAGEMENT – PLANNING

### 1 Introduction

1.1 Many situations arise which may result in abnormally high traffic levels in the international network, or loss of network capacity, or both. These situations may be categorized as follows:

- peak calling days;
- failure and planned outages;
- disasters.

Experience has shown that advanced planning for these situations has a beneficial effect on overall network management efficiency and effectiveness. The timely application of planned control strategies can be instrumental in improving network performance.

1.2 For known or predictable events, predetermined network management plans should be developed and agreed between Administrations. The degree of detail of any plan will depend on the type of situation to be covered. For example, a recurring event such as Christmas or New Year's Day may be planned in great detail. The lack of real-time network management facilities in an Administration should not preclude planning activities.

1.3 When unforeseen situations arise for which predetermined plans do not exist, ad hoc arrangements will need to be agreed at the time. Whether network management actions result from a negotiated plan, or an ad hoc arrangement, it is essential that agreement be reached between Administrations concerned before such actions are actually implemented.

1.4 Network management planning is performed by the "network management planning and liaison" point, in Recommendation E.413.

1.5 Another aspect of network management planning is long-range planning for the development and introduction of new network management techniques and capabilities for surveillance and control. This function is performed by the "network management development" point in Recommendation E.413.

### 2 Peak day planning

2.1 There are a variety of peak days which can affect the international telephone service. These include:

i) events which occur at the same time each year, and have a widespread effect on the international network. Examples of such events are Christmas and New Year's Day.

ii) events which do not occur at the same time each year and which can have a widespread effect on the international network, or can focus on one location. There are a number of religious holidays in the former category and the FIFA World Cup is an example of the latter.

iii) events which may or may not occur at the same time each year and whose effects are localized to only a few Administrations. Certain national holidays may fall in this category.

iv) non-recurring events which may have a widespread or localized effect on the international network. Such events can be special trade fairs, major international meetings or conferences, or the visits of international statesmen, etc. These events may present the greatest problems for planning, in that there may be little previous experience which will give guidance.

2.2 *Plans for peak days may include the following*:

i) provision of temporary additional circuits;

ii) directionalization of both-way circuits;

iii) reconfiguration of the routing plan to take advantage of transit points not normally used, or to avoid normal transit points that are expected to be congested, or both;

iv) identification of destinations that may become heavily congested and which may require controls to reduce attempts, or to inhibit alternate routing;

v) special calling procedures for operators;

vi) special recorded announcements;

vii) criteria for implementing the plan.

Plans may involve the implementation of these measures only for certain periods of the day, for example, to exploit time zone differences.

## 3 Failures and planned outages

A failure or planned outage of a transmission system or international switching centre has the potential of isolating a large portion of the network. While it is virtually impossible to plan in advance for every possible failure situation, a reasonable number of plans are possible. These plans should include "initial" actions which are taken as a first step when the extent of the failure is not clear, and "subsequent" actions which are applied after the diagnosis of the failure and the resulting network conditions can be determined. These plans should include the following:

i) identification of destinations or points affected for originating and terminating traffic,

ii) temporary alternative routes which may be utilized to bypass the failure, and hours of availability,

iii) control actions required in other Administrations,

iv) emergency call handling procedures for operators,

v) special instructions to customers, when required,

vi) required changes to automatic controls, where provided,

vii) notification procedures,

viii) criteria for implementing the plan.

## 4 Disasters

Disasters can be natural (for example, a typhoon or an earthquake) or man-made (as in the case of an airplane or railroad accident, etc.). These events can result in either damage to network facilities or stimulation of extraordinary calling, or both. While it is difficult to predict such a disaster, the effects of a disaster on the telephone network can be predicted with some degree of accuracy and plans developed accordingly. These plans should include:

i) contact and notification lists,

ii) control actions required locally and/or in other Administrations,

iii) arrangements for additional staffing and extended hours of operation.

## 5 Alternate plans and periodic review

5.1 When developing network management plans, it is important that each plan contain a number of alternatives, since a planned action may not be available in any specific situation because:

i) it may be involved in the same problem,

ii) a planned transit exchange may be in congestion at the time,

iii) there may not be any spare circuit capacity to or from the transit point at the time.

5.2 Plans should be reviewed periodically to ensure that they reflect changes and additions that may have occurred in the network. These include changes in alternate routing, the addition of new routes or exchanges and/or the addition of new network management capabilities.

## 6 Negotiation and coordination

### 6.1 *Negotiation*

Administrations should exchange information concerning their network management capabilities as part of the network management planning process. Specific plans should be negotiated in advance on a bilateral or multilateral basis, as appropriate. Negotiation in advance will allow time to fully consider all aspects of a proposed plan and to resolve areas of concern, and will permit prompt activation when needed.

### 6.2 *Coordination*

The use of any network management plan must be coordinated with the involved Administrations at the time of implementation; this will include (as appropriate):

i) determining that planned transit exchange(s) have switching capacity to handle the additional traffic,

ii) determining that there is capacity in the route(s) between the planned transit point and the destination,.

iii) advising the transit Administration(s) that transit traffic will be present in its routes and exchanges,

iv) arranging for the activation of controls at distant locations,

v) arranging for surveillance of the plan while in effect to determine the need to modify the plan.

When the use of a plan is no longer required, all involved Administrations should be notified of its discontinuance, so that the network can be restored to its normal configuration.

**Recommendation E.413**

# INTERNATIONAL NETWORK MANAGEMENT – ORGANIZATION

## 1 General

The required high degree of cooperation and coordination in international network management can best be achieved by efficient and effective interworking between international network management organizations in the various countries. This Recommendation specifies the organizational elements necessary for this purpose, and outlines the functions and responsibilities of each element.

Only those organizational elements vital to the development planning, implementation and control of network management at the "international level" are dealt with in the Recommendation. It is recognized that other functions must necessarily be carried out within the network management organization, either in support of the functions specified below or in connection with the management of the national network.

It is also recognized that Administrations may not wish to assign each element to a separate staff or create a separate organization. Administrations are, therefore, afforded the freedom to organize such functions in a manner which best suits both their own situation and the level of development of network management within their country.

## 2 International network management – organization

2.1 As far as international cooperation and coordination are concerned, network management should be based on an organization comprising the following elements, all of which must exist in each country practicing international network management:

a) network management planning and liaison;

b) network management implementation and control;

c) network management development point.

Each element represents a set of functions and reponsibilities, and are further defined in §§ 3 to 5.

2.2 At the discretion of the Administration concerned, the elements defined in §§ 3 to 5 below can be grouped together in a single organizational entity, for example, an International Network Management Centre. This is likely to be the most convenient and efficient approach where the level of development and degree of practice of network management is high in a particular country. Where such an approach is not possible, or is impractical, international network management functions could be carried out at locations where related activities are performed. § 6 offers specific guidance on the relationship between network management and network maintenance, and includes consideration for the possible combining of organizational elements involved in the two fields of activity.

2.3 Irrespective of which arrangement a country decides for its international network management organization, it must ensure that the functions and responsibilities of a particular organizational element are not divided between two separate locations. Administrations can then issue a list of contact point information (see § 7 for guidance) which will give telephone, telex numbers, service hours etc. for each element.

## 3 Network management planning and liaison

3.1 Network management planning and liaison is an element within the international network management organization of a country. It is concerned with liaising with other Administrations to develop plans to cater for unforeseen high traffic levels and any other situation likely to adversely affect the completion of international calls.

3.2 Network management planning and liaison is responsible for the following set of functions:

a) liaising with similar points in other Administrations to determine the actions necessary to overcome unforeseen high traffic levels and other situations adversely affecting the completion of international calls;

b) producing plans to cater for the abnormal traffic levels produced by foreseen national and international events;

c) liaising with the restoration control point(s)[1] within the Administration concerning failures and planned outages;

d) liaising with similar points in other Administrations to establish the required actions when plans to overcome abnormal situations cannot be implemented;

e) ensuring that the facilities and network management controls required for the rapid implementation of agreed plans are available and ready for use when required.

## 4 Network management implementation and control

4.1 Network Management implementation and control is an element within the international network management organization of a country. It is concerned with monitoring the performance and status of the network in real time, determining the need for network management action, and, when necessary, implementing and controlling such action.

4.2 Network management implementation and control is responsible for the following set of functions:

1) monitoring the status and performance of the network;

2) collecting and analysing network status and performance data;

3) determining the need for the control of traffic as indicated by one or more of the following conditions:

   a) the failure or planned outage of an international or national transmission system;

   b) the failure or planned outage of an international or national switching centre;

   c) congestion in an international switching centre;

   d) congestion in a distant network;

   e) congestion to an international destination;

   f) heavy traffic caused by an unusual situation.

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1) The restoration control point is a functional element in the general maintenance organization (see Recommendation M.725).

4) applying or arranging for network management control action, as described in Recommendation E.411, § 6, in one of the following categories as appropriate to ensure maximum utilization of the network under all conditions:

   a) pre-arranged by mutual agreement;

   b) initiated by the outgoing Administration at the required moment, for example, suppression of traffic;

   c) negotiated by the Administrations involved at the required moment, for example, concerning temporary alternative routing arrangements;

5) liaising and cooperating with similar points in other Administrations in the application of network management controls;

6) liaising with the fault report point (network)[2] within the Administration concerning the exchange of information available at either point;

7) disseminating information as appropriate within its own Administration concerning network management actions taken.

## 5 Network management development point

5.1 The network management development point is an element within the international network management organization of a country. It is concerned with the development and introduction of techniques and facilities for the purpose of network management surveillance and control at the international level.

5.2 The network management development point is responsible for the following set of functions:

a) developing facilities to enable the application of current network management techniques;

b) long range planning for the coordinated introduction of new network management techniques and improved network surveillance and controls;

c) evaluating the effectiveness of current plans, controls and strategies with a view to identifying the need for improved controls, control strategies and support systems.

## 6 Cooperation and coordination between network management and network maintenance organizations

Considerable benefit may be obtained by close cooperation and coordination between the network management organization identified in this Recommendation and the network maintenance organization identified in the M.700 series of Recommendations. For example, reports of network difficulties received by the fault report point (network) in the maintenance organization may assist the network management implementation and control point in refining its control action. Similarly, difficulties reported to the fault report point (network) may be explained by information already available to the network management implementation and control point. For this reason, and to take into account the particular operating situation and stage of development of network management within an Administration, some of the functional elements identified in this Recommendation may be located with one of the groupings of functional elements of the network maintenance organization as outlined in Recommendation M.710.

Where it is advantageous to create a separate international management centre containing the elements defined above, care should be taken to ensure that suitable liaison and information flows occur between such a centre and the network maintenance organization.

## 7 Exchange of contact point information

For each of the three organizational elements in §§ 3 to 5 above, Administrations should exchange contact point information. Network management contact points should be exchanged as part of the general exchange of contact point information as specified in Recommendation M.93.

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[2] The fault report point (network) is a functional element in the general maintenance organization (see Recommendation M.716).

## SECTION 3

# CHECKING THE QUALITY OF THE INTERNATIONAL TELEPHONE SERVICE

**Recommendation E.420**

## CHECKING THE QUALITY OF THE INTERNATIONAL TELEPHONE SERVICE – GENERAL CONSIDERATIONS

### 1 Quality of service parameters

An adequate picture of the level of quality of service (QOS) in the network can be defined by a set of parameters which are measured, registered and data processed.

In Recommendation G.106 a set of performance concepts is defined in order to provide a satisfactory description of the quality of service and the interconnection of those concepts is shown. Each performance concept can be impaired by a number of particular causes. These causes, either singly or in groups, lie behind the failure symptoms observed by the user.

A user views the provided service from outside the network and his perception can be described in observed quality of service parameters. The link between the observed quality of service parameters and the impairment causes can be indicated in the form of tables.[1)]

Five main observed quality of service parameters are derived; they reflect the quality of:

i) providing the customer with the ability to use the desired services;

ii) furnishing a desired level of service for:
- connection establishment
- connection retention
- connection quality
- billing integrity.

These main parameters can be supervised by quality of service indicators (e.g. efficiency rate, call cutoff rate, etc.).

Objectives can be set for these indicators and can be revised at regular intervals.

When a deterioration of these supervision indicators is detected, or when an improvement programme is started, more data must be collected by measurements to permit a more detailed analysis in order to locate the impairment causes which lie behind the observed problem areas.

### 2 Methods of measuring the quality of service

The following methods of measuring the quality of service are described:

1) service observations by external means;
2) test call (simulated traffic);
3) customer interviews;
4) internal automatic observations.

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1) Such tables can be found in the manual on Quality of service, network management and network maintenance.

Administrations are recommended to draw up a programme for observations and tests designed for assessment of circuits and equipment, supervision of operators and evaluation of the quality of service given to subscribers. It would be desirable if telephone Administrations were to exchange statistics on quality of service.

Table 1/E.422 relates to the manual and semi-automatic observations of the quality of international automatic and/or semi-automatic service. It provides in particular a check of the percentage of unsuccessful calls due to technical faults (equipment shortages or failures).

Table 2/E.422 relates the same information as Table 1/E.422 but does not include information which can only be obtained by operators listening in (automatic observation).

Table 1/E.423 relates to observations on traffic set up by operators. It provides, in manual and semi-automatic service, a means of determining the efficiency of international circuits, of assessing the work of operators and the quality of transmission.

Table 2/E.423 summarizes observations of the time – to-answer by operators. The table is compiled by automatic means.

Table 1/E.424 is used to record the results of test calls undertaken especially when the observations shown in Table 1/E.422 make it clear that the percentage of faults is too high.

The use of customer interviews as a method of measuring telephone service quality is the subject of Recommendation E.125 which is particularly concerned with the determination of sources of user difficulty which may arise when making an international automatic telephone call.

Recommendation E.426 contains a general guide to the expected percentage of effective international call attempts.

Table 1/E.427 may be used to supplement the information contained in Table 1/E.422 when the observations shown in that table make it clear that the percentage of faults due to customer difficulties is too high or the outcome of the application of Recommendation E.125 demonstrates the need for additional information.

Recommendation E.425 describes the data that might be taken from the switching centres with respect to quality of service, and the exchange of that data.

Paying attention to the quality of service of the incoming traffic stream is of major importance, since the incoming Administration is in a better position to improve the situation.

In the past less attention has been paid by several Administrations on the quality of service (QOS) on incoming calls than on outgoing calls. This situation should not persist in the future.

Therefore, in addition to the measurement of QOS of the outgoing traffic stream which is described in this series of Recommendations, Administrations are strongly advised to observe the incoming traffic stream with the aim to improve the QOS.

## 3 Other sources of information on the quality of service

The following sources are identified as being useful to consider when trying to improve the quality of service:

- subscriber complaints;
- other Administrations or organizations such as INTELSAT (SPADE reports);
- operators contacting maintenance staff for direct action;
- operators giving information on QOS: if operator traffic is significant one might consider organizing the flow of this type of information by establishing "trouble codes", e.g. echo, no tone, no answer, etc.;
- reports from "national" switching centres: the QOS as experienced by the subscriber does not only depend on the international network and the network of the country of destination but also on the national network of the country of origin;
- user organizations/large companies: as large companies have much to gain from an improved QOS they might be willing to cooperate with Administrations;
- holding time versus conversation time measurements;
- average conversation time;
- traffic measurements;
- transmission measurements.

## ANNEX A

(to Recommendation E.420)

A possible approach to integrate activities measuring the quality of service into an overall problem-investigating process is given below:

1) check country performance such as answer seizure ratio (ASR) or answer bid ratio (ABR), whichever is appropriate;

2) check the actual daily observations versus the profile as measured in the past;

3) check the country performance with results obtained by other Administrations to the same destination;

4) perform detailed analysis: when possible, monitor circuit groups performance and do analyses of a destination code basis. Furthermore it is essential to be aware of "killer trunks" (it should be noted that observation of the QOS is not directly intended to discover killer trunks);

5) discuss possible improvements with counterpart.

A flowchart of a typical problem identification process is given in Figure A-1/E.420. The numbers 1) through 5) in the figure correspond to the process described above.

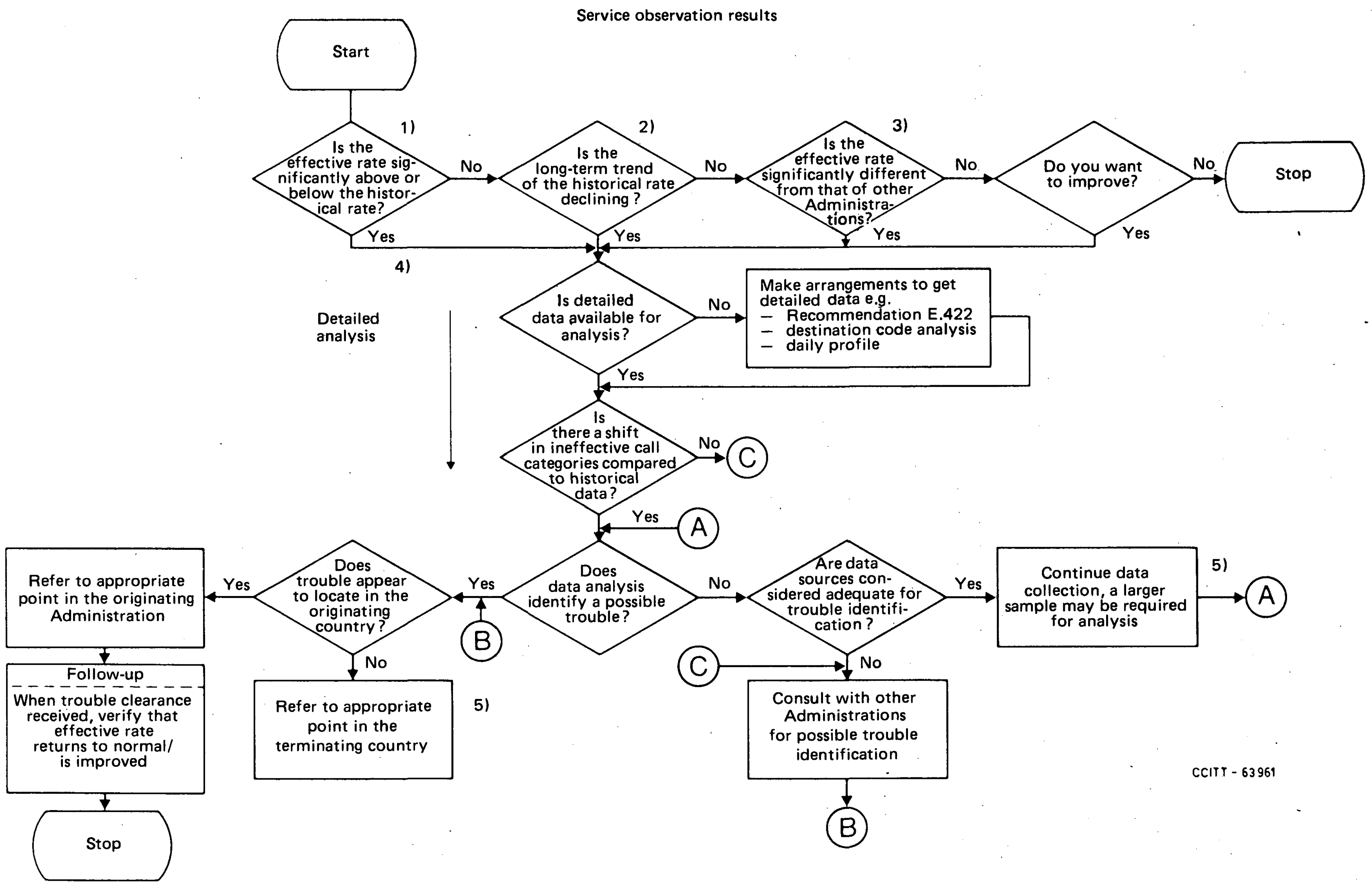


FIGURE A-1/E.420

**Flowchart of problem identification process**

**Recommendation E.421**

## SERVICE QUALITY OBSERVATIONS ON A STATISTICAL BASIS

### 1 Definitions

**1.1 service observation**

*F: observation de la qualité de service*

*S: observación de la calidad del servicio*

Monitoring to obtain a complete or partial assessment of the quality of telephone calls, excluding test calls.

**1.2 manual observation**

*F: observation manuelle*

*S: observación manual*

Monitoring of telephone calls by an observer without using any automatic data-recording machine.

**1.3 automatic observation**

*F: observation automatique*

*S: observación automática*

Monitoring of telephone calls without an observer.

**1.4 semi-automatic observation**

*F: observation semi-automatique*

*S: observación semiautomática*

Monitoring of telephone calls using equipment which records some data automatically. For example, equipment in which information such as exchange being observed, number dialled by the subscriber, metering pulses and time of call are recorded automatically on some means suitable for data processing. The observer merely has to key in a code indicating the condition observed.

### 2 Relative merits of manual, automatic and semi-automatic observations

2.1 The three methods mentioned above in §§ 1.2, 1.3 and 1.4 are not exclusive, for example: automatic observations may be used to supplement observations taken by an operator. It was considered in 1968 that the need for automatic observations would increase in view of the heavy cost associated with manual or semi-automatic observations on the rapidly expanding international network. It was also considered that automatic observations would not entirely supersede observations taken by an observer within the foreseeable future.

The relative merits of the three methods can be assessed as follows:

2.2 *Manual observation*

Provides all the data required in Tables 1/E.422 and 1/E.423.

Observations can be carried out with a minimum of equipment.

Observations can permit the detection of a number of abnormalities which cannot be detected automatically, e.g. very poor speech transmission (item 5.2 of Table 1/E.422), or difficulty with audible tones encountered in the international service (item 6.4 of Table 1/E.422).

### 2.3 *Semi-automatic observation*

Provides all the data required in Tables 1/E.422 and 1/E.423.

There is a saving in staffing costs compared with manual observation.

Greater accuracy compared with manual observation is possible due to the fact that there is an automatic recording of the number dialled, the time of the call, etc.

It is possible for the observer to give more attention to the more critical conditions being checked during observations of calls.

The results are produced in a form suitable for subsequent mechanized analysis.

Owing to the reduction of costs it is possible to obtain a larger sample for the same expenditure.

Semi-automatic equipment may be converted, during certain hours of the day, to automatic operation.

### 2.4 *Automatic observation*

Operating cost is minimum (staff reduction).

Continuous observation is possible.

It is possible to have a larger sample.

Human error is eliminated.

Automatic processing of data is facilitated.

Conversational privacy is ensured.

Control of the time at which observations are made is facilitated.

Some of the differences between internal and external automatic observations are given below:

2.4.1 Internal automatic observations can be made in the switching centre itself, on the incoming side or the outgoing side or in between, according to the way the switching centre is engineered:

a) Only line signals, such as seizure, answer, etc. can be monitored, and also register signals as long as they do not pass through the exchange in an end-to-end signalling procedure.

b) Signals received are only monitored if the exchange itself operates correctly in that respect.

c) Item b) applies also to outgoing signals. If there is a fault in the exchange it can happen that signals have not been sent in the appropriate way without the exchange being aware of it.

More information on this type of observation technique is given in Recommendation E.425.

2.4.2 External automatic observations are made by means of monitoring equipment which is supervising the traffic on incoming or outgoing lines:

- All signalling signals can be monitored.
- The detection of tones, speech and data is possible if advanced equipment is used.
- This observation technique provides all the data required in Table 2/E.422 and Table 2/E.423.
- The application is very flexible and can be used instead of manual or semi-automatic observation techniques.

## 3 Time of observations

The results of all observations taken over the whole day should be recorded in Table 1/E.422 or Table 2/E.422.

In the case where observations are not taken over the whole day the observation period is recorded under the heading "Time of observations" and should include the three busiest hours of the day.

## 4 Observation access points

4.1 Observations for Table 1/E.422 or Table 2/E.422 should be carried out from access points as close as possible to the outgoing international exchange.

The following access points can be considered:

i) outgoing relay set of an international circuit ("exchange" side), i.e. *international circuit access point*[1]);
ii) incoming relay set of a national circuit;
iii) link circuits of the international exchange.

Observations will be made only while the call is being set up, and a few seconds after the called subscriber's reply.

When the circuit access point[1]) is used for observation of international calls it is possible that the service quality of the international exchange may not be checked by either international or national observation programmes.

Preferably, and where technically feasible for the most complete results, observations for Table 1/E.422 should be carried out as close as possible to the international exchange on the national side. This would be more representative of service to the subscriber, and allows observation of call failure at the outgoing international exchange. Where it is not possible to make the distinction between failures in the outgoing international exchange, and failures beyond this exchange, or where there is a meaningful advantage in doing so, observations should be taken on the outgoing side.

It is necessary to state in Table 1/E.422 or Table 2/E.422 the access point where the observations have been made, as observations obtained at each one of the three access points mentioned above are not comparable.

4.2 Observations for Table 1/E.423 must be carried out from access points on the operators' positions.

## 5 Number of observations

5.1 Service observing programmes should be established in such a manner that statistical results obtained be as reliable as practicable bearing in mind the cost of obtaining large samples.

5.2 According to the studies carried out by the CCITT in 1964-1968, the quantities shown below are considered the *minimum* quantities to provide a general indication of the quality of service.

### 5.2.1 *Table 1/E.422*

The minimum number of observations per outgoing circuit group for Table 1/E.422 should be 200 per month when more than 20 circuits are included in a group, 200 per quarter when there are between 10 and 20 circuits in a group and 200 per year if there are less than 10 circuits in a group.

### 5.2.2 *Table 1/E.423*

The minimum number of observations for Table 1/E.423 should be 200 per quarter when there are more than 20 circuits in the group, 200 per semester when there are between 10 and 20 circuits and 200 per year when there are less than 10 circuits in the group.

### 5.2.3 *Transit traffic*

Where an outgoing circuit group also carries transit traffic it is desirable to obtain data for each destination country reached via this circuit group. In principle, the number of observations for each destination should be obtained as indicated above. To accomplish this, one should use for each destination country its corresponding number of erlangs and derive from these erlangs a theoretical number of circuits.

However, where only a very small amount of traffic is handled, e.g. less than 5 erlangs, each Administration may wish either to make a smaller number of observations or (e.g. in case of no complaints) no observations at all and rely on the information obtained at the transit exchange.

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1) For definitions of test access points see Recommendation M.700. See also Recommendation M.110.

5.3 The number of observations specified above will provide a general indication of results on quality of service in certain broad categories. Administrations may desire more accurate results especially for the individual categories in Table 1/E.422.

Attention is drawn to Table 1/E.421 which gives the number of observations required to obtain a certain degree of accuracy.

TABLE 1/E.421

| Expected percentage rate of failure | Number of observations of a random sample required to predict with 95% confidence the true percentage of failure with an accuracy of: | | | | | |
|---|---|---|---|---|---|---|
| | ± 25% | ± 30% | ± 35% | ± 40% | ± 45% | ± 50% |
| 2 | 3136 | 2178 | 1600 | 1225 | 1030 | 880 |
| 4 | 1536 | 1067 | 784 | 600 | 500 | 440 |
| 6 | 1003 | 696 | 512 | 392 | 330 | 290 |
| 8 | 736 | 511 | 376 | 288 | 245 | 215 |
| 10 | 576 | 400 | 294 | 225 | 195 | 170 |
| 12 | 469 | 326 | 239 | 183 | 150 | 132 |
| 14 | 393 | 273 | 201 | 154 | 128 | 112 |
| 16 | 336 | 233 | 171 | 131 | 112 | 98 |
| 18 | 292 | 202 | 149 | 114 | 95 | 80 |
| 20 | 256 | 178 | 131 | 100 | 85 | 70 |
| 30 | 149 | 104 | 76 | 60 | 50 | 42 |
| 40 | 96 | 67 | 50 | 38 | 30 | 24 |
| 50 | 64 | 44 | 33 | 25 | 20 | 16 |

Annex to Table 1/E.421

*Examples of use of Table 1/E.421*

*Example 1* – It is estimated from previous results that a particular type of failure occurs on about 4% of calls. If it is required to confirm, with 95% confidence, that the existing failure rate is between 3% and 5% (i.e. ± 25% of 4%), then observations must be made on a random sample of 1536 calls.

*Example 2* – For an expected failure rate of 2%, observations must be made on a random sample of about 1200 calls (1225 in the table) to predict, with 95% confidence, that the true percentage is between 1.2% and 2.8% (i.e. ± 40% of 2%). This means that when 200 observations are taken over a period it is necessary to take the "rolling average" of conditions over six periods. The rate of failure for a number of categories important from the maintenance point of view is expected to be about 2%.

*Example 3* – After observations have been taken and the rate of failure in the sample has been calculated, the table may be used in a "backward" direction to give a rough indication of the accuracy of the result.

Suppose that out of a sample of 1000 observations, there were 29 failures due to cause "X" and 15 failures due to cause "Y". The rates of failure in the sample due to X and Y, respectively, are then 2.9% and 1.5%. From the table, it is apparent from this sample of 1000 calls that the true rate of failure due to X has an accuracy of about ± 35% (i.e. is between 1.9% and 3.9%), and that due to Y has an accuracy of about ± 50% (i.e. is between 0.8% and 2.3%).

## 6 Exchange and analysis of the results of observations

### 6.1 *Exchange of the results of observations*

The following periodicities are proposed for the exchange of results between Administrations:

Table 1/E.422 or Table 2/E.422 – a monthly exchange is desirable;

Table 1/E.423 or Table 2/E.423 –, a quarterly exchange is desirable.

Nevertheless, in the case of small groups of circuits (less than 20 circuits) the information should be exchanged after 200 observations have been made but never later than one year in any case; attention is drawn to the fact that less than 200 observations are of little value.

Results of observations will be reported without delay:

- to the Administrations and the network analysis point of the country where observations are carried out;
- to the Administrations and the network analysis point of the other country (including transit Administrations and their network analysis point when involved).

The benefits to be derived from service observations tend to decrease if there is any increase in the time taken to make the results available to those who can take action to bring about an improvement. The results of service observations according to Tables 1/E.422 and 1/E.423 should therefore be made available to the Administration in the countries of destination as soon as possible after completion of the observation period and in any case within six weeks.

6.2 *Analysis of observation results*

An analysis of the results should be carried out in the country of origin as well as in the country of destination.

Some Administrations have found it useful to distribute to other Administrations concerned, service observation statistics in the form of graphs.

**Recommendation E.422**

## OBSERVATIONS ON INTERNATIONAL OUTGOING TELEPHONE CALLS FOR QUALITY OF SERVICE

### 1 Objectives concerning Table 1/E.422 and Table 2/E.422

1.1 The purpose of service observation in the international service is to assess the quality of service obtained by the calling subscriber. Consequently, it is essential to have factual or objective recording of observations (i.e., successful and unsuccessful calls), and to present them in the form of a table (see Table 1/E.422 for manual or semi-automatic observations and Table 2/E.422 for automatic observations).

### 2 Manual or semi-automatic observations (Table 1/E.422)

2.1 Table 1/E.422 should be capable of being completed through the use of a wide range of observation facilities, i.e. from the simple to the sophisticated.

2.2 Specialized training of observers should be kept to a minimum.

2.3 The table should be self-explanatory so that reference to detailed how-to-complete instructions is unnecessary.

2.4 The major categories should be selected so that they:

- identify the major factors adversely affecting the quality of service;
- are suitable for the centralized processing of observation results.

2.5 To permit the orderly collection of data for human factors studies to identify sources of difficulty in customer use of the international (automatic) telephone service, Recommendation E.427 contains an additional table to Table 1/E.422.

### 3 Comments concerning the use of Table 1/E.422

3.1 Table 1/E.422 summarizes observations made on outgoing automatic and/or semi-automatic traffic, on a country of origin to a country of destination basis. A separate form should be used for each country of destination, and if required, for each group of circuits to which traffic to a country of destination has access at the outgoing international exchange (or exchanges). It is not necessary to make observations on both automatic and semi-automatic services. An Administration may select the service to be observed, provided that the service is the majority of the traffic to the country of destination.

TABLE 1/E.422

**Observations of international outgoing telephone calls for quality of service**

Country of origin ................................................................

Outgoing international exchange ....................................

Group of circuits ................................................................

Service { automatic [a) ] / semi-automatic [a)]

Period: from ............................. to ..................................

Point of access:

National side ............................................................

Link circuits ............................................................

Outgoing side ............................................................

Time of observations ..........................................................

| Category | Number | | Percentage | |
|---|---|---|---|---|
| | Subtotal | Total | Subtotal | Total |
| 1. Calls successfully put through (see note 1) . . . . . . . . . . . . . . . . | | . . . | | . . . |
| 2. Ring tone received but no answer . . . . . . . . . . . . . . . . . . . | | . . . | | . . . |
| 3. Unsuccessful calls: *Positive* indication of congestion, including subscriber busy, from beyond the outgoing international exchange. Visual signal, tone or recorded announcement . . . . . . | | . . . | | . . . |
| 3.1 Subscriber busy/congestion indicated by visual signal . . . . . . | . . . | | . . . | |
| 3.2 Subscriber busy/congestion indicated by busy/congestion tone . | . . . | | . . . | |
| 3.3 Congestion indicated by a recorded announcement . . . . . . . | . . . | | . . . | |
| 4. Unsuccessful calls: Other visual signals, tones or recorded announcements, not positively identified as category 3 or 8 . . . . . | | . . . | | . . . |
| 4.1 Visual signal received . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 4.2 Tone received . . . . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 4.3 Recorded announcement received . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 5. Unsuccessful calls for other technical reasons . . . . . . . . . . . . . | | . . . | | . . . |
| 5.1 Wrong number obtained . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 5.2 Abandoned due to very poor speech transmission . . . . . . . . | . . . | | . . . | |
| 5.3 No tone, no answer after waiting ..... seconds . . . . . . . . . . . | . . . | | . . . | |
| 5.4 Reception of answer signal when the called party does not reply . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 5.5 Other failures of a technical kind . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 6. Unsuccessful calls due to incorrect handling by the calling party . . | | . . . | | . . . |
| 6.1 Wrong number dialled . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 6.2 Incomplete number . . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 6.3 Call prematurely abandoned before receipt of signal, tone or announcement (within less than ..... seconds) . . . . . . . . . . . | . . . | | . . . | |
| 6.4 Call prematurely abandoned after receipt of ring tone (within less than 30 seconds) . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 6.5 Other failures due to incorrect handling . . . . . . . . . . . . . . | . . . | | . . . | |
| 7. *Total calls monitored* (categories 1-6) . . . . . . . . . . . . . . . . . | | . . . | | 100 |
| 8. Unsuccessful calls: *Positive* indication of failure from outgoing international exchange . . . . . . . . . . . . . . . . . . . . . . . . . . . . | | . . . | X | X |
| 8.1 Congestion on outgoing international circuits . . . . . . . . . . . | . . . | | X | X |
| 8.2 All other indications . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | X | X |
| 9. Successful calls with defects. These calls are included in category 1 . | | . . . | X | X |
| 9.1 Non-reception of answer signal on chargeable calls . . . . . . . . | . . . | | X | X |
| 9.2 Call with impaired intelligibility but not abandoned . . . . . . . | . . . | | X | X |
| 9.3 Other calls with defects but not abandoned . . . . . . . . . . . . | . . . | | X | X |

a) Delete whatever is inapplicable.

*Note 1* — A successful call is one that reaches the wanted number and allows conversation to proceed. All successful calls are entered in category 1. However, a successful call may or may not have noticeable defects. Successful calls with noticeable defects should also be entered in category 9.

*Note 2* — With the exception noted above for categories 1 and 9, the results of one call observation should be entered under one category only, namely the most appropriate one from (1) to (6).

*Note 3* — Administrations should periodically exchange necessary information to interpret the observation data recorded under categories 4.1, 4.2 and 4.3.

3.2 For an explanation of the point of access, see Recommendation E.421, § 4.1.

3.3 The result of each call observed should be entered only under the most appropriate category. In the case of several faults on one call, the most significant cause of failure should be entered.

3.4 In completing Table 1/E.422 reference should be made to the following explanations.

## 4 How to fill in Table 1/E.422

*Category 1* – To ensure objective recording and to avoid producing a biased sample resulting from the exclusion of calls which require subjective assessment, the successful call is defined as a call that reaches the wanted number and allows conversation to proceed. All non-abandoned calls are entered into category 1 and of these calls those which are subjectively adjudged to be defective are also entered into category 9. Thus it is required of the observer to make *two* entries for successful calls with noticeable defects.

Enter in category 1 then, calls successfully put through. This includes answered calls for which a clearback signal is received after some words have been spoken, without knowing for what reason the call is abandoned. If it is observed that the caller has dialled a wrong number, the call will be entered under 6.1. Category 1 will also include calls put through correctly to operator positions, information services, or to machines replying in place of the subscriber or to their equivalents.

*Category 2* – Enter in this category calls on which ring tone was heard but the subscriber did not answer before the attempt was abandoned, the caller having waited at least 30 seconds after commencement of ring tone before clearing forward. (See category 6.4 if the call was abandoned *less* than 30 seconds after ring tone commenced.)

*Category 3* – Enter in this category all unsuccessful calls in which a *positive* indication of subscriber busy or congestion beyond the outgoing international exchange had been encountered, either by visual signal, tone or recorded announcement. Congestion encountered on common control equipment should be entered in this category as well (e.g. no "proceed-to-send" signal). Where a positive indication of these conditions has *not* been received, enter in category 4.

Categories 3.1, 3.2 and 3.3 are entered for the specific indication received.

When more than one indication is received, e.g. visual signal and audible tone, only one entry should be made. In this case, the preferred order of entry should be tone, announcement, visual signal.

*Category 4* – Enter in this category all other indications on unsuccessful calls whether by visual signal, tone or recorded announcement that cannot be positively identified and entered in category 3 or 8.

Categories 4.1, 4.2 and 4.3 are entered for the specific indication received.

When more than one indication is received, e.g. visual signal and audible tone, only one entry should be made. In this case, the preferred order of entry should be tone, announcement, visual signal.

*Category 5* – Enter in this category those calls which fail for technical reasons not included in categories 3, 4 and 8. Category 5 subdivides as follows:

*Category 5.1* – Calls on which the wrong number was obtained, although the caller dialled correctly.

*Category 5.2* – Calls abandoned by the caller because of very poor speech transmission, although the answer signal was received. (See category 9.2 if speech transmission is poor but the call is not abandoned.) In some countries observers may be required to cease listening immediately after conversation is established, thus reducing the number of calls that would be reported in this category.

*Category 5.3* – Calls on which the dialling information was correctly and completely sent, but the caller received no signal, tone or announcement before abandoning the call, having waited for at least the specified period before clearing forward.

The value of this time period left open under this category should be filled in by the Administrations of the originating country according to its experience in this matter. The prescribed value may differ depending on the international destination. It is, however, recommended to limit the number of such different quoted periods to a maximum of three values (e.g. 10, 20 or 30 seconds or any other value considered pertinent by the Administrations concerned).

*Category 5.4* – Calls on which an answer signal was received, although the called subscriber did not answer.

*Category 5.5* – Call failures due to technical reasons which are unable to be entered in categories 5.1 to 5.4. These should be very few, if any, and this category is provided in case they do arise. All possible information about these failures should be supplied as an attachment to the summary of the table. This category includes calls abandoned due to reception of a clear-back signal while connecting with the extension number (PBX).

*Category 6* – Enter in this category all unsuccessful calls which have failed due to incorrect handling by the caller (subscriber or operator). Category 6 subdivides as follows:

*Category 6.1* – Calls on which it was determined that the number which should have been dialled was different from the number actually dialled.

*Category 6.2* – Calls on which it was determined that the number dialled had insufficient digits to be successful.

*Category 6.3* – Calls on which the digital information was correctly and completely sent, but the caller abandoned the call without receiving any signal, tone or announcement, and without waiting for at least the specified period.

The value of the time period left open under this category should be filled in by the Administrations of the originating country according to its experience in this matter. The prescribed value may differ depending on the international destination. It is, however, recommended to limit the number of such different quoted periods to a maximum of three values (e.g. 10, 20 or 30 seconds or any other value considered pertinent by the Administration concerned).

The value quoted under category 6 must be the same as that quoted under category 5.

*Category 6.4* – Calls prematurely abandoned after receipt of the ringing tone on which the caller disconnected less than 30 seconds after the ringing tone commenced. (See category 2 if the call was abandoned after *more* than 30 seconds had elapsed from the time of commencement of ringing tone.)

*Category 6.5* – Calls which failed due to incorrect handling by the caller which cannot be classifed under categories 6.1 to 6.4. All possible information about these failures should be supplied as an attachment to the summary of the table. As in categories 5.5, these should be very few, if any.

*Category 7* – Enter in category 7 the number of calls monitored (categories 1-6).

*Category 8* – Category 8 will be useful for those Administrations which observe on the national side of the outgoing international exchange. (See Recommendation E.421, § 4.1.) Positive indications of failure, congestion or other, are to be entered here. They are not to be included with categories 1-6, which give the data for calls monitored for category 7.

Thus, when category 8 is viewed with categories 3 and 4 a more complete picture is provided of quality of service received by the caller.

*Category 9* – Entries in category 9 are for successful calls (entered in category 1) which encountered defects, but which were not abandoned. They are thus automatically included in the total of category 7.

*Category 9.1* – Enter here chargeable calls for which no answer signal was received. If abandonment should be detected on such calls, enter in category 5.5.

*Category 9.2* – Enter here calls on which poor speech transmission was observed, but the call was not abandoned. (See category 5.2 if the call was abandoned.) All possible information about these calls should be supplied as an attachment to the summary of the table. Note that in some countries observers may be required to cease listening immediately after conversation was established, thus reducing the number of calls that would be reported under this category.

*Category 9.3* – Enter here calls encountering switching, signalling or transmission defects, but which were not abandoned and which cannot be classified under categories 9.1 or 9.2.

## 5 **Automatic observations** (Table 2/E.422)

Considering the limitation of abilities of automatic observation equipment (for example, automatic observation equipment cannot understand announcements) and the variety of signals used in signalling systems, the table recommended for CCITT Signalling System No. 5 is given below.

TABLE 2/E.422

**Automatic observations of international outgoing telephone calls for quality of service**

Country of origin . . . . . . . . . . . . . . . . . . . . . . . . . .

Outgoing international exchange . . . . . . . . . . . . . . . . .

Group of circuits . . . . . . . . . . . . . . . . . . . . . . . . . .

Service { automatic [a) ] / semi-automatic [a)]

Period: from . . . . . . . . . . . . to . . . . . . . . . . . . . . .

Point of access

National side . . . . . . . . . . . . . . . . . . . . . . . . . .

Link circuits . . . . . . . . . . . . . . . . . . . . . . . . . .

Outgoing side . . . . . . . . . . . . . . . . . . . . . . . . .

Time of observations . . . . . . . . . . . . . . . . . . . . . . . .

| Category | Number | | Percentage | |
|---|---|---|---|---|
| | Subtotal | Total | Subtotal | Total |
| 1. Calls successfully put through . . . . . . . . . . . . . . . . . . . . . | | . . . | | . . . |
| 2. Ring tone received but no answer . . . . . . . . . . . . . . . . . . . | | . . . | | . . . |
| 3. Unsuccessful calls: *Positive* indication of congestion, including subscriber busy, from beyond the outgoing international exchange. Visual signal or tone . . . . . . . . . . . . . . . . . . . . | | . . . | | . . . |
| 3.1 Subscriber busy/congestion indicated by visual signal . . . . | . . . | | . . . | |
| 3.2 Subscriber busy/congestion indicated by busy/congestion tone . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 4. Unsuccessful calls: Other tones or recorded announcements, not positively identified as category 3 or 8 . . . . . . . . . . . . . . . . | | . . . | | . . . |
| 4.1 Tone received . . . . . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 4.2 Recorded announcement received . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 5. Unsuccessful calls for other technical reasons . . . . . . . . . . . . | | . . . | | . . . |
| 5.1 No tone, no answer signals after waiting ..... seconds . . . . . | . . . | | . . . | |
| 5.2 Reception of answer signal when the called party does not reply . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 5.3 Other failures of a technical kind . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 6. Unsuccessful calls due to incorrect handling by the calling party | | . . . | | . . . |
| 6.1 Call prematurely abandoned before receipt of signal, tone or announcement (within less than ..... seconds) . . . . . . . . . . | . . . | | . . . | |
| 6.2 Call prematurely abandoned after receipt of ring tone (within less than 30 seconds) . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 6.3 Other failures due to incorrect handling . . . . . . . . . . . . | . . . | | . . . | |
| 7. *Total calls monitored* (categories 1-6) . . . . . . . . . . . . . . . . . | | . . . | | 100 |
| 8. Unsuccessful calls: *Positive* indication of failure from outgoing international exchange . . . . . . . . . . . . . . . . . . . . . . . . . | | . . . | X | X |
| 8.1 Congestion on outgoing international circuits . . . . . . . . . | . . . | | X | X |
| 8.2 All other indications . . . . . . . . . . . . . . . . . . . . . . . | . . . | | X | X |
| 9. Successful calls with defects. These calls all included in category 1 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | | . . . | X | X |
| 9.1 Non-reception of answer signal on chargeable calls . . . . . . | . . . | | X | X |
| 9.2 Other calls with defects . . . . . . . . . . . . . . . . . . . . . | . . . | | X | X |

a) Delete whatever is inapplicable.

## 6 Comments concerning the use of Table 2/E.422

6.1 Table 2/E.422 summarizes observations made on outgoing automatic and semi-automatic traffic, on a country of origin to a country of destination basis. A separate form should be used for each country of destination, and if required, for each group of circuits to which traffic to the country of destination has access at the outgoing international exchange (or exchanges).

6.2 For an explanation of the point of access, see Recommendation E.421, § 4.1.

6.3 The result of each call observed should be entered only under the most appropriate category. In the case of several faults on one call, the most significant cause of failure should be entered.

6.4 As the function of sound analysis by automatic observation equipment is not concerned with the signalling system used and since some signalling systems e.g. Signalling System No. 6 have more information exchanged in the signalling system than those of sound signals, it is expected that the proposed table will be applied to all signalling systems for the present.

6.5 In completing Table 2/E.422 reference should be made to the following explanations.

## 7 How to fill in Table 2/E.422

*Category 1* – The successful call is defined as a call that allows conversation to begin between subscribers, or allows to begin sending facsimile or data. This includes calls put through to operator positions, information services, or to machines replying in place of the subscriber or to their equivalents. In other words, the successful call is such that the automatic observation equipment detected voice on both sending and receiving lines, or that it detected sending tone of facsimiles or data, or that it detected voice on the receiving line after receipt of answer signal.

*Category 2* – This category includes those calls for which the automatic observation equipment detected ringing tone, but there was no answer signal and the clear-forward signal was sent 30 seconds after the detection of ringing tone.

*Category 3* – Enter in category 3 all unsuccessful calls for which a positive indication of subscriber busy or congestion beyond the outgoing international exchange has been encountered, either by visual signal (busy-flash signal) or by tone (also includes no "proceed-to-send" signal).

*Category 4* – Enter in category 4 unsuccessful calls for which the automatic observation equipment detected a tone, but could not classify it, or the equipment detected announcement (that is, it detected voice on receiving line without answer signal).

*Category 5* – Enter in category 5 those calls which failed for technical reasons not included in categories 3, 4 and 8. Category 5 subdivides as follows:

> *Category 5.1* – Calls on which the dialling information was completely sent, but the automatic observation equipment received no signal, tone or announcement and it received a clear-forward signal after a specified period. The value of this time period left open under this category should be filled in by the Administrations of the originating country according to its experience in this matter. The prescribed value may differ depending on the international destination. It is, however, recommended to limit the number of such different quoted periods to a maximum of three values (e.g. 10, 20 or 30 seconds or any other value considered pertinent by the Administrations concerned).
>
> *Category 5.2* – Calls on which an answer signal was received, although the called subscriber did not answer. In other words, calls for which the automatic observation equipment received an answer signal, although it detected no voice on receiving line.
>
> *Category 5.3* – Failed calls due to technical reasons which are unable to be entered in categories 5.1 and 5.2. For example, a call for which there was a busy-flash signal after receiving ringing tone.

*Category 6* – Enter in category 6 all unsuccessful calls which have failed due to incorrect handling by the caller (subscriber or operator). Category 6 subdivides as follows:

> *Category 6.1* – Calls on which the dialling information was completely sent, but the automatic observation equipment received no signal, tone or announcement and it received a clear-forward signal within a specified period. (For this period, see category 5.1 above.)
>
> *Category 6.2* – Calls prematurely abandoned after receipt of the ringing tone on which a clear-forward signal was received less than 30 seconds after the ringing tone was detected.

*Category 6.3* – Calls which failed due to incorrect handling by the caller which cannot be classified under categories 6.1 and 6.2. For example, a call for which the automatic observation equipment received an answer signal after receiving ringing tone, and then the ringing tone stopped, but the equipment could not detect any voice either on the sending line or the receiving line.

*Category 7* – Enter in category 7 the number of calls monitored (categories 1-6).

*Category 8* – Category 8 will be useful for those Administrations which observe on the national side of the outgoing international exchange. Positive indications of failure, congestion or other, are to be entered here.

*Category 9* – Entries in category 9 are for successful calls (entered in category 1) which encountered defects. Category 9 subdivides as follows:

*Category 9.1* – Calls on which no answer signal was received, but the conversation was begun.

*Category 9.2* – Calls which encountered switching or signalling defects, but on which the conversation was begun.

**Recommendation E.423**

# OBSERVATIONS ON TRAFFIC SET UP BY OPERATORS

## 1 Comments concerning the use of Table 1/E.423

1.1 This table summarizes observations relating to manual and semi-automatic outgoing traffic originated by operators. These observations will be made, if possible, during the whole call duration. Observations for the categories 1 to 7 may be omitted in case of semi-automatic service, if there is no problem regarding the efficiency of international circuits.

1.2 Administrations should, if possible, make a distinction between the different types of call, e.g. station-to-station, personal and collect calls; they should use a separate column for each under the heading "Type of call".

1.3 For collect calls, the times to be recorded will be those observed in the country where the call request was made.

1.4 It is recommended that these observations be spread over the whole day.

1.5 Each outgoing Administration will select the international circuit groups on which observations should be carried out.

1.6 In completing this table, reference should be made to the following explanations:

## 2 How to fill in Table 1/E.423 (Traffic observations determined by the operators)

*Category 1* – This category should show the mean duration of calls observed which are successful and have been charged for ("effective" calls).

*Category 2* – This category will show the mean *chargeable* duration of all effective calls observed.

*Category 3* – This category will show, for each type of observed call, the average time per effective call during which the international circuit has been occupied for manoeuvres or for call preparation.

This average should be based on the time during which the international circuit is held:

a) to obtain information concerning the called number;

b) to obtain information about routing and trunk codes;

c) to call operators, in the incoming international exchange;

d) to exchange information on how to set up the call;

e) to (or attempt to) obtain the called number even when it is engaged or does not reply;

f) to (or attempt to) obtain the called person (in personal calls);

g) between replacement of the receiver by the called person and release of the circuit;

h) because the operator is holding the circuit (whether she is on the line or not) and for any other reasons for which the circuit is engaged.

TABLE 1/E.423

**Observations on traffic set up by operators**

International outgoing exchange: ..........

Circuit group: ..........

Service { semi-automatic [a] / manual [a] }

Period from .......... to ..........

| Category | Type of call [b] | | | |
|---|---|---|---|---|
| | Ordinary | Personal | | |
| 1. Mean call duration – in seconds | | | | |
| 2. Mean chargeable duration – in seconds | | | | |
| 3. Mean holding time of circuits for manœuvres and preparation of calls – in seconds | | | | |
| 4. Number of effective calls observed | | | | |
| 5. Mean number of times the international circuit was seized per effective call | | | | |
| 6. Mean number of "attempts" per effective call | | | | |
| 7. Percentage of calls set up at the first "attempt" | | | | |

| 8. Time-to-answer by operators | Total number of calls answered and unanswered | | Calls answered | | | | | | Calls unanswered (abandoned calls) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number | Mean waiting time in seconds | under 15 seconds | | in 15 to 30 seconds | | after 30 seconds | | within 30 seconds | | after 30 seconds | |
| Operators: | | | No. | % | No. | % | No. | % | No. | % | No. | % |
| — incoming operator (code 11) | | | | | | | | | | | | |
| — delay operator (code 12) | | | | | | | | | | | | |
| — assistance operator | | | | | | | | | | | | |
| — information operator | | | | | | | | | | | | |

| 9. Quality of transmission from the subscriber's viewpoint: | Number | % | 10. Comments |
|---|---|---|---|
| — good | | | |
| — defective | | | |
| Total | | 100 | |

[a] Delete whichever is inapplicable.
[b] In accordance with § 1.2.

The times listed above, which exclude the conversation time, should be added together. This total should be divided by the number of effective calls observed during the period in question to obtain the value to be entered in Table 1/E.423.

*Category 4* – The number of effective calls observed considered in category 1.

*Category 5* – The mean number of times the international circuit was seized per effective call (see category 3). This number is usually obtained by meter recordings.

*Category 6* – The mean number of *attempts* (as specifically defined hereafter from the operating point of view to set up a call. Should the operator try several times to set up a call while continuously occupied on that call, all these operations must be considered as being one attempt. Similarly, if the operator makes several tries to set up a call and each time encounters a congestion or busy condition and if, after the last try, she informs the caller, only one attempt must be entered. Calls to information services or to obtain routing particulars, and all calls not directly related to the establishment of a call or to information required by the caller, should not be considered as attempts and should not be included.

The total number of attempts during the period of observation should be divided by the number of effective calls observed in the same period to obtain the mean number of attempts per call.

The total number of attempts is usually determined from markings or notations on call tickets.

*Category 7* – The data for this category will be taken from all tickets prepared for the relation concerned, during the period of observation or a comparable period.

*Category 8* – The mean waiting time for outgoing operators to receive an answer will be indicated in seconds. This average will include both answered and unanswered calls.

An outgoing operator waits on the circuit (waiting time) for the period:

a) until the incoming operator answers, or

b) until she abandons the attempt, should the incoming operator not answer.

Thus while mean waiting time relates to the outgoing operator it is also a measure of the performance of the incoming operators.

*Category 9* – It will be difficult to obtain absolutely comparable results from all observers for this category. However, the observer should consider the quality of transmission from the subscribers' viewpoint, taking into account comments made in this respect by subscribers and the number of requests for conversation to be repeated.

*Category 10* – This category should include any comments likely to explain the probable cause of difficulties frequently noted during the observations.

## 3 **Automatic observations of the time-to-answerby operators** (Comments concerning the use of Table 2/E.423)

3.1 This table summarizes observation of the time-to-answer by operators.

3.2 Administrations should make a distinction between the different types of incoming operators if the types of operators are distinguished by the selecting digits.

3.3 It is recommended that these observations be spread over the whole day.

3.4 Each outgoing Administration will select the international circuit groups on which observations should be carried out.

3.5 The time-to-answer of the assistance operator cannot be measured automatically.

3.6 In completing this table, reference should be made to the explanations in § 4.

## 4 **How to fill in Table 2/E.423** (Automatic observations of the time-to-answer by operators)

The mean waiting time for outgoing operators to receive an answer will be indicated in seconds. This average will include both answered and unanswered calls.

The mean waiting time is defined as the time interval between the instant the outgoing circuit is seized (the seizing signal is sent) and:

a) the instant the incoming operator answers, or

b) the instant the outgoing operator abandons the attempt (a clear-forward signal is sent).

TABLE 2/E.423

**Automatic observations of the time-to-answer by operators**

International outgoing exchange . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Circuit group . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

Service: semi-automatic

Period from . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . to . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

| Time-to-answer by operators | Total number of calls answered and unanswered | | Calls answered | | | | | | Calls unanswered (abandoned calls) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number | Mean waiting time in seconds | under 15 seconds | | in 15 to 30 seconds | | after 30 seconds | | within 30 seconds | | after 30 seconds | |
| Operators: | | | Number | % | Number | % | Number | % | Number | % | Number | % |
| – incoming operator | | | | | | | | | | | | |
| – delay operator | | | | | | | | | | | | |
| – information operator | | | | | | | | | | | | |

**Recommendation E.424**

## TEST CALLS

### 1 General

Test calls carried out manually or automatically to assess the functioning of international circuits or connections are of four types:

a) *Type 1 test call*

A test call conducted between two directly connected international centres to verify that the transmission and signalling on an international circuit of a given group are satisfactory.

b) *Type 2 test call*

A test call conducted between two international centres not directly connected to verify transit operational facilites of an intermediate international centre.

c) *Type 3 test call*

A test call from an international centre to a subscriber type number in the national network of the distant country, generally as a result of a particular kind of fault.

d) *Subscriber-to-subscriber type test call*

A subscriber-to-subscriber type test call is a test call from a test equipment having the characteristics of an average subscriber line in one national network to a similar equipment in the national network of a distant country.

Test calls types 1, 2, 3 and subscriber-to-subscriber test calls must not interfere with customer traffic. If, however, test calls contributing a significant load on a part of a network are to be made, prior advice should be given to the other Administration(s) concerned. Types 1 and 2 test calls for preventive maintenance should be conducted during light load periods. Types 1 and 2 test calls should be conducted as and when required for the investigation and clearance of faults.

Type 3 test calls should be conducted only after adequate testing has been done by means of type 1 or 2 test calls and after the distant Administration has made the necessary check in its national network. Type 3 test calls should be conducted during light load periods.

In order to find faults in last-choice equipment, it may be necessary for tests to be carried out at the time when the traffic load approaches the full capacity of the route under test. The agreement of the distant network analysis point will be necessary before this test is carried out.

Subscriber-to-subscriber type test calls can be made by agreement of the network analysis point in the countries concerned.

Normally, unless there is a specific agreement between the Administrations concerned, subscriber-to-subscriber type test calls would be considered for fault location after:

1) verifying that there are no evident faults in the international switching centres involved that would cause the poor quality of service or subscriber complaint being investigated;
2) verifying that type 1 or type 2 test calls have been made on the international circuits that might have been involved;
3) verifying that there are no evident faults in the national network from the outgoing exchange to the international centre in the originating country;
4) verifying that there are no evident faults in the national network in the distant country, from the international centre to the called exchange.

When subscriber-to-subscriber type test calls are made, the network analysis point in the two countries should consider such factors as:

i) the expected nature of the fault;
ii) international accounting agreements;
iii) the need for making the test calls in the busy hour;
iv) the possibility of causing or aggravating congestion at the time the calls are made.

The responding equipments used for subscriber-to-subscriber type test calls could be those used for maintenance of the national network.

## 2 **Results of test calls** (see Table 1/E.424)

## 3 Comments concerning the use of Table 1/E.424

3.1 Table 1/E.424 summarizes tests carried out manually or automatically to assess the functioning of the international circuit or connection.

3.2 It is essential to indicate clearly the way in which the tests have been carried out and to give full information about the testing apparatus used.

3.3 Administrations may insert additional categories in Table 1/E.424 as they see fit.

TABLE 1/E.424

**Results of test calls**

International outgoing exchange: ........................................................................................

Circuit group: ........................................................................................

Service { semi-automatic [a)] / automatic [a)]

Period from .............................................. to ......................................................................

Type of test call
Type 1 [a)]
Type 2 [a)]
Type 3 [a)]
Sub-to-Sub [a)]

| Category | Number | | Percentage | |
|---|---|---|---|---|
| | Subtotal | Total | Subtotal | Total |
| 1. Satisfactory tests . . . . . . . . . . . . . . . . . . . . . . . . . . . . | | . . . | | . . . |
| 2. Signalling and charging faults . . . . . . . . . . . . . . . . . . . . . | | . . . | | . . . |
| 2.1 Wrong number . . . . . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 2.2 No tone, no answer . . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 2.3 Absence of a backward line signal . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 2.4 Other faults . . . . . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 3. Transmission faults . . . . . . . . . . . . . . . . . . . . . . . . . . . | | . . . | | . . . |
| 3.1 Conversation impossible . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 3.2 Call overamplified or underamplified . . . . . . . . . . . . . . . | . . . | | . . . | |
| 3.3 Noise . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 3.4 Fading . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 3.5 Crosstalk . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | . . . | | . . . | |
| 4. Congestion . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | | . . . | | . . . |
| 5. Other faults . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | . . .<br>. . .<br>. . . | . . . | . . .<br>. . .<br>. . . | . . . |
| Tests carried out . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | | . . . | | 100 |
| Test procedure followed (apparatus used, destination of calls, etc.) | | | | |

[a)] Delete whichever is inapplicable.

# INTERNAL AUTOMATIC OBSERVATIONS[1)]

## 1 Definitions

### 1.1 essential information (of internal automatic observations)

The answer seizure ratio (ASR) (see § 1.3) or answer bid ratio (ABR) (see § 1.4), whichever is appropriate in terms of attempts, completed attempts and percentage completed.

### 1.2 supplementary information (of internal automatic observations)

Information on signalling faults, subscriber behaviour and the network.

### 1.3 answer seizure ratio (ASR)

ASR gives the relationship between the number of seizures that result in an answer signal and the total number of seizures. This is a direct measure of the effectiveness of the service being offered and is usually expressed as a percentage as follows:

$$\text{ASR} = \frac{\text{Seizures resulting in answer signal}}{\text{Total seizures}} \times 100$$

Measurement of ASR may be made on a route or on a destination code basis.

### 1.4 answer bid ratio (ABR)

Gives the relationship between the number of bids that result in an answer signal and the total number of bids.

$$\text{ABR} = \frac{\text{Bids resulting in answer signal}}{\text{Total bids}} \times 100$$

ABR is expressed as a percentage and is a direct measure of the effectiveness of traffic from the point of measurement. It is similar to ASR except that it includes bids that do not result in a seizure.

## 2 Merits of internal automatic observations

The advantage of internal monitoring is the large volume of records which can be collected. The large volume of data obtained from an internal observation system allows day-to-day evaluation of network performance. Daily analysis of this information has proven invaluable in trouble detection, and coupled with a good maintenance response, is instrumental in providing the best possible quality of service.[2)] The disadvantage is that this method does not have the capability of detecting tones or speech and therefore cannot present a complete representation of all call dispositions.

To overcome this disadvantage Administrations are recommended to use also Recommendation E.422 to supplement the data obtained from internal automatic observations.

## 3 Time of observations

The results of all observations taken over the whole day should be recorded.

1) This Recommendation also applies in case external monitoring equipment is used when a route is monitored constantly for all or a large (statistical significance) number of calls. Refer to Recommendation E.421, § 2.4.

2) Using these techniques one can improve the quality of service even when no distinction can be made between: ring no answer, subscriber busy (or congestion indicated by congestion tone) and recorded announcement.

## 4 Exchange of the results of observations

4.1 The essential information[3] should be exchanged monthly (preferably by facsimile or telex) to all network analyses points of those Administrations who are interested (the analyses points can then make comparisons between different streams going to the same destination). If information on ASR or ABR can be supplied separately for direct routes and indirect routes via transit countries, this should also be exchanged as being essential information, including the name of the transit country involved.

4.2 With respect to supplementary data such as: signalling faults, failures due to calling subscriber, failures due to called subscriber and failures due to the network, a quarterly exchange of information is appropriate. Because different formats will be required, mail seems the most likely means to be used for exchanging supplementary data.

4.3 Besides the monthly and quarterly exchange of information, a direct contact on all aspects should be made (by telephone) as soon as action is required to prevent a persistent drop in the quality of service.

## 5 Classes of calls

The distinction between classes of calls (such as operator-operator, subscriber-subscriber and operator-subscriber) is considered useful in identifying problems relating to the quality of service. This can only be done if the language digit[4] and some of the subsequent digits are analyzed.

## 6 Destination analysis from service observation data

Consideration should be given to include the dialled digits, as observed by the monitoring equipment, in the exchange of information, especially for the sake of destination analyses (see Recommendation E.420, Annex A).

## 7 Details about supplementary information for CCITT Signalling System No. 5

### 7.1 *Signalling faults*

- faulty signals;
- time outs, the main item in this category being no proceed-to-send signal;
- busy flash. (Since busy flash is applied in many situations, including failures due to calling and called subscriber and the network, it is considered useful to distinguish between busy flash received within 0-15 seconds, 15-30 seconds and after 30 seconds when making destination analysis.)

### 7.2 *Ineffective calls associated with the calling subscriber*

Premature release, to distinguish between release before or after having received ringing tone; equipment which can detect audible signals is required.

### 7.3 *Ineffective calls associated with the called subscriber*

Ringing tone no answer cannot be detected without equipment which can detect audible signals.

### 7.4 *Network*

Here only the busy flash can be detected without equipment which can detect audible signals.

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3) The Administration supplying the data must indicate whether the ASR or ABR is used.

4) The language or discrimination digit is inserted automatically, or by the operator, between the country code (Recommendation E.161) and the national (significant) number.

## 8 Equipment impact

8.1 Administrations are recommended to consider inclusion of appropriate facilities in existing and new exchanges to record all or some of the following phases:

a) Calls switched to speech position, then:
   1) answered;
   2) unanswered, but released by calling party;
   3) timed out awaiting answer;
   4) a call failure signal (busy flash or equivalent) received;
   5) timed out after clearback signal;
   6) faulty signal received after answer.

b) Calls failing to switch to speech position:
   1) clear forward signal received;
   2) insufficient digits received;
   3) congestion on international circuits;
   4) faulty signals received into exchange;
   5) signalling fault into next exchange;
   6) time out while signalling to next exchange;
   7) congestion signal received from next exchange;
   8) vacant number received;
   9) busy subscriber signal received;
   10) line out of order signal received;
   11) transferred subscriber signal received.

As a minimum requirement one should be capable of determining the answer seizure ratio (ASR) or the answer bid ratio (ABR). This recording can be done by off-line processing of call records if they contain some more information than the information already required for international accounting.

8.2 Another way to assemble date on the quality of service (QOS) on outgoing circuit groups is through event counters. Five event counters already give a reasonable amount of information, three of them being common to the Signalling Systems No. 5, No. 6 and R2: seizure, answer and busy signals[5)].

*Signalling System No. 5*

The number of:

- seizing signals sent;
- end-of-pulsing (ST) signals sent;
- proceed-to-send signals received;
- busy flash signals received;
- answer signals received.

*Signalling System No. 6*

The number of:

- initial address messages (IAM) sent;
- congestion (switching-equipment; circuit groups; national network) signals, call-failure signals and confusion signals received;
- address-complete (subscriber-free, charge; subscriber-free, no charge; subscriber-free, coinbox; charge; no charge; coinbox) signals received;
- subscriber busy signals received;
- answer (charge; no charge) signals received.

5) In case the event counting is used to analyze the quality of service to a particular destination, the counting should be done separately for each signalling system.

The number of:

- seizing signals sent;
- congestion [national network (A4 or B4); international exchange (A15)] signals received;
- address complete (charge; subscriber's line free, charge; subscriber's line free, no charge) signals received;
- subscriber line busy signals received;
- answer signals received.

**Recommendation E.426**

# GENERAL GUIDE TO THE PERCENTAGE OF EFFECTIVE ATTEMPTS WHICH SHOULD BE OBSERVED FOR INTERNATIONAL TELEPHONE CALLS

## 1 General considerations

1.1 The success of call attempts is fundamental to an automatic international telephone service of high quality.

1.2 The periodic observation of efficiency rates[1] and the categorization of failures to destination countries together with the exchange of such information between countries are valuable to establish and/or maintain a high service quality.

1.3 The call efficiency rate of the national network of a given country, as manifested through its international switching centre(s), affects the efficiency of operation of all countries routing traffic to that country.

1.4 Call efficiency rate information can be provided either internally in an SPC international switching centre or externally at the level of the outgoing international circuits in any international switching centre in which access to the circuits is provided for the purpose of establishing the disposition of call attempts.

1.5 The availability, flexibility and capacity of minicomputers provides an economically attractive method of obtaining call efficiency rate information with extreme accuracy. This includes the observation of tones when suitable interfaces with the minicomputer are provided.

## 2 A guide to the proportion of effective call attempts

2.1 A general guide for the expected percentage of effective call attempts during the mean busy hour and its two immediately adjacent hours, as observed at the originating international switching exchange, is indicated below. An effective call attempt is defined, for this purpose, as one for which an answer is received at the originating international exchange. Faults caused by the originating international exchange shall be excluded to the extent feasible. All attempts which succeed in seizing an international circuit shall be included in the results:

a) low level of effective call attempts: less than 30%;

b) medium level of effective call attempts: 30% to 60%;

c) high level of effective call attempts: more than 60%.

2.2 When an originating country notes a downward change in the level of effective call attempts towards any destination, the originating, destination or transit Administrations should initiate investigations to determine and alleviate the underlying causes (e.g. network provisioning, subscriber behaviour). The objective of this action is to avoid degradation of the effective call attempts to a lower category.

[1] The efficiency rate is the percentage of call attempts which receive an answer signal.

## COLLECTION AND STATISTICAL ANALYSIS OF SPECIAL QUALITY OF SERVICE OBSERVATION DATA FOR MEASUREMENTS OF CUSTOMER DIFFICULTIES IN THE INTERNATIONAL AUTOMATIC SERVICE

This Recommendation is provided to permit the orderly collection of data required for special studies to identify sources of difficulty in customer use of the international automatic telephone service.

When calls are made to points outside a customer's home country, many different sets of ringing and busy tones are encountered. In order to measure the effect of unusual sounding ringing tones and busy tones on customer behaviour, it has been decided to collect data on how long customers listen to such foreign tones as well as to their national tones in order to compare them.

The data are to be collected in the same manner as those required for the completion of Table 1/E.422. These data are an extension of those collected for Table 1/E.422, and, as an aid to subsequent analysis, a copy of the current version of that table should be used with the table of this Recommendation.

Table 1/E.427 contains questions numbered 1-9. Their relationship to the questions of Table 1/E.422 is shown in parentheses.

A preferred set of analyses for identifying the statistical significance of differences between data collected from subscribers when setting up national calls and the corresponding data collected from subscribers when setting up international calls is given below.

**1** Determine the percentage change in any measure by use of the formula:

$$\text{Change } (C_i) = \left[\frac{f_{ij}}{N_j} - \frac{f_{iH}}{N_H}\right] \times 100 \qquad j = \text{A, B, C}$$

$$i = \text{0-2, 2-5} \ldots > 30$$

where

$f_{ij}$ is the observed frequency of calls of category $i$ in the country $j$,

$N_j$ is the total number of observations in the country $j$ sample,

$f_{iH}$ is the observed frequency of calls of category $i$ in the home country $H$, and

$N_H$ is the total number of observations in the home country sample.

**2** Compare the central location of the distributions by use of the Kruskal-Wallis One-Way Analysis of Variance [1].

**3** Compare the "forms" or "shapes" of the distribution by means of the chi-square test [2].

**4** Compare changes in single valued variables, e.g. percentage incomplete-trunk-code, by use the chi-square test.

TABLE 1/E.427

(Supplement to Table 1/E.422)

**Observations of international outgoing telephone calls for quality of service**
**Additional details regarding subscriber dialled calls**

Outgoing international exchange: ..........

Group of circuits: ..........

Period from .......... to ..........

| Category | Number | | Percentage | |
|---|---|---|---|---|
| | Subtotal | Total | Subtotal | Total |
| Details of dialled calls [a)b)c)] | | | | |
| 1. Calls with errors in the dialled number [d)] | | | | |
| 1.1(6.1) Wrong number dialled | | ... | | 100 |
| 1.1.1 Wrong country code | ... | | ... | |
| 1.1.2 National trunk prefix (e.g. "0") wrongly included | ... | | ... | |
| 1.1.3 Wrong trunk code | ... | | ... | |
| 1.1.4 Wrong subscriber number | ... | | ... | |
| 1.2(6.2) Incomplete number dialled | | ... | | 100 |
| 1.2.1 National (significant) number not dialled or incomplete | ... | | ... | |
| 1.2.2 Trunk code not dialled or incomplete | ... | | ... | |
| 1.2.3 Subscriber number not dialled or incomplete | ... | | ... | |
| 2. (5.3) (6.3) Calls abandoned prematurely before receipt of a tone or announcement | | ... | | 100 |
| Interval from end of dialling to disconnect [e)]: | | | | |
| 0- 5 s | ... | | ... | |
| 5-10 s | ... | | ... | |
| 10-20 s | ... | | ... | |
| 20-30 s | ... | | ... | |
| 30-50 s | ... | | ... | |
| > 50 s | ... | | ... | |
| 3. Post dialling delay on all calls that are maintained beyond the start of a tone or announcement | | ... | | 100 |
| Interval from end of dialling to tone or announcement: | | | | |
| 0- 5 s | ... | | ... | |
| 5-10 s | ... | | ... | |
| 10-20 s | ... | | ... | |
| 20-30 s | ... | | ... | |
| 30-60 s | ... | | ... | |
| 60-90 s | ... | | ... | |
| > 90 s | ... | | ... | |
| Average excluded portion [f)] ... | | | | |
| 4. Calls that encounter ringing tones [g)] | | | | |
| 4.1(1) Completed calls | | ... | | 100 |
| Interval from beginning of tone to answer: | | | | |
| 0-10 s | ... | | ... | |
| 10-20 s | ... | | ... | |
| 20-30 s | ... | | ... | |
| 30-50 s | ... | | ... | |
| > 50 s | ... | | ... | |
| 4.2(2.6.4) Incomplete calls | | ... | | 100 |
| Interval from beginning of tone to disconnect: | | | | |
| 0-10 s | ... | | ... | |
| 10-20 s | ... | | ... | |
| 20-30 s | ... | | ... | |
| 30-50 s | ... | | ... | |
| > 50 s | ... | | ... | |

| Category | | Number | | Percentage | |
|---|---|---|---|---|---|
| | | Subtotal | Total | Subtotal | Total |
| 5. (3.2) | Calls that encounter busy/congestion tones [g] | | ... | | 100 |
| | Interval from beginning of tone to disconnect: | | | | |
| | 0- 2 s | ... | | ... | |
| | 2- 5 s | ... | | ... | |
| | 5-20 s | ... | | ... | |
| | 20-30 s | ... | | ... | |
| | > 30 s | ... | | ... | |
| 6. (4.2) | Calls that encounter tones that the observer cannot identify | | ... | | 100 |
| | Interval from beginning of tone to disconnect: | | | | |
| | 0- 2 s | ... | | ... | |
| | 2- 5 s | ... | | ... | |
| | 5-10 s | ... | | ... | |
| | 10-30 s | ... | | ... | |
| | > 30 s | ... | | ... | |
| 7. (3.3, 4.3) | Calls encountering recorded announcements | | ... | | 100 |
| | Interval from beginning of announcement to disconnect: | | | | |
| | 0-10 s | ... | | ... | |
| | 10-20 s | ... | | ... | |
| | 20-30 s | ... | | ... | |
| | > 30 s | ... | | ... | |
| 8. List types of errors in dialling and tone interpretation which could not be categorized | | | | | |
| 9. List restrictions on subscriber sample [h] | | | | | |

[a] The term "calls" throughout this table refers to circuit seizures by outgoing traffic.

[b] The data for each called country should be collected separately and not combined with other countries.

[c] The interpretation of these results cannot be made adequately except by comparing them with similar results on national calls.

[d] The practicability of putting the observation in category 1 will depend upon the observation access point and knowledge of the national numbering plan of the outgoing country and of the destination country.

[e] 0- 5 s implies $0 \leqslant t \leqslant 5$.
5-10 s implies $5 < t \leqslant 10$.

[f] The "post-dialling delay" measurements may not represent the actual delay from the time the subscriber finishes dialling to the receipt of tone. To the extent that this measurement as observed on the trunk excludes the time from completion of dialling to seizure of trunk, the average duration of this excluded time should be reported.

[g] Identification of tone categories should be made by service observers who are trained to identify the tone categories reliably.

[h] If access to the trunks being observed is restricted to some specified population of subscribers, e.g., heavy users, non-coin users, or residents of large urban centres, such restrictions should be noted and reported with the service observations.

**References**


[1] MARASCUILO (L. A.), McSWEENEY (M.): Non-Parametric and Distribution-Free Methods for the Social Sciences, *Wadsworth Publishing Co.*, California, 1977.

[2] SIEGEL (S.): Non-Parametric Statistics for the Behavioural Sciences, *McGraw Hill*, New York, 1956.

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# PART II

## Recommendations E.500 to E.600

## TRAFFIC ENGINEERING

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SECTION 1

# MEASUREMENT AND RECORDING OF TRAFFIC

**Recommendation E.500**

## MEASUREMENT AND RECORDING OF TRAFFIC

### 1 Introduction

1.1 Traffic measurements provide the data base from which the planning, operation, management and in some cases accounting for transit considerations of the telephone network are carried out. Different applications may exist for the same traffic measurement. The various Recommendations of the E.500 Series, plus Recommendation E.410 in effect describe these applications.

1.2 This Recommendation and Recommendations E.501 and E.506 describe the acquisition and preparation of traffic data needed to implement the other Recommendations mentioned. In particular, this Recommendation defines the load levels with which grade of service standards are to be associated, specifies the data which must be collected and describes the computation of the standard load levels from the collected data.

1.3 For the trunking (international) network, it is necessary to measure for individual circuit groups[1]:

- carried traffic intensity;
- bids;
- overflow/blocked bids, or seizures.

The number of bids and preferably also the carried traffic intensity should also be determined by individual relations (destinations). Data so obtained are applied as follows:

- in operations: for the activation of circuit groups;
- in planning: for dimensioning of circuit groups, routing exchanges, establishment of new links.

1.4 Exchanges are complex combinations of interacting components. As a consequence bids, seizures and overflow/blocked bids, queue lengths and carried traffic intensity may have to be measured by individual equipment component groups as dictated by the structure of the exchange. These data are applied as follows:

- in operations: for loading and balancing;
- in planning: for routine and major additions to and rearrangement of equipment quantities in response to growth.

1.5 In the longer term, the planning of the establishment of new exchanges makes use of both circuit and exchange measurements.

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[1] It is assumed that circuit groups are in a fully operative condition, or that any faulty circuits have been taken out of service. If faulty circuits or faulty transmission or signalling equipment associated with these circuits remain in service, then the measurements may give misleading results.

1.6 The measurements required for network management are generally similar to those described above, but are defined in Recommendation E.411. They will in general require a variable and shorter reporting interval.

## 2 Normal and high load levels

Traffic measurements must provide base data for calculating the following parameters:

1) "normal" and "high" load offered traffic intensity, and
2) normal and high load call attempts,

for estimating future circuit group and exchange requirements.

Offered traffic intensity should first be estimated from carried traffic measurements. Estimation procedures are presented in Recommendation E.501.

Using time consistent busy hours normal and high load are defined in Tables 1/E.500 and 2/E.500.

TABLE 1/E.500

**Circuit groups**

| Parameter | Normal load | High load |
|---|---|---|
| Offered traffic intensity | Mean of the 30 highest working [a] days during a 12-month period | Mean of the five highest days in the same period as normal load |
| Number of bids | Mean of the same 30 days on which the offered traffic intensities are highest | Mean of same five days on which the offered traffic intensities are the highest |

[a] Usually working days are used, but Administrations may also require other measurements to provide for particular cases as described in § 3.

TABLE 2/E.500

**Exchanges**

| Parameter | Normal load | High load |
|---|---|---|
| Offered traffic intensity | Mean of the ten highest days during a 12-month period | Mean of the five highest days in the same period as normal load |
| Number of call attempts | Mean of the ten highest days (not necessarily the same as the highest offered traffic days) during a 12-month period | Mean of the five highest days (not necessarily the same as the highest offered traffic days) in the same period as normal load |

Where appropriate, all traffic engineering Recommendations should have a reference to these load level definitions.

Where continuous measurements are available, the base data corresponding to normal and high load parameters can be selected directly from the full year's data. Where limited sample measurements are used, the base data must be derived from the measurement results, as described in § 3.2.

In some circumstances, such as with noncontinuous measurements, actual values of high day loads are not available. In such cases, various Administrations use standard ratios of high to normal load for forecasting for design or planning purposes. Such ratios depend on the environment in which the exchange will operate. In particular, the size and type of the exchange and the definitions of high and normal load should be considered.

For example, as a general order of magnitude, the following ratios of high to normal load may be used as a guide for a healthy network:

| *Parameter* | *Circuit groups* | *Exchanges* |
|---|---|---|
| Offered traffic intensity | 1.2 | 1.1 |
| Number of call attempts | 1.4 | 1.2 |

## 3 Measurement of carried traffic intensity, bids and overflow/blocked bids or seizures

Traffic statistics should be measured for the significant period of each day of the whole year by automatic measuring and recording equipment capable of running continuously, if possible. The significant period may in principle be 24 hours of the day.

### 3.1 *Continuous measurements*

The base measurements for computing normal traffic load should be the 30 highest days in a fixed 12-month period. Normally these will be working days, but in some cases separate weekend or tariff-related period measurements should be examined so that Administrations can agree bilaterally on appropriate measures to maintain a reasonable grade of service (GOS) for weekends and tariff-related periods. Recurring exceptional days (e.g. Christmas, Mother's Day, etc.) should be excluded for planning purposes although the data should be collected for network management purposes (Recommendation E.410). This method gives traffic information of relatively high accuracy and is suitable for circuit groups operated automatically or semiautomatically.

#### 3.1.1 *Traffic measurements for different types of groups*

The traffic-recording device is required particularly to collect carried-traffic statistics. As a general rule, carried-traffic measurements will refer to the whole of a group of circuits between two exchanges. Such circuits may carry one-way or both-way traffic.

##### 3.1.1.1 *Direct (point-to-point) circuit groups*

In some cases, the traffic for a particular relation will use an independent group of direct circuits (without overflow facilities) and the traffic measurement should be made according to § 3.1 above.

##### 3.1.1.2 *High-usage and final circuit groups*

Some relations will be served by high-usage routes and by final routes. In such cases, the high-usage and final routes can be measured according to § 3.1 above.

High-usage and final group arrangements form a network; therefore, all measurements for all groups within the network *must* be measured during the *same* time period. This requirement is necessary to develop first route loads (for forecasting and planning).

#### 3.1.2 *Exchange measurements*

Recording equipment should make a record of the carried traffic intensity, bids, overflow/blocked bids or seizures and queue lengths by individual equipment component groups as dictated by the structure of the exchange (see § 2 for time periods to be measured). Busy hours may vary between types of equipment component groups and the traffic busy hour may differ from bid busy hour for the same component.

### 3.2 *Non-continuous measurements*

A second method which yields information of a lower degree of accuracy may be used by Administrations. This second method allows less control over the day-to-day operation of the network and may involve extra network cost.

This method comprises the taking of measurements on a limited sample of days in each year. Limited sample measurements will normally be taken on working days, but Administrations may agree bilaterally to measure weekend or reduced tariff periods separately.

Any Administration proposing to use a non-continuous measurement procedure is advised to confer with other end Administrations to ensure that the maximum information is available to assist in the choice of measurement days. For example, if the other end Administration has continuous measurement capability it may be possible to identify busy seasons or consistent low-traffic days.

The following estimation method should be used to estimate normal and high load levels from limited sample measurements:

#### 3.2.1 *Principle of estimation method*

Measurements are taken on a limited sample of days, and the mean ($M$) and standard deviation ($S$) of the daily time-consistent busy hour traffic loads are calculated. Normal and high load level estimates ($L$) are given by:

$$L = M + k \cdot S,$$

different values of the factor $k$ being used for normal and high load levels.

#### 3.2.2 *Base period for measurements*

It is important to determine the "base period" since the length of this period influences the values assigned to the multiplication factors $k$.

The base period is the set of valid days in each year from which measurement days are selected. This period should include all days which are potential candidates for being among the 30 highest days (but excluding recurring exceptional days – see § 3.1).

The base period may be restricted to a busy season (which need not necessarily comprise a set of consecutive weeks), provided that the traffic is known to be consistently higher during this period than during the remainder of the year.

The base period may be the whole year, but Administrations may also decide to exclude known low-traffic days.

#### 3.2.3 *Selection of measurement days*

Measurement days should be distributed reasonably evenly throughout the base period. If the base period extends over the whole year then the measurement sample should include some days from the busiest part of the year, if these are known. The limited sample should comprise at least 30 days to ensure reliable estimates.

If this is not possible, then a minimum of 10 measurement days may be used. In this case the accuracy of the estimate may be poor.

*Note* – Further study of these sampling and estimation methods is necessary.

#### 3.2.4 *Estimation of standard deviation*

If measurements are taken on at least 30 days, then the sample standard deviation may reliably be used.

$$S = \left( \frac{1}{n} \sum_{i=1}^{n} x_i^2 - M^2 \right)^{1/2}$$

where

$x_i$ is the time-consistent busy hour traffic measured on the $i$th day,

$M = \frac{1}{n} \sum_{i=1}^{n} x_i$ is the sample mean, and

$n$ is the number of measurement days.

If the measurement period is less than 30 days, then this estimate will not be very reliable. In this case Administrations should, if possible, carry out special measurement studies to determine typical values of the standard deviation (e.g. as a function of the sample mean).

3.2.5 *Multiplication factors*

Multiplication factors $k$ for 5-day, 10-day, and 30-day load levels are given by the curves in Figure 1/E.500, as a function of the number of days in the base period. These factors are derived from tables of order statistics from the normal distribution [1].

When the base period extends over the whole year these factors may not always be reliable because of the effects of differing seasonal patterns. Individual Administrations may than prefer to use different values for the factors, if they have obtained more precise information from special measurement studies.

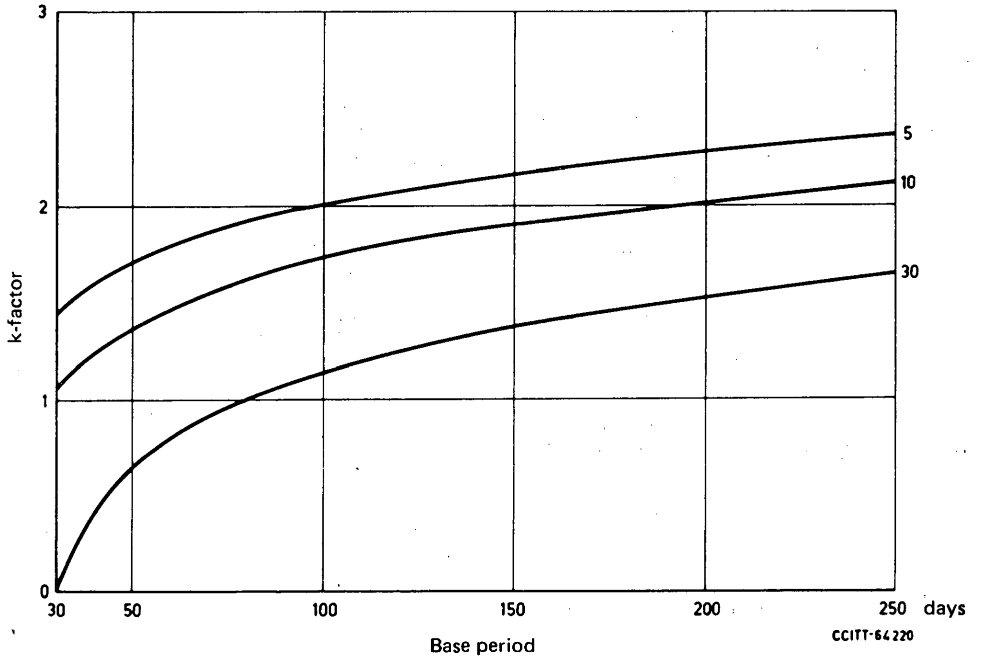



FIGURE 1/E.500

**Multiplication factors $k$ for estimating mean of 5, 10 or 30 highest days from noncontinuous measurements**

3.3 *Determination of time-consistent busy hour*

To determine the time-consistent busy hour:

- for a number of consecutive days, the carried traffic values observed for the same quarter of an hour each day are added together;
- the time-consistent busy hour is then determined as being the four consecutive quarter-hours which together give the largest sum of observed values.

This procedure applies equally both to exchanges and to individual circuit groups. In principle, the time-consistent busy hour may be different for each circuit group and different again for the exchange itself.

### 3.4 *Notification of mean busy hour traffic, bids and seizures on circuit groups*

All traffic measurement results collected according to § 3.1 above should be communicated to other Administrations concerned.

## 4 Standardized measurement points for international circuits

To properly monitor and forecast short- and long-term circuit requirements, Administrations must identify the points of measurement for circuit groups. Proper placement of data collection systems will provide Administrations with the information needed for demand servicing and forecasting.

### 4.1 *One-way incoming circuit groups*

Carried traffic intensity and incoming seizures should be measured on the incoming side of the switch for this type of circuit group.

### 4.2 *One-way outgoing circuit groups*

Bids, overflow bids and carried traffic intensity should be measured on the outgoing side of the switch for this type of circuit group.

### 4.3 *Both-way circuit groups*

Bids, overflow bids, carried traffic intensity and incoming seizures should be measured at both the incoming and outgoing side of the switch for this type of circuit group.

### 4.4 *Circuit groups with a combination of one-way incoming, one-way outgoing and both-way circuits*

Data collected as indicated in §§ 4.1, 4.2, 4.3 should be obtained. This should provide for the monitoring of each individual circuit sub-group.

### 4.5 *Transit traffic to one or more Administrations*

Bids, overflow bids and carried traffic intensity should be measured on the outgoing side of each circuit group to collect total traffic statistics. One bid register should record all bids including transit traffic. This total bid register will allow network management and the traffic engineer to monitor the performance of the total traffic flow to an Administration. Each Administration should determine if it requires data for the various transit traffic streams and then install registers accordingly for this data collection.

## 5 Measurements within the national network

The information obtained from measurements on international circuit groups (as in § 4 above) may be supplemented by equivalent measurements taken on national circuit groups which carry international traffic.

5.1 For originating traffic it is desirable to take measurements of bids, overflow bids and carried traffic intensity on a route and destination basis, at the national switching centres. Measurements can be made on the incoming side of the international switching centre but information will be restricted to carried traffic intensity and bids arriving at the international centre.

5.2 Terminating international traffic should be measured on the national side of the international switching centre. Bids, overflow bids and carried traffic intensity should be measured by route and by destination within the national network.

5.3 The information obtained from these measurements will be complementary to the information obtained from international circuit groups and can be used for various planning functions including:

a) planning the development of the national routes which carry international traffic;

b) achieving a balanced load between multiple international switching centres in one country;

c) planning the introduction of new international switching centres;

d) facilitating the calculation of traffic offered to international networks;

e) providing background information which will assist in formulating network management action.

*Note* – When the international switching centre is combined with a national switching centre special features might be incorporated in order to obtain the required data.

**Reference**

[1] *Biometrika Tables for Statisticians*, Table 9, Vol. 2, Cambridge University Press, 1972.

**Recommendation E.501**

## ESTIMATION OF TRAFFIC OFFERED TO INTERNATIONAL CIRCUIT GROUPS

### 1 Introduction

Traffic offered to international circuit groups may be used for planning the growth of the international network. This Recommendation gives methods of estimating traffic offered from measurements taken on circuit groups. The term *traffic offered* as used here is different from the *equivalent traffic offered* used in the pure lost call model, which is defined in Annex B.

§ 2 of this Recommendation deals with estimation of traffic offered to fully operative only-route circuit groups. § 3 deals with estimation of traffic offered to high-usage/final group arrangements.

### 2 Only-route circuit group

2.1 *No significant congestion*

Traffic offered will equal traffic carried measured according to Recommendation E.500. No estimation is required.

2.2 *Significant congestion*

Let $A_c$ be the *traffic carried* on the circuit group. Then on the assumption that augmentation of the circuit group would have no effect on the mean holding time of calls carried, or on the completion ratio of calls carried, the *traffic offered* to the circuit group may be expressed as

$$A = A_c \frac{(1 - WB)}{(1 - B)}$$

where $B$ is the present average loss probability for all call attempts to the considered circuit group, and $W$ is a parameter representing the effect of call repetitions. Models for $W$ are presented in Annex A.

*Note 1* – Annex A gives a derivation of this relationship, and also describes a more complex model which may be of use when measurements of completion ratios are available.

*Note 2* – When measurements of completion ratios are not available a $W$ value may be selected from the range 0.6-0.9. It should be noted that a lower value of $W$ corresponds to a higher estimate of traffic offered. Administrations are encouraged to exchange the values of $W$ that they propose to use.

*Note 3* – Administrations should maintain records of data collected before and after augmentations of circuit groups. This data will enable a check on the validity of the above formula, and on the validity of the value of $W$ used.

*Note 4* – In order to apply this formula it is normally assumed that the circuit group is in a fully operative condition, or that any faulty circuits have been taken out of service. If faulty circuits, or faulty transmission or signalling equipment associated with these circuits remain in service, then the formula may give incorrect results.

## 3 High-usage/final network arrangement

### 3.1 *High-usage group with no significant congestion on the final group*

3.1.1 Where a relation is served by a high-usage and final group arrangement, it is necessary to take simultaneous measurements on both circuit groups.

Let $A_H$ be the traffic carried on the high-usage group, and $A_F$ the traffic overflowing from this high-usage group and carried on the final group. With no significant congestion on the final group, the traffic offered to the high-usage group is:

$$A = A_H + A_F$$

3.1.2 Two distinct types of procedure are recommended, each with several possible approaches. The method of § 3.1.2.1 a) is the primary recommendation providing the most accurate method although it may be the most difficult. The methods of § 3.1.2.2 may be used as additional estimates.

3.1.2.1 Simultaneous measurements are taken of $A_H$ and the total traffic carried on the final group. Three methods are given for estimating $A_F$, in decreasing order of preference:

a) $A_F$ is measured directly. In most circumstances this may be achieved by measuring traffic carried on the final group on a destination basis.

b) The total traffic carried on the final group is broken down by destination in proportion to the number of effective calls to each destination.

c) The traffic carried on the final group is broken down according to ratios between the bids from the high-usage groups and the total number of bids to the final group.

3.1.2.2 Two alternative methods are given for estimating the traffic offered to the high-usage group, which in this circumstance equals the equivalent traffic offered:

a) $A$ is estimated from the relationship

$$A_H = A[1 - E_N(A)]$$

Here $E_N(A)$ is the Erlang loss formula, $N$ is the number of working circuits on the high-usage group. The estimation may be made by an iterative computer program, or manually by the use of tables or graphs.

The accuracy of this method may be adversely affected by non-randomness of the offered traffic, intensity variation during the measurement period, or use of an incorrect value for $N$.

b) $A$ is estimated from

$$A = A_H/(1 - B)$$

where $B$ is the measured overflow probability. The accuracy of this method may be adversely affected by the presence of repeat bids generated by the exchange if they are included in the circuit group bid register.

It is recommmended to apply both methods a) and b); any significant discrepancy would then require further investigation. It should be noted however that both of these methods may become unreliable for high-usage groups with high overflow probability: in this situation a longer measurement period may be required for reliable results.

### 3.2 *High-usage group with significant congestion on the final group*

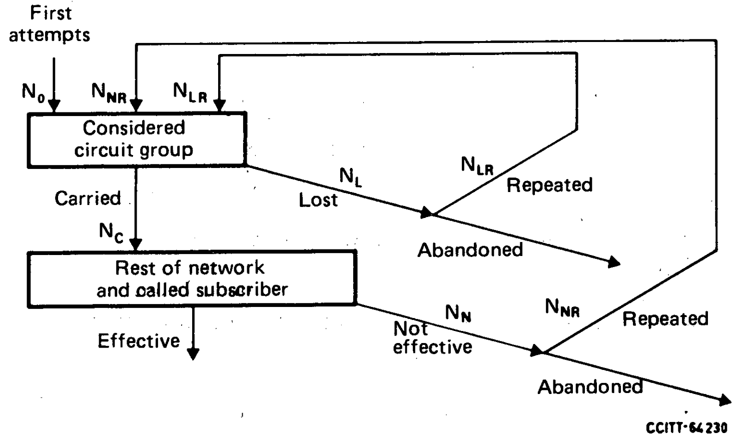
In this case estimation of the traffic offered requires a combination of the methods of §§ 2.2 and 3.1. A proper understanding of the different parameters, through further study, is required before a detailed procedure can be recommended.

ANNEX A

(to Recommendation E.501)

**A simplified model for the formula presented in § 2.2**

The call attempts arriving at the considered circuit group may be classified as shown in Figure A-1/E.501.




$N_0$ First attempt calls
$N_C$ Carried calls
$N_L$ Lost calls
$N_{LR}$ Lost calls repeated
$N_N$ Non-effective calls
$N_{NR}$ Non-effective calls repeated

FIGURE A-1/E.501

The total call attempt rate at the circuit group is

$$N = N_0 + N_{NR} + N_{LR}.$$

We must consider $N_0 + N_{NR}$ which would be the call attempt rate if there were no congestion on the circuit group.

Let

$B = \frac{N_L}{N}$ = measured blocking probability on the circuit group.

$W = \frac{N_{LR}}{N_L}$ = proportion of blocked call attempts that re-attempt.

We have

$$N_0 + N_{NR} = N - N_{LR} = (N - N_{LR}) \frac{N_c}{N_c} = N_c \frac{(N - N_{LR})}{(N - N_L)} = N_c \frac{(1 - BW)}{(1 - B)}.$$

Multiplying by the mean holding time of calls carried on the circuit group, $h$ gives

$$A = A_c \frac{(1 - BW)}{(1 - B)},$$

where

$A_c$ the traffic carried on the circuit group.

The above model is actually a simplification since the rate $N_{NR}$ would be changed by augmentation of the circuit group.

An alternative procedure is to estimate an equivalent persistence $W$ from the following formulae:

$$W = \frac{r'H}{1 - H(1 - r')}$$

$$H = \frac{\beta - 1}{\beta(1 - r)}$$

$$\beta = \frac{\text{All call attempts}}{\text{First call attempts}}$$

where $r'$ is the completion ratio for seizures on the considered circuit group and $r$ is the completion ratio for call attempts to the considered circuit group.

These relationships may be derived by considering the situation after augmentation (see Figure A-2/E.501).

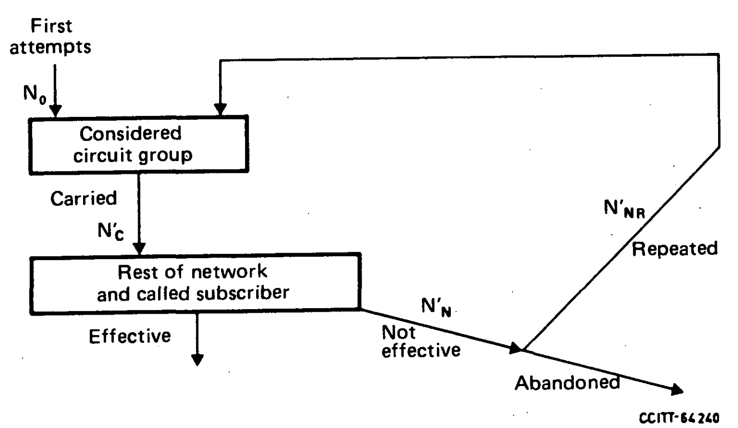



FIGURE A-2/E.501

It is required to estimate $N'_c$, the calls to be carried when there is no congestion on the circuit group. This may be done by establishing relationships between $N_c$ and $N_0$ (before augmentation) and between $N'_c$, and $N_0$ (after augmentation), since the first attempt rate $N_0$ is assumed to be unchanged. We introduce the following parameters:

$H$ = overall subscriber persistence,

$r'$ = completion ratio for seizures on the circuit group.

Before augmentation:

$$H = \frac{N_{NR} + N_{LR}}{N_N + N_L}$$

$$r' = \frac{N_c - N_N}{N_c}$$

After augmentation:

$$H = \frac{N'_{NR}}{N'_N}$$

$$r' = \frac{N'_c - N'_N}{N'_c}$$

It is assumed for simplicity that $H$ and $r'$ are unchanged by the augmentation. The following two relationships may be readily derived:

$$N_0 = \frac{N_c[1 - H(1 - r') - r'BH]}{1 - B}$$

$$N_0 = N'_c[1 - H(1 - r')].$$

Hence

$$N'_c = \frac{N_c\left[1 - \left(\frac{r'H}{1 - H(1 - r')}\right)B\right]}{1 - B}$$

On multiplying by the mean call holding time, $h$, this provides our estimate of traffic offered in terms of traffic carried.

The relationship $$\mathrm{H} = \frac{\beta - 1}{\beta(1 - r)}$$

is valid both before and after augmentation, as may easily be derived from the above diagrams.

*Note 1* – Other Administrations may be able to provide information on the call completion ratio to the considered destination country.

*Note 2* – The evaluation of the factor $W$ needs further study during the next study period. Some Administrations, indeed, have presented other expressions which are not yet quite understood. Such a study is important in order to avoid some overdimensioning in the network, and should be the topic of a new Question.

## ANNEX B

(to Recommendation E.501)

### Equivalent traffic offered

In the lost call model the equivalent traffic offered corresponds to the traffic which produces the observed carried traffic in accordance with the relation

$$y = A(1 - B)$$

where

$y$ is the carried traffic

$A$ is the equivalent traffic offered

$B$ is the call congestion through the part of the network considered.

*Note 1* – This is a purely mathematical concept. Physically it is only possible to detect bids whose effect on occupancies tells whether these attempts give rise to very brief seizures or to calls.

*Note 2* – The equivalent traffic offered, which is greater than the traffic carried and therefore greater than the effective traffic, is greater than the traffic offered when the subscriber is very persistent.

*Note 3* – $B$ is evaluated on a purely mathematical basis so that it is possible to establish a direct relationship between the traffic carried and call congestion $B$ and to dispense with the role of the equivalent traffic offered $A$.

# TRAFFIC AND OPERATIONAL REQUIREMENTS FOR SPC (ESPECIALLY DIGITAL) TELECOMMUNICATION EXCHANGES

## 1 Introduction

Traffic measurements on exchanges and surrounding telephone network provide the data base from which the dimensioning, planning, operation and management of the telephone network are carried out.

The main aim of these measurements include:

- identifying traffic patterns and distributions on a route and destination basis;
- determining the amount of traffic in the exchange and the network;
- monitoring the continuity of service and the grade of service.

The above data and information are gathered with the purpose of supporting the following fundamental activities:

a) dimensioning, planning and administration of the exchange and surrounding network;

b) performance monitoring of the exchange and surrounding network;

c) network management;

d) operation and maintenance of the exchange and surrounding network;

e) tariff and marketing studies;

f) forecasting.

The information generated by the exchange can be provided to the end user in either real-time or non real-time (post processed). The activities being performed by the end user will dictate the speed of this response: for example, operation and maintenance will require real-time information while the forecasting and planning information can be provided after the event in non real-time.

For these activities, the following major steps can be identified:

- data generation, collection and output;
- data analysis;
- use of the analysis results.

Raw data generation, collection and outputs must be achieved by continuous as well as periodic and non-periodic measurements carried out in the exchange.

Data analysis of this information implies the computing of suitable results on the basis of data supplied by the exchange.

The data analysis may be performed by the SPC exchange or by another system depending on the following:

- total amount of data;
- need for analysis of data from multiple exchange;
- processor load constraints.

The operating procedures for the use of the results of the analysis are given for the following operational areas in the Series E Recommendations as follows:

- Recommendation E.175 defines the network model for planning purposes;
- E.410 series of Recommendations and associated Supplement No. 6 provide information for network management and network management actions;
- Recommendation E.502 describes the traffic and grade of service (GOS) parameters to be considered in the dimensioning of the international telephone network and exchanges;
- Recommendation E.506 defines the forecasting methods for international traffic;
- Recommendation E.543 defines the parameters to be observed for monitoring grade of service;

Paragraph 2 of this Recommendation deals with the traffic measurements. § 3 presents a general framework for the analysis of the data provided by the exchange in order to derive suitable information. § 4 provides the traffic measurements and operational facilities for network management.

For the sake of completeness and to provide guidance to Administrations, the traffic measurements here defined apply to local, transit and international exchanges. However this is a preliminary proposal; the full set of traffic and operational requirements are for further study.

## 2 Traffic measurements

The classification of traffic measurement is based on a general measurements model. The aim of the model is to provide clear information about what is intended for traffic measurement in this Recommendation.

### 2.1 *Traffic measurement model*

A measurement is identified by three basic elements: time, entities, objects.

"Time" includes all the necessary information to define the start, the duration and periodicity of a certain measurement. "Entities" describe the quantities for which data collection must be performed with a certain measurement. Some examples are:

- traffic volume;
- number of call attempts;
- number of seizures;
- number of effective calls;
- number of call attempts for which delay exceeds a predetermined threshold value.

"Objects" are individual items on which the measurements are performed. Some examples are:

- subscriber line groups;
- circuit groups;
- common control units;
- auxiliary devices.

A measurement type is a particular combination of entities and objects.

Part of these measurement types may be recommended while others are system- and/or Administration-dependent. A detailed description of the model is given in Annex A.

### 2.2 *Traffic flows*

Each type of traffic flow occurring in/through the exchange can be distinguished by association with an inlet[1] or outlet[2] of the exchange, or both. The different types of traffic flow for a generalized exchange, viz. one that combines both local and transit functions and that provides operator (telephonist) service, are illustrated as shown in Figure 1/E.502:

From Figure 1/E.502 the following relations apply:

$$A = E + F + G + H + Z_1$$
$$B = I + J + K + L + Z_2$$
$$C = O + P$$
$$D = M + N + Z_3$$

where $Z_1$, $Z_2$ and $Z_3$ account for traffic flows corresponding to calls with incomplete or invalid dialling information, and

$$Q = M + F + K + O - d_1$$
$$R = N + G + L + P - d_2$$
$$S = H + J - d_3$$
$$T = E + I - d_4$$

where $d_1$, $d_2$, $d_3$ and $d_4$ account for traffic flows corresponding to calls that fail within the exchange owing to any of the following reasons:

a) all suitable outlets are busy or unavailable;

b) internal congestion;

c) incomplete dialling;

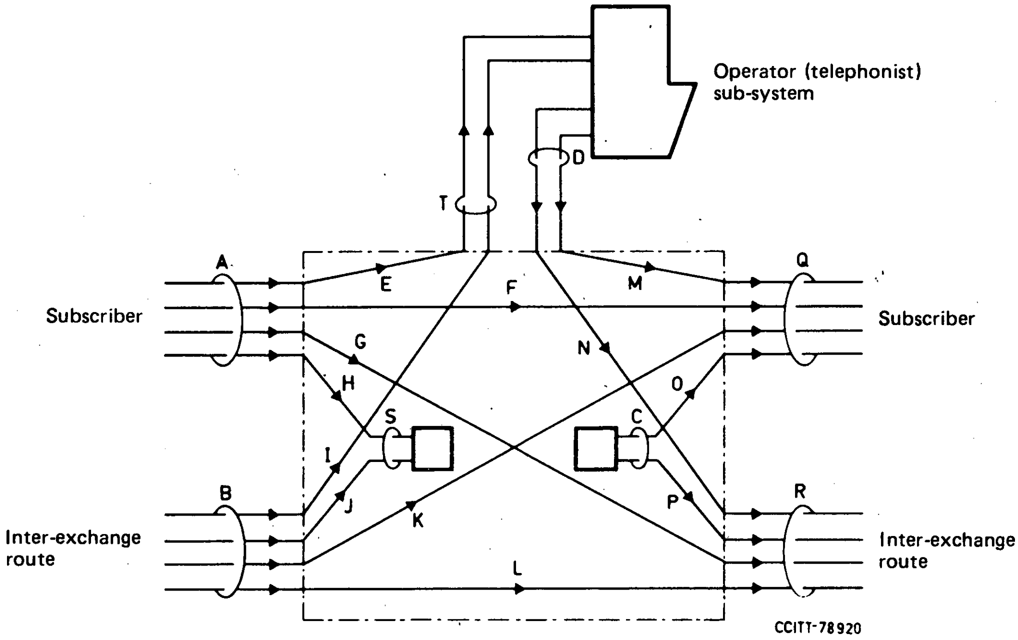
d) invalid destination code;

e) service barring/blocking (as a result of, say, network management controls, or the operation of some supplementary service, e.g. absentee service, or because the calling/called party is disallowed such service).

---

1) Inlet is the point on or within the boundary of the exchange system where a call attempt arrives or arises.

2) Outlet is the point on or within the boundary of the exchange system to which a call attempt bearing adequate and valid dialling information would tend to be routed.




A – Originating traffic
B – Incoming traffic
Q – Terminating traffic
R – Outgoing traffic
F – Internal traffic
G – Originating outgoing traffic
H – Originating system terminating traffic
J – Incoming system terminating traffic
K – Incoming terminating traffic
L – Transit traffic
O – System originating terminating traffic
P – System originating outgoing traffic
S – System terminating traffic
C – System originating traffic
T – Operator terminating traffic
D – Operator originating traffic
E – Originating operator terminating traffic
I – Incoming operator terminating traffic
M – Operator originating terminating traffic
N – Operator originating outgoing traffic

FIGURE 1/E.502

**Main traffic flow diagram**

The types of calls, viz. *system-originating* call and *system-terminating* calls, result from the operation of some of the supplementary or value-added services that SPC exchange offer in addition to conventional telephone service. In the traffic flow diagram Figure 1/E.502, system-originating and system-terminating calls are identified by the aggregate traffic flows *C* and *S* respectively.

2.3 *Basic measurements types*

Depending on the activities listed in § 1, a different degree of detail may be needed.

In order to provide bulk data for each of the above-mentioned traffic categories, overall measurements can be performed on the totality of subscriber lines and/or circuits.

Such overall measurements have been taken into account in this Recommendation only for the traffic items from *A* to *P* in Figure 1/E.502, while they have not been considered for items *Q*, *R*, *S* and *T* since, with the assumptions made above, it is possible to achieve the relevant information by taking into account the relationship between these items and the measured ones. It is recognized that the overall measurements results might be partitioned to cover various Administrations' needs. As an example, in an international transit exchange, the traffic data measured on the totality of incoming circuits should be split into data measured on national incoming circuits and international incoming circuits, which, in their turn, could be differentiated depending on the relevant countries.

More detailed information on traffic data relevant to the exchange and surrounding network performance can be provided by means of measurements on selected sets of circuit groups, subscriber line groups, common channel signalling links, auxiliary and control units.

A means to get very detailed traffic data can be based on the analysis of call records.

These call records should be produced by the exchange, containing all data (e.g. time of occurrence of signalling event, dialled digits, etc.) characterizing each individual call attempt.

The relationships between the above measurements and the potential applications are shown in Table 1/E.502.

The basic measurement types are given in Annex B.

Their applicability will depend on the function of the exchange (local, transit, international, etc.)

TABLE 1/E.502

| Potential applications / Measurements basis | Exchange dimensioning, planning and adminis-tration | Network dimensioning, planning and adminis-tration | Exchange performance monitoring | Network performance monitoring | Support to mainte-nance | Network manage-ment [a)] | Tariff and marketing studies |
|---|---|---|---|---|---|---|---|
| Overall traffic | | | X | X | X | X | |
| Circuit groups | X | X | X | X | X | X | |
| Subscriber line groups | X | | X | | | | |
| Auxiliary units | X | | X | | X | | |
| Control units | X | | X | | X | X | |
| Common channel signalling [b)] | | X | | X | X | X | |
| Call records | X | X | X | X | X | X | X |

[a)] The measurements to support network management functions are defined in § 4.

[b)] Measurements related to common channel signalling systems are specified in the appropriate Series Q Recommendations.

2.4 *Traffic measurements administration*

Traffic measurements administration is related to the control of traffic data production and collection. The data collected by means of traffic measurements carried in the exchange is output by the system in a suitable form.

In order to administer traffic measurements, the operator should perform a series of related activities (referred to as "jobs") and the system should support such jobs by means of suitable system functions. Details are given in Annex C.

The traffic measurement output should contain the measured data together with the information about the measurement and network which would assist in the data analysis, for example, the number of blocked devices on a route or temporary alternative routing in effect.

## 3 Traffic analysis

### 3.1 *Introduction*

The aim of traffic measurements is to enable the Administration to manage and plan the network effectively and efficiently. The resulting measured data can be used to support the various activities as stated in § 1. In order to reduce the amount of data transfer and postprocessing, data could be analysed in the exchange or at the operation and maintenance centre (OMC) level to some extent for:

- eliminating unnecessary data values;
- replacing missing or wrong values in an appropriate way;
- performing simple calculations on the values of the basic measurement entities to derive characteristics parameter values of the traffic;
- storing some measured or calculated values in particular traffic data records;
- producing appropriate user friendly report printouts.

For each measurement object, there is a data record in which a certain number of traffic values are stored.

Also some calculated values, e.g. moving average, are stored and updated there.

The internal functions of the analysis are not specified and they depend on the requirements for the output results which are specified by the Administration.

A possible method is to collect the data as required either in a buffer file or directly in the traffic data record and perform the calculations and report printout during periods of low activity or alternatively processing the records off-line.

### 3.2 *Traffic analysis model*

Corresponding to a variety of measurements, there are a variety of analyses, some of which are typically running continuously from day to day. From the viewpoint of a particular measurement there are one or more analyses for which the measured data are written in particular files which are included in the output device list of a measurement as logical devices. These files are input files from the viewpoint of a traffic analysis and the process can be viewed as a transformation of the measurement entities into desired output information to the traffic analyst to aid in making various decisions.

For example, various criteria for dimensioning and verification of the grade of service could be produced by one or more analyses. A schematic picture of the flow of information is presented in Figure 2/E.502 as an activity diagram.

The following information is associated to each traffic analysis:

- identities of the related measurements;
- parameter values which are user-selectable to define the desired option or mode of the analysis;
- report dates of such report types for which the user must define the printout schedule;
- output devices for all report types.

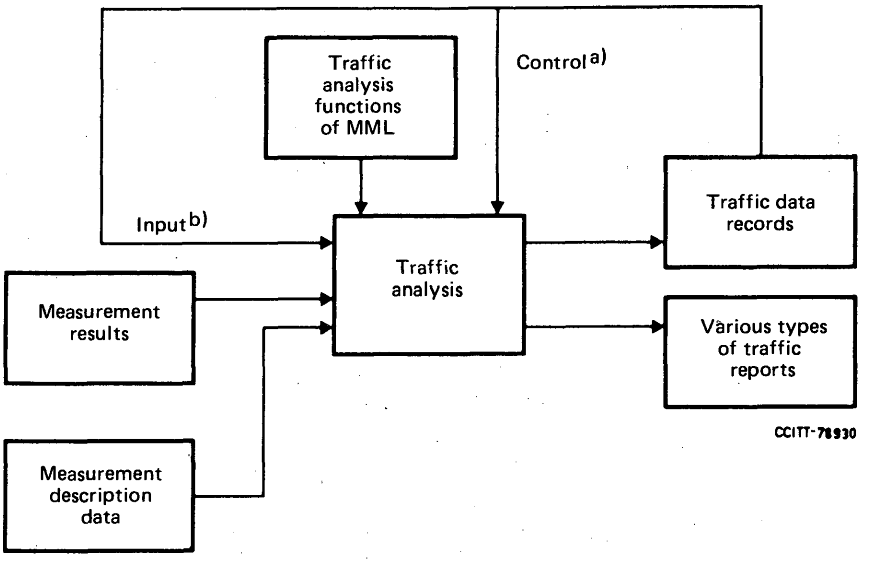
In addition to this, each analysis is associated with a traffic data record per each measurement object involved in the related measurements. The user has an access to investigate and modify the contents of the data records of the desired object.

### 3.3 *Traffic analysis administration*

In order to administer traffic analysis the operator should perform a series of related activities and the system should support such activities by suitable system functions. Details are given in Annex D.

## 4 Network management

Dedicated operational capabilities (e.g. measurement types, traffic controls, man-machine language (MML) interfaces, interface facilities) need to be provided for network management. Preliminary proposals for this are contained in Annex E.




a) The traffic values in the data record may have an effect on the internal functional steps.

b) There is a traffic data record for each individual measurement object which is included in the analysis. The past traffic values, and also calculated values, are used as input when updating the contents of the record at the time of a new traffic value.

FIGURE 2/E.502

**Activity diagram of the information flows associated with traffic analysis**

## ANNEX A

## (to Recommendation E.502)

## Traffic measurement model

### A.1 *Traffic measurement model*

A measurement is identified by three basic elements: time, entities, objects. Time includes all the necessary information to define the start, the duration and periodicity of a certain measurement. Entities describe the quantities for which data collection must be performed with a certain measurement. Objects are individual items on which the measurements are performed. Some examples of entities and objects are given below:

*Entities*

- traffic volume;
- number of call attempts;
- number of seizures;
- number of successful call attempts;
- number of call attempts for which delay exceeds a predetermined threshold value.

*Objects*

- subscriber line groups;
- circuit groups;
- common control units;
- auxiliary devices.

The measurements are classified into different measurement types on the basis of a measurement matrix in which each row represents an entity and each column represents an object (Figure A-1/E.502).

A measurement type is a particular combination of entities and objects corresponding to certain entries in the measurement matrix. Part of these measurement types may be standardized while the rest of them seem to be system and/or Administration dependent. It should be noted that all the entries in the measurement matrix cannot be used because some of them will be impossible and some others may be more or less meaningless. In all measurement types, the entities are fixed although some entities may not be measured for some applications. Selected objects form an object list. In some measurement types, the object list is fixed. In other types one can choose for the actual measurement some or all of the allowed objects. A measurement set is a collection of measurement types.

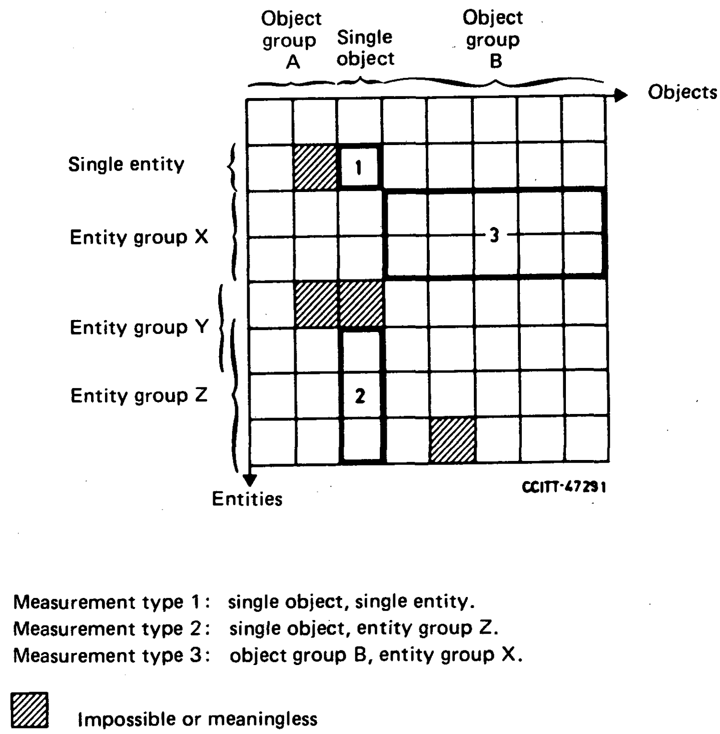



FIGURE A-1/E.502

**Measurement matrix**

A.2 *Traffic measurement structure*

A traffic measurement consists of:

– measurement set information;

– time information;

– output routing and scheduling information (output parameters).

Measurement set information, time information and output routing and scheduling information may be predefined as well as object lists. It should be noted that predefinition characteristic are system-dependent. Time data output routing and the schedule may be fixed.

A.2.1 *Measurement set information*

Measurement set information consists of one or several selected measurement types with defined object (object lists) and measurement types with defined object (object lists) and measurement type dependent parameters (e.g. sampling interval, number of events in a certain category, destination codes, etc.).

A.2.2 *Time information*

Measurements may have:

- an undetermined duration (stop date is not prespecified), or
- a predetermined duration.

In addition measurements may be performed:

- continuously (e.g. each day), or
- on a non-continuous basis (e.g. time consistent busy hour).

For measurements of undetermined duration and performed non-continuously, the recording days must be determined on a periodic basis (periodicity pattern within a calendar week). For measurements of predetermined duration, the recording days may be determined on a periodic basis or by defining the dates of the recording days (see Figure A-2/E.502).

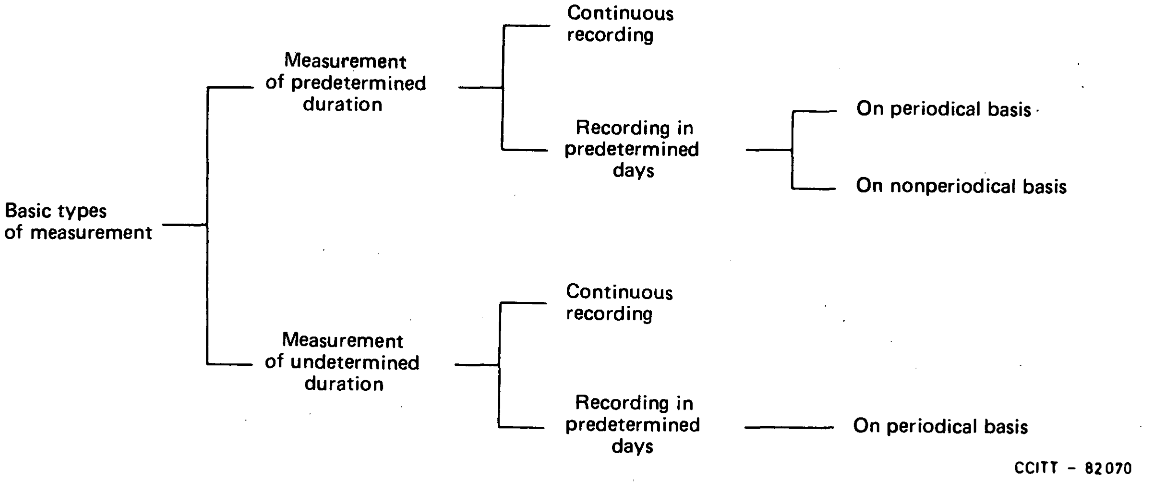



FIGURE A-2/E.502

As shown in Figure A-3/E.502, time data are measurement level, recording day level and recording period level.

*Measurement level:* Contains information about dates of recording days for non-periodic measurements or periodicity pattern for periodic measurements.

*Recording day level:* Contains information about the start and stop time for recording periods within a recording day.

*Recording period level:* Contains information about the periodicity of the data collection, controlled by the result accumulation period. The result accumulation period can be shorter than the recording period; in that case, more than one set of data is collected for each of the recording periods, to be routed toward the output media according to the results output schedule.

A.2.3 *Output routing and scheduling information*

Output routing information defines where the produced measurement results should be routed to for the recording; the output routing may be toward either a physical medium (e.g. printer) or a logical medium (e.g. file).

Output scheduling information defines when (days and time) the output of the results is to be made. The output of results may be tied to the end of the result accumulation period.

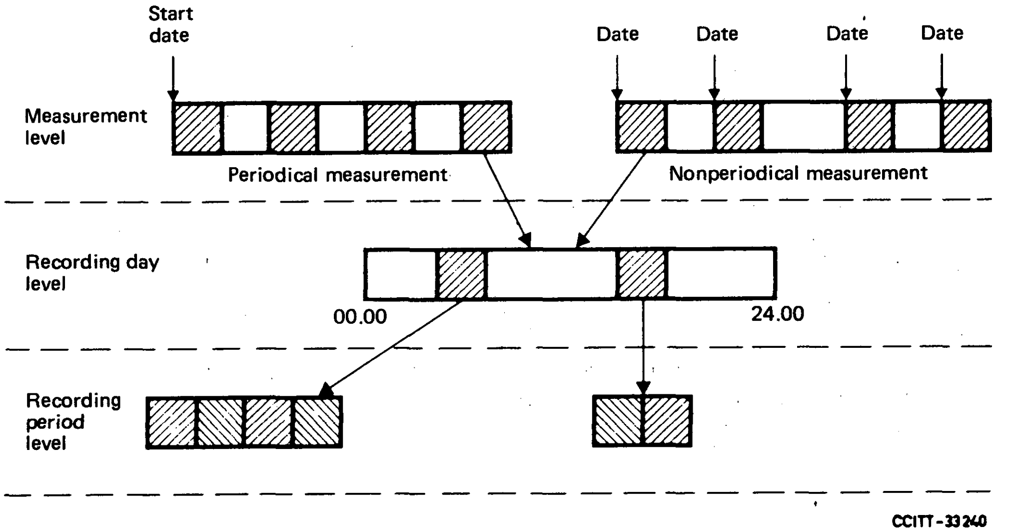



FIGURE A-3/E.502

## ANNEX B

(to Recommendation E.502)

**Proposal for basic measurement types**

This is a preliminary proposal for basic measurement types. Further studies may be required in the Study Period 1985-1988.

B.1 *Overall measurements*

*Type 1:* Overall measurements on originating traffic ($A$).

*Object:* Totality of subscriber lines.

*Entities:*

a) Number of originating seizures;

b) Number of call attempts not routed due to:
   i) no dialling (including permanent signal),
   ii) incomplete dialling[3],
   iii) invalid address;

c) Number of call attempts lost due to internal congestion[4].

*Type 2:* Overall measurements on internal traffic ($E + F + H$)[5].

*Object:* Totality of subscriber lines.

*Entities:*

a) Number of internal seizures;

b) Number of call attempts lost due to internal congestion;

3) Not enough digits to discriminate if internal or outgoing call.

4) When possible, broken down by reason of congestion, e.g. c-1 blocking through the switching network, c-2 unavailability of common resources, c-3 system faults.

5) Entities may be broken down according to relevant traffic flows.

c) Number of successful call attempts:
   i) with called-party busy,
   ii) with called-party free/no answered[6],
   iii) answered;
   iv) line out of order,
   v) vacant national number,
   vi) transferred subscriber;

d) Number of unsuccessful call attempts due to incomplete dialling[7].

*Type 3:* Overall measurements on originating outgoing traffic ($G$).

*Object:* Totality of subscriber lines.

*Entities:*

a) Number of outgoing seizures;

b) Number of call attempts lost due to internal congestion;

c) Number of call attempts in overlow on the last choice route;

d) Number of successful call attempts getting:
   i) no answer[8],
   ii) answer or metering pulse(s);

e) Number of unsuccessful call attempts due to incomplete dialling[9].

*Type 4:* Overall measurements on incoming traffic ($B$).

*Object:* Totality of incoming circuits and both-way circuits.

*Entities:*

a) Number of incoming seizures;

b) Number of call attempts not routed due to:
   i) incomplete dialling[9],
   ii) invalid address;

c) Number of call attempts lost due to internal congestion.

*Type 5:* Overall measurements on incoming terminating traffic ($I + J + K$)[7].

*Object:* Totality of incoming circuits and both-way circuits.

*Entities:*

a) Number of incoming terminating seizures;

b) Number of call attempts lost due to internal congestion;

c) Number of successful call attempts:
   i) with called-party busy,
   ii) with called-party free/no answered,
   iii) answered or metering pulse(s);

d) Number of unsuccessful call attempts due to incomplete dialling.

---

6) Expiring of time-outs calling-party's abandon.

7) Entities may be broken down according to relevant traffic flows.

8) Due to time-out expiring or calling-party's abandon or called-party busy.

9) Not enough digits to discriminate if internal or outgoing call.

*Type 6:* Overall measurements on transit traffic ($L$).

*Object:* Totality of incoming circuits and both-way circuits.

*Entities:*

a) Number of incoming transit seizures;

b) Number of call attempts lost due to internal congestion;

c) Number of call attempts in overflow on the last choice route;

d) Number of successful call attempts obtaining:
   i) no answer [10].
   ii) no answer or metering pulse(s);

e) Number of unsuccessful call attempts due to incomplete dialling [10].

*Type 7:* Overall measurements on system originating traffic ($O + P$) [11].

*Object:* Exchange system.

*Entities:*

a) Number of system originating seizures;

b) Number of call-attempts lost due to internal congestion;

c) Number of successful call-attempts:
   i) with called-party busy or no free outlet,
   ii) with called party free/not answered (for $O$),
   iii) answered.

*Type 8:* Overall measurements on operator-originating traffic ($M + N$) [11].

*Object:* Totality of operator board trunks.

*Entities:*

a) Number of operator originating seizures;

b) Number of unsuccessful call attempts due to:
   i) incomplete dialling,
   ii) invalid address,
   iii) internal congestion;

c) Number of successful call attempts:
   i) with called party busy or no free outlet,
   ii) with called party free/not answered (for $M$),
   iii) answered.

B.2 *Measurements on selectable objects*

*Type 9:* Incoming traffic measurements.

*Object:* Each incoming circuit group and both-way circuit group.

*Entities:*

a) Number of incoming seizures;

b) Traffic volume;

c) Number of call attempts lost due to internal congestion [12];

d) Number of circuits in service;

e) Number of circuits out of service.

---

10) Expiring of time-out or receiving a release forward.

11) Entities may be broken down according to relevant traffic flows.

12) When possible, broken down by reason of congestion, e.g. c-1 blocking through the switching network, c-2 unavailability of common resources, c-3 system faults.

*Type 10:* Outgoing traffic measurements.

*Object:* Each outgoing circuits group and both-way circuit group.

*Entities:*

a) Number of outgoing seizures;

b) Traffic volume;

c) Number of call attempts in overflow;

d) Number of seizures obtaining answer;

e) Number of circuits in service;

f) Number of circuits out of service.

g) Number of dual seizures (both-way circuits only).

*Type 11:* Destination traffic measurements.

*Object:* Each outgoing circuit group and both-way circuit group.

*Entities:*

a) Identity of outgoing circuit group;

b) Number of outgoing seizures for each destination;

c) Number of effective call attempts to each destination;

d) Traffic volume to each destination;

e) Number of call attempts, for each destination, lost due to congestion on the circuit group;

f) Source (identity of incoming circuit group) – if available.

*Type 12:* Measurements on subscriber line groups.

*Object:* Set of lines composing a functional unit.

*Entities*:

a) Originating traffic volume;

b) Terminating traffic volume;

c) Number of originating seizures;

d) Number of terminating seizures;

e) Number of terminating call attempts.

*Type 13:* Measurements on auxiliary units [13].

*Object:* Selected groups of auxiliary units.

*Entities:*

a) Number of seizures;

b) Traffic volume;

c) Numbers of non-serviced call attempts;

d) Number of units in service;

e) Number of units out of service.

B.3 *Measurements on control unit(s)*

*Type 14:* Measurements on control unit(s).

*Object:* Control unit(s).

These measurements are highly system-dependent and therefore no specific recommendations on relevant entities can be made. However, it is essential that systems will have provisions for determining the utilization of control units as required for dimensioning, planning, and grade of service monitoring of the exchange.

[13] By auxiliary units it is meant multifrequency code (MFC) receivers, tone circuits, etc.

B.4 *Measurements on call records*[14)]

*Type 15:* Traffic dispersion and duration.

*Object:* Originating (by subscriber, exchange system, operator) and/or incoming seizures $(A + B + C + D)$.

*Entities:*

a) Source or inlet (local subscriber, exchange system or incoming/bothway circuit group);

b) Time of seizure of inlet;

c) Dialled digits;

d) Service characteristic of call attempt[15)] for successful call attempt;

e) Identity of exchange outlet;

f) Time of seizure of outlet;

g) Time of occurrence of call attempt at exchange outlet;

h) Time of address-complete signal (if available);

i) Time of answer signal;

j) Time of release of outlet;

k) Time of release of inlet.

*Type 16:* Quality-of-service assessment.

*Object:* Originating (by subscriber, exchange system, operator) and/or incoming seizures $(A + B + C + D)$.

*Entities:*

a) Source or inlet (local subscriber, exchange system) or incoming/both-way inter-office circuit group;

b) Time of seizures of inlet;

c) Dialled digits.

For unsuccessful call attempt, specify causes of failure:

d) No dialling;

e) Incomplete dialling;

f) Invalid address;

g) No free outlet;

h) Internal congestion.

For successful call attempt:

i) Order of routing choice (first, second, ..., last) (when considering the automatic repeated attempts and/or rerouting);

j) Time of address-complete signal (undifferentiated subscriber free, subscriber busy, backward congestion) (if available);

k) Result of call attempt (answer, release due to abandon, release due to congestion).

B.5 *Delay grade-of-service (GOS) monitoring*

Measuring delays on a per call basis could produce severe cost penalties to the exchange. Since the accuracy requirements from the statistical viewpoint are not very high, call sampling procedures or test calls are normally sufficient for GOS monitoring purposes. For this reason these measurement types are listed separately even if types 16 and 17 should belong to § B.1 and measurement type 18 to § B.2 of this annex.

B.5.1 *On a per exchange basis*

*Type 17:* Overall delay grade-of-service parameters monitoring.

*Object:* Totality of subscriber lines.

*Entities:*

a) Total number of originating seizures;

b) Total number of originating seizures for which the required information for setting up a through connection is available for processing in the exchange;

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14) The collection of the totality of call attempts could cause an excessive load for the SPC system resources, therefore such measurements might be performed on a sampling basis.

15) Whether the call attempt uses or seeks to use any of the supplementary facilities of the exchange; if so, the supplementary facility concerned shall be specifically indicated.

c) Total number of originating seizures for which sufficient address information has been received, which are addressed to a certain outgoing circuit group and for which the seizing signal or the corresponding address information is sent to the subsequent exchange;

d) Total number of originating seizures for which the dial tone delay exceeds a predetermined threshold value;

e) Seizures already counted in b) for which the through-connection delay exceeds a predetermined threshold value;

f) Seizures already counted in c) for which the call set-up delay exceeds a predetermined threshold value.

*Type 18:* Overall delay grade-of-service parameters monitoring.

*Object:* Totality of incoming or both-way circuit groups.

*Entities:*

a) Total number of incoming seizures;

b) Total number of incoming seizures for which the required information for setting up a through connection is available for processing in the exchange for a certain circuit group;

c) Total number of incoming seizures for which sufficient address information has been received, which are addressed to a certain outgoing circuit group and for which the seizing signal or the corresponding address information is sent to the subsequent exchange;

d) Total number of incoming seizures for which the incoming response delay exceeds a predetermined threshold value;

e) Seizures already counted in b) for which the through-connection delay exceeds a predetermined threshold value;

f) Seizures already counted in c) for which the call set-up delay exceeds a predetermined threshold value.

B.5.2 *On per circuit group basis*

*Type 19:* Delay grade-of-service parameters monitoring.

*Object:* Each incoming or both-way circuit group.

*Entities:*

a) Total number of incoming seizures;

b) Total number of incoming seizures for which the required information for setting up a through connection is available for processing in the exchange for a certain circuit group;

c) Total number of incoming seizures for which sufficient address information has been received, which are addressed to a certain outgoing circuit group and for which the seizing signal or the corresponding address information is sent to the subsequent exchange;

d) Total number of incoming seizures for which the incoming response delay exceeds a predetermined threshold value;

e) Seizures already counted in b) for which the through-connection delay exceeds a predetermined threshold value;

f) Seizures already counted in c) for which the call set-up delay exceeds a predetermined threshold value.

## ANNEX C

(to Recommendation E.502)

**Traffic measurement administration**

C.1 *List of jobs*

The following list of jobs is not intended to be complete, however, it aims to cover the main operator's activities in the area of the traffic measurements administration:

1) To create new measurements or measurement's components and to modify old ones, by selecting the measurement types, object identities and parameters of the measurements themselves (WHAT, WHEN and HOW to measure);

2) To delete measurements or measurement's components which are no longer useful;

3) To define output routing and scheduling of measurement results (WHEN and WHERE the results will be output);

4) To activate and/or to deactivate the performance of the measurements that have been previously defined;

5) To retrieve different kinds of information related to the existing measurements.

C.2 *List of system functions*

To support the operator jobs, the system should offer the following functions:

1) Performance of traffic measurements;
2) Scheduling of traffic measurement execution and results output;
3) Management of measurement's description data;
4) Retrieving of measurement's description data.

C.3 *Man-machine language (MML) functions*

A preliminary list of MML functions needed to control the system functions previously given is listed below; the complete specification of such functions will appear in the Series Z Recommendations:

– Create a measurement;
– Create a measurement set;
– Create an object list;
– Create a time data list;
– Create an output routing list;
– Create a results output schedule;
– Modify a measurement;
– Modify a measurement set;
– Modify an object list;
– Modify a time data list;
– Modify an output routing list;
– Modify a results output schedule;
– Delete a measurement;
– Delete a measurement set;
– Delete an object list;
– Delete a time data list;
– Delete an output routing list;
– Delete a results output schedule;
– Activate a measurement;
– Deactivate a measurement;
– Interrogate a measurement;
– Interrogate a measurement set;
– Interrogate a measurement type;
– Interrogate an object list;
– Interrogate a time data list;
– Interrogate an output routing list;
– Interrogate a results output schedule.

ANNEX D

(to Recommendation E.502)

**Traffic analysis administration**

D.1 *List of jobs*

The following list of jobs is not intended to be complete, it aims to cover the operator's main activities in the area of traffic analysis administration:

1) to define parameter values in the parameter list of the analysis and to modify old values;
2) to define report dates for each type of report in a report date list as required and to modify it;

3) to define output routing for each type of report by an output routing list, as required, and to modify the dates;
4) to activitate and/or deactivate the performance of the analysis;
5) to retrieve different kinds of information related to the existing traffic analysis;
6) to administer traffic data records of the measurement object which are included in the analysis.

D.2 *List of system functions*

The system should offer the following functions to support the jobs of the operator and the analysis itself:

1) transfer of the measured data to the analysis;
2) scheduling of various functions within the analysis, e.g. end-of-day calculation, report printout on report dates, etc.;
3) management of traffic data records;
4) management of analysis description data;
5) transfer of the identification and capacity information of the measurement object to the analysis, e.g. title of a circuit group and the number of circuits assigned to it[16)];
6) management of the printout of reports;
7) supervision control on the time delay of the various operations associated with the analysis.

D.3 *List of MML functions*

Only a preliminary list of MML functions is presented in the following and the complete specifications of such functions will appear in the Series Z Recommendations:

– define analysis parameters;
– define a report date list;
– define an output routing list;
– administer traffic data records;
– activate a traffic analysis;
– deactivate a traffic analysis;
– interrogate a traffic analysis;
– interrogate a traffic analysis versus measurements;
– interrogate an output routing list;
– interrogate analysis parameters;
– interrogate a report date list.

ANNEX E

(to Recommendation E.502)

**Network management requirements for SPC (especially digital) telecommunication exchanges**

E.1 *Introduction*

General information on network management is contained in Recommendation E.410. Network management requires "real-time" monitoring and measurement of network status and performance and the ability to take prompt action to control the flow of traffic when necessary.

E.2 *Status information*

Network management requires information in real time about where and when difficulties are occurring, or are likely to occur in the network (Recommendation E.410 refers). This includes information on the status of circuit groups and circuits, exchanges and exchange components and common channel signalling links. This status information can be provided to the network manager by one or more of several types of displays, including data terminals, CRT devices, visual arrangements such as display boards, and network management consoles.

16) All this information may or may not be available in the collection of the measured data.

In addition, these status indicators should be suitable for transmission to other locations (for example, when network management for a number of exchanges is being performed on a centralized basis), or to provide information to other Administrations. When status indicators are being transmitted to other locations, the ability to manually initiate or inhibit the transmittal should be provided.

E.2.1 *Circuit group status*

Real-time indicators should be provided that show when all circuits in a route are busy and when all available routes to a destination are busy. These indicators should be in a form that would permit transmission to other international switching centres, as appropriate, either via a common channel signalling system or other systems external to the exchange. The requirements at the receiving SPC exchange are described in § E.5 below.

E.2.2 *Exchange status*

Real-time indicators should be provided which show the service availability of major components of the SPC exchange. When the processing capability of an exchange has totally or partially failed or load reduction controls are being implemented the exchange is said to be in congestion.

Real-time indicators should be provided that show when the SPC exchange is in congestion. These congestion indicators should indicate, as a minimum:

- no congestion (congestion level 0 – clearing signal);
- when the exchange is in moderate congestion (congestion level 1);
- when the exchange is in serious congestion (congestion level 2);
- when the exchange is unable to process any calls (congestion level 3).

The exchange should escalate through each congestion level and not, for example, pass directly from congestion level 0 to congestion level 2 and vice versa. This will ensure smooth operation when these signals are used to control traffic automatically at the receiving end. Further information relating to exchange status is detailed in Recommendation E.411.

When congestion signals are transmitted to other locations to automatically control traffic, a "fail-safe" mechanism must be provided to guard against improper actions caused by false signals.

The requirements at the receiving SPC exchange are described in § E.5 below.

The network manager should have the ability to set the thresholds for the generation of congestion levels 1 and 2.

E.2.3 *Common channel signalling status*

Indicators should be provided to show the occurrence of the conditions associated with common channel signalling systems: Such conditions may include:

i) Receipt of a transfer prohibited signal (Signalling System No. 6, Signalling System No. 7);
ii) Initiation of an emergency restart procedure (Signalling System No. 6);
iii) Presence of a signalling terminal buffer overflow condition (Signalling System No. 6);
iv) Failure or removal from service of a signalling link (Signalling System No. 7);
v) Signal link unavailability (Signalling System No. 7);
vi) Signal route unavailability (Signalling System No. 7);
vii) Destination inaccessible (Signalling System No. 7).

E.2.4 *Equipment availability status*

It should be possible to assess the availability of the network for service, by indicating the number or percentage of circuits on each route, and certain key items of equipment where appropriate, that are made busy or are available.

### E.2.5 *Network management control status*

Information should be available to all necessary points (for example, the network management centre, exchange staff) as to which network management controls, detailed in § E.4, are currently activated and whether the controls were activated by manual or automatic means.

## E.3 *Performance information*

Performance data is required to identify and quantify difficulties as they occur in the network to alert network managers that some action may be required, to measure the effect of any network management action taken, and to indicate when a network management action should be modified, or removed. Accordingly, traffic data must be collected and processed in real time and should be based on a system of measurement which is either continuous, or of a sufficiently rapid sampling rate to provide the required information accurately.

Performance data for network management purposes is derived from bids, seizures, answer signals, clears and the time of their occurrence. The data can be used to measure:

- circuit group performance;
- destination code performance;
- exchange performance;
- common channel signalling system performance.

### E.3.1 *Circuit group and destination code performance*

Network management staff should be provided with the basic data plus a number of performance parameters. A range of performance parameters is described in Recommendation E.411. The actual parameters to be used by an Administration may depend on such factors as application of exchange and routing structure used and should therefore be specified individually.

### E.3.2 *Exchange performance*

The exchange should provide the following data on exchange performance for the total exchange and for major exchange components, where appropriate:

i) bids;

ii) percentage of real-time capacity in use;

iii) queue lengths and overflows;

iv) number and percentage of bids encountering delays;

v) cross-exchange delay measurements;

vi) switching loss;

vii) counts of calls affected by network management control, by type of control.

### E.3.3 *Common channel signalling systems performance*

The exchange should provide data for common channel signalling links. Such data may include:

i) counts of signal units and percent occupancy;

ii) counts of outgoing initial address messages (IAM) and incoming answer signals (ANC and ANN), and from these, outgoing answer-seizure ratio for the signalling link;

iii) counts of incoming initial address messages (IAM) and outgoing answer signals (ANC and ANN), and from these, incoming answer-seizure ratio for the signalling links;

iv) counts of changeovers;

v) counts of occurrences of terminal buffer overflow conditions;

vi) counts of calls overflowed due to terminal buffer overflow;

vii) counts of circuit group congestion (CGC), national network congestion (NNC) and/or switching equipment congestion (SEC) signals sent and received on the signalling link;

viii) counts of transfer-prohibited signals sent and received on the signalling link.

### E.3.4 *Performance reports*

Performance reports can be provided in the following ways, as required by the network manager:

i) automatic data – this data is provided automatically as specified in the exchange program;

ii) scheduled data – this data is provided according to a schedule established by the network manager;

iii) demand data – this data is provided only in response to a specific request by the network manager. In addition to performance data, demand data includes reference data, such as the number of circuits provided or available for service, routing information, assigned threshold values, numbers of installed switching system components, etc.;

iv) exception data – this data is provided when a data count for calculation exceeds a threshold established by the network manager.

Data reports can be provided on a 5 minute, 15 minute or 30 minute basis. The specific interval for any data report will be determined by the network manager. Historic data relating to the previous two or three periods (5, 15 or 30-minute) must also be available.

## E.4 *Network management controls*

Exchanges should be capable of applying a wide range of network management controls to alter the flow of traffic, as directed by the network manager.

It is desirable that these controls be activated to affect a variable percentage of traffic (for example 25%, 50%, 75% or 100%). Alternatively, the number of call attempts routed in a particular period may be controlled (for example 10 calls per minute). It may also be desirable to apply controls on a destination code basis and/or for particular traffic elements (for example, direct routed, alternate routed, transit, operation originated, direct dialled).

Many of the controls specified below could be activated by manual or automatic means (see § E.4.5). When automatic activation is provided, however, an ability for manual overridge must also be provided.

The following controls are required:

### E.4.1 *Code blocking*

This control bars or restricts routing for a specific destination code. Code blocking can be done on a country code, an area code, an exchange code or an individual line number as specified by the network manager.

### E.4.2 *Cancellation of alternative routing*

There are several variations of this control. One is to prevent traffic from the selected route overflowing onto the next alternate route. Another is to prevent overflow traffic from all sources from accessing a specific route.

### E.4.3 *Restriction of direct routing*

This control limits the amount of direct routed traffic accessing a route.

### E.4.4 *Skip Route*

This control allows traffic to bypass a specific route and advance instead to the next route in its normal routing pattern.

### E.4.5 *Temporary alternative routing*

This control redirects traffic from congested routes to routes not normally available which have idle capacity at the time. This can be done for subscriber, and/or operator initiated traffic.

E.4.6 *Circuit directionalization*

This control changes both-way operated circuits to one-way operated circuits. At the end of the circuit for which access to the route is inhibited this is a protective action, whereas at the other end of the circuit (where access is still available) it is an expansive action.

E.4.7 *Circuit turndown/busying*

This control removes one-way and/or both-way operated circuits from service.

E.4.8 *Special recorded announcements*

These are announcements which give special instructions to operators and subscribers, such as to defer their call to a later time, during congestion, failures, or other abnormal events.

E.4.9 *Circuit reservation*

This control reserves the last few idle circuits in a circuit group for a particular type of traffic such as, for example, direct routed traffic or operator originated traffic.

E.4.10 *Switching system controls*

These are internally provided automatic controls that are part of the exchange design. They improve switching performance during overloads by:

- inhibiting second trials;
- inhibiting low-priority tasks;
- reducing the acceptance of new calls based on the availability of major components, or other load reduction actions;
- informing connected exchanges that protective controls should be activated.

E.5 *Automatic control of traffic flow*

Exchanges should provide automatic, and/oı dynamic network management controls, which represent a significant improvement over static manual controls. These controls, which are pre-assigned, can respond automatically to conditions internally detected by the exchange, or to status signals from other exchanges (§ E.4.2) and are promptly removed when no longer required.

Part of the improved performance of automatic controls can be derived from the ability to distinguish between traffic that is easy-to-reach (ETR) and traffic that is hard-to-reach (HTR), i.e. traffic with a low answer bid ratio, and applying heavier controls to HTR traffic. This distinction can be based on:

i) internal performance measurements within the exchange, (for example, low answer seizure ratio to a destination code). This information can then be transmitted to other exchanges via a common channel signalling system or other external systems; or

ii) similar information received from other exchanges. The network manager should have the ability to set the threshold for HTR determination and to assign manually a destination code as HTR traffic.

Whether the control signal is generated within the exchange (HTR) or forwarded by another exchange (HTR, circuit group/destination status – § E.3.1, Exchange status – § E.3.2), the network manager must have the ability to assign the control signal to an appropriate control mentioned in § E.4.4 above.

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SECTION 2

# FORECASTING OF TRAFFIC

**Recommendation E.506** [1)]

## FORECASTING INTERNATIONAL TELEPHONE TRAFFIC

### 1 Introduction

In the operation and administration of the international telephone network, proper and successful development depends to a large degree upon estimates for the future. Accordingly, for the planning of equipment and circuit provision and of telephone plant investments, it is necessary that Administrations forecast the traffic which the network will carry. In view of the heavy capital investments in the international network, the economic importance of the most reliable forecast is evident.

Econometric and time series model development and forecasting requires familiarity with a large spectrum of methods and techniques to deal with a wide range of distinctly different situations. Thus, the purpose of this Recommendation is to present some of the basic ideas and leave the explanation of the details to the publications cited in the reference list. As such, this Recommendation is not intended to be a complete guide to econometric and time series modeling and forecasting.

### 2 Base data for forecasting

2.1 An international route may carry not only point-to-point traffic between international exchanges of terminal countries, but also transit traffic destined for or arriving from other points in the international network. Therefore forecasts for each of these components are required. The forecasts should be prepared by the Administration originating the traffic jointly (where applicable) with any other Administration involved in a transit function for the traffic component, and should be supplied to the destination Administration and to any other Administration involved in transit arrangements. It must also be recognized that certain adjustments between the two ends of a traffic relation may be necessary in arriving at the final forecast.

2.2 There are two different strategies for deriving future international circuit quantities, namely the *direct Erlang forecasting strategy* which is based on forecasting the offered busy-hour Erlang traffic and which is a more direct method where the necessary data is available and the *composite forecasting strategy* which is based on forecasting monthly paid minutes and various traffic-dependent conversion factors.

2.3 With direct Erlang forecasting, the traffic carried (in Erlangs) for each relation would be regarded as base data in forecasting traffic growth.

2.4 Composite forecasting uses two sets of base data:

- historical international accounting data of monthly paid minute traffic and
- a number of factors which are used for converting a paid-minutes forecast on the basis of the accounting data into busy-hour Erlang forecasts.

[1)] This Recommendation was formerly numbered E.502 in the *Yellow Book*

2.5 Administrations planning installation of traffic measuring equipment are advised to ensure that this equipment records the data in computer-legible form (punched paper tape, magnetic tape, etc.). This greatly facilitates computer processing and makes it easier to analyze more frequent measurements.

## 3 Direct and composite forecasting

3.1 In accordance with the direct Erlang forecasting strategy (§ 2.3), an Administration would at regular intervals measure the level of busy-hour traffic carried for each relation. The carried traffic is converted to offered traffic in accordance with the formula in Recommendation E.501.

3.2 In accordance with the composite forecasting strategy (§ 2.4) monthly paid-minute traffic demands are forecast using historical international accounting records of monthly paid-minutes. The forecasts are converted to dimensioning busy-hour Erlang forecasts by the application of a number of traffic related conversion factors forecast for each service category. The conversion is carried out in accordance with the formula.

$$A = Mdh/60e \qquad (3.2.1)$$

where

$A$ is the estimated mean traffic in the busy hour,

$M$ is the monthly paid minutes,

$d$ is day-to-month ratio,

$h$ is the busy hour-to-day ratio and

$e$ is the efficiency factor.

The formula is described in detail in Annex A.

3.3 In situations where paid minute information is recorded separately for the standard rate charging period and the busy hour lies within this standard rate period, it is likely that a more stable relationship can be derived between busy hour erlangs and standard rate paid minutes rather than total paid minutes.

3.4 Wherever possible, both the direct and composite forecasting strategies should be used and compared. This comparison may reveal irregularities not evident from the use of only one method. Where these are significant, in particular in the case of the busy hour, the causes for the differences should be identified before the resulting forecast is adopted.

## 4 Length of forecast period

For normal extensions of switching equipment and additions of circuits, a forecast period of about six years is necessary. However, a longer forecast period may be necessary for the planning of new cables or other transmission media or for major plant installations. Estimates in the long term would necessarily be less accurate than short-term forecasts but that would be acceptable.

In forecasting with a statistical model, the length of the forecast period is entirely determined by:

a) the historical data available,

b) the purpose or use of the forecast,

c) the market structure that generates the data,

d) the forecasting model used,

e) the frequency of the data.

The historical data available depends upon the period over which it has been collected and the frequency of collection (or the length of the period over which data is aggregated). A small historical data base can only support a short prediction interval. For example, with 10 or 20 observations a model can be used to forecast 4-5 periods past the sample (i.e. into the future). On the other hand, with 150-200 observations, potentially reliable forecasts can be obtained for 30 to 50 periods past the sample – other things being equal.

Certainly, the purpose of the forecast affects the number of predicted periods. Long range facility planning requires forecasts extending 15-20 or more years into the future. Rate change evaluations may only require forecasts for 2-3 years. Alteration of routing arrangements could only require forecasts extending a few months past the sample.

Stability of a market, or lack thereof, also affect the length of the forecast period. With a stable market structure one could conceivably extend the forecast period to equal the historical period. However, a volatile market does not afford the same luxury to the forecaster: the forecast period can only consist of a few periods into the future.

The forecasting models used to generate forecasts do, by their nature, influence the decision on how far out one can reasonably forecast. Structural models tend to perform better than other models in the long run, while for short-run predictions all models seem to perform equally well.

It should be noted that while the purpose of the forecast and the forecasting model affect the length of the forecast, the number of periods to be forecasted play a crucial role in the choice of the forecasting model and the use to which a forecast is put to.

## 5 Different forecasting models

In order to prepare a traffic forecast, it is necessary to take into account irregularly recurring features which may have affected past traffic or may affect present traffic. Examples are changes in tariffs, changes in the signalling system, major changes in the structure of the network, removal of hindrances in the network and the substitution of subscriber-to-subscriber dialling methods for manual methods of setting up calls. Changes that effect the environment may introduce discontinuities in the traffic profile and may shorten or lengthen the duration of the peak period, i.e. alter the busy-hour/day ratio, to a considerable extent and affect the concentration of traffic in this period. Administrations should develop means of identifying these factors and evaluating them quantitatively (see examples of discontinuities in the graphs of Figures 2/E.506, 3/E.506, 4/E.506 and 5/E.506). From such an evaluation it will be possible to make a modified set of values of past traffic from which a future trend may be extrapolated.

Where such discontinuities are identified, it is advantageous to use the composite forecasting strategy method to aid in the quantitative evaluation of the discontinuities. This is true even where the direct Erlang forecasting method is used for the projections.

### 5.1 *Building the forecasting model*

This procedure can conveniently be described as four consecutive steps. The first step consists in finding a useful class of models to describe the actual situation. Examples of such classes are simple models, smoothing models, autoregressive models, autoregressive integrated moving average (ARIMA) models or econometric models. Before choosing the class of models, the influence of external variables should be analyzed. If special external variables have significant impact on the traffic demand, one ought to include them in the forecasting models, provided enough historical data are available.

The next step is to identify one tentative model in the class of models which have been chosen. If the class is too extensive to be conveniently fitted directly to data, rough methods for identifying subclasses can be used. Such methods of model identification employ data and knowledge of the system to suggest an appropriate parsimonious subclass of models. The identification procedure may also, in some occasions, be used to yield rough preliminary estimates of the parameters in the model. Then the tentative model is fitted to data by estimating the parameters. Usually, maximum likelihood estimators or least square estimators are used.

The next step is to check the model. This procedure is often called diagnostic checking. The object is to find out how well the model fits the data and, in case the discrepancy is judged to be too severe, to indicate possible remedies. The outcome of this step may thus be acceptance of the model if the fit is acceptable. If on the other hand it is inadequate, it is an indication that new tentative models may in turn be estimated and subjected to diagnostic checking.

In Figure 1/E.506 the steps in the model building procedure are illustrated.

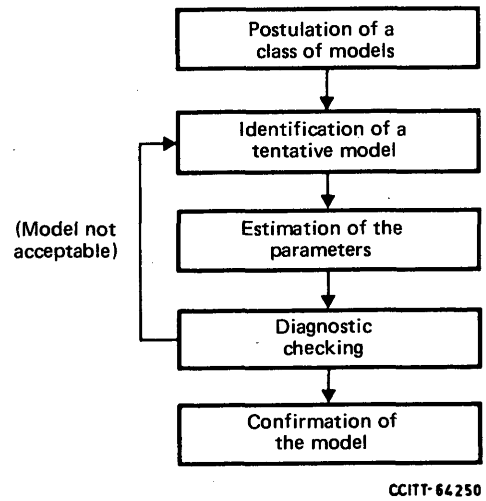



FIGURE 1/E.506

**Steps in the model building procedure**

5.2 *Simple models*

An adaptive forecasting system using time as an independent variable is recommended for estimates of the future traffic from the values derived in accordance with § 5 above. On this basis, the traffic trend is extrapolated by calculating the values of the parameters of some function which is expected to characterize the growth of international traffic. The numerical calculations in curve fitting can be performed by using the least squares method. If the traffic values available cannot be expected to yield mathematically reliable values, a rough survey can be obtained by simply plotting a continuation of the curve of available traffic data.

In view of the historical absence of saturation effects in international communications and taking account of the prospects for future expansion, a simple exponential or parabolic function may be used to represent the growth of international telephone traffic. The equations of these two functions are:

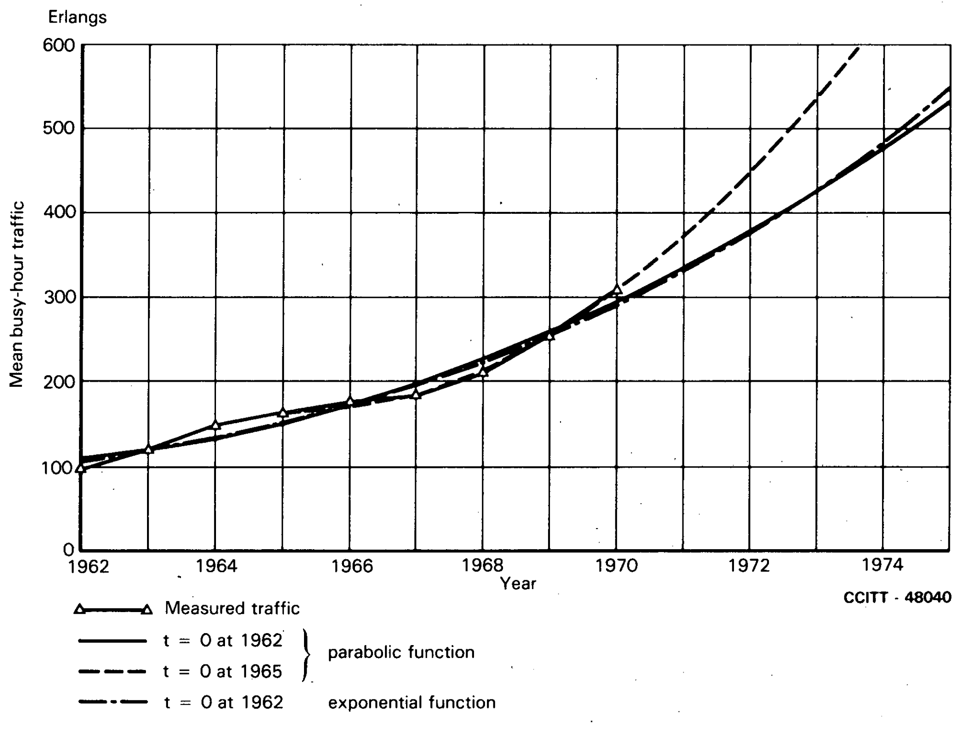
Exponential: $Y_t = Ae^{Bt}$ (5-1)

Parabolic: $Y_t = A + Bt + Ct^2$ (5-2)

In the above equations, $Y_t$ is the traffic after $t$ time intervals, while $A$, $B$ and $C$ are constants (parameters depending on the route observed). It is found that both these functions can be used for forecasts up to, say, six years, whereas the parabolic function can be applied for longer-term forecasts. However, care must be applied in the use of the parabolic function if the estimate of $C$ is negative, as this will lead to unreliable forecasts.

Examples of curve fitting by means of the method of least squares applied to traffic data from some international telephone relations are given in the graphs of Figures 2/E.506 and 3/E.506. In the examples the growth trends are approximated by the exponential and parabolic functions.

For prediction of changes in factors used for composite forecasting, a linear forecasting model may be sufficient.




Mean busy-hour traffic (Erlangs); 10 consecutive working days, Recommendation E.500, § 3.2.

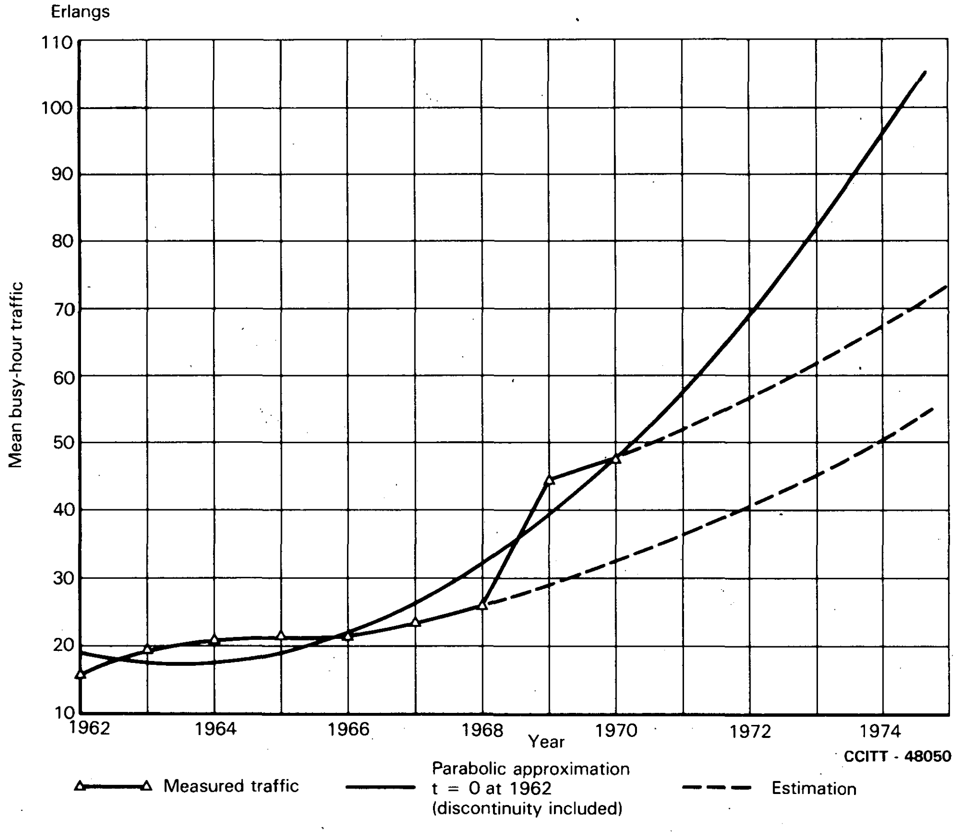
FIGURE 2/E.506

**Mean busy-hour traffic Federal Republic of Germany - Switzerland**

5.3 *Smoothing models*

By using a smoothing process in curve fitting, it is possible to calculate the parameters of the model to fit current data very well but not necessarily the data obtained from the distant past.

The best known smoothing process is the moving average. The degree of smoothing is controlled by the number of most recent observations included in the average. All observations included in the average have the same weight. In the method of exponential smoothing the weight given to previous observations decreases geometrically with age. The speed with which the effect of past observations is reduced is controlled here by the chosen value of a smoothing constant. Use of smoothing methods is appropriate especially for short-term forecasts.




Mean busy-hour traffic (Erlangs); 10 consecutive working days, Recommendation E.500, § 3.2.

FIGURE 3/E.506

**Mean busy-hour traffic Federal Republic of Germany - Sweden**

## 5.4 *Autoregressive models*

If the traffic demand, $X_t$, at time $t$ can be expressed as a linear combination of earlier equidistant observations of the past traffic demand, the process is an autoregressive process. Then the model is defined by the expression:

$$X_t = \Phi_1 X_{t-1} + \Phi_2 X_{t-2} + \dots + \Phi_p X_{t-p} + a_t \qquad (5\text{-}3)$$

where

$a_t$ is white noise at time $t$;

$\Phi_k$, $k = 1, \dots p$ are the autoregressive parameters.

The model is denoted by $AR(p)$ since the order of the model is $p$.

By use of regression analysis the estimates of the parameters can be found. Because of common trends the exogenous variables ($X_{t-1}$, $X_{t-2}$, ... $X_{t-p}$) are usually strongly correlated. Hence the parameter estimates will be correlated. Furthermore, significance tests of the estimates are somewhat difficult to perform.

Another possibility is to compute the empirical autocorrelation coefficients and then use the Yule-Walker equations to estimate the parameters $[\Phi_k]$. This procedure can be performed when the time series $[X_t]$ are stationary. If, on the other hand, the time series are non stationary, the series can often be transformed to stationarity e.g., by differencing the series. The estimation procedure is given in Annex B, § B.1.

### 5.5 *Autoregressive integrated moving average (ARIMA) models*

The class of autoregressive moving average models denoted by ARIMA-models is an extention of the class of autoregressive models which also includes the moving average models. A moving average model of order $q$ is given by:

$$X_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} \dots - \theta_q a_{t-q} \tag{5-4}$$

where

$a_t$ is white noise at time $t$;

$[\theta_k]$ are the moving average parameters.

Assuming that the white noise term in the autoregressive models in § 5.4 is described by a moving average model, one obtains the so-called ARIMA $(p, q)$ model:

$$X_t = \Phi_1 X_{t-1} + \Phi_2 X_{t-2} + \dots + \Phi_p X_{t-p} + a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} \dots - \theta_q a_{t-q}. \tag{5-5}$$

The method for analyzing such time series was developed by G. E. P. Box and G. M. Jenkins [1]. To analyze and forecast such time series it is usually necessary to use a time series program package.

As indicated in Figure 1/E.506 a tentative model is identified. This is carried out by determination of necessary transformations and number of autoregressive and moving average parameters. The identification is based on the structure of the autocorrelations and partial autocorrelations.

The next step as indicated in Figure 1/E.506 is the estimation procedure. The maximum likelihood estimates are used. Unfortunately, it is difficult to find these estimates because of the necessity to solve a nonlinear system of equations. For practical purposes, a computer program is necessary for these calculations. The forecasting model is based on equation (5-5) and the process of making forecasts $l$ time units ahead is shown in § B.2.

The forecasting models described so far are univariate forecasting models. It is also possible to introduce explanatory variables. In this case the system will be described by a transfer function model. The methods for analyzing the time series in a transfer function model are rather similar to the methods described above.

### 5.6 *Econometric models*

Econometric models involve equations which relate a variable which we wish to forecast (the dependent or endogenous variable) to a number of socio-economic variables (called independent or exogenous variables). The form of the equations should reflect an expected casual relationship between the variables. Given an assumed model form, historical or cross sectional data is used to estimate coefficients in the equation. Assuming the model remains valid over time, estimates of future values of the independent variables can be used to give forecasts of the variables of interest. Some examples of typical econometric models are given in Annex C.

There is a wide spectrum of possible models and a number of methods of estimating the coefficients (e.g., least squares, varying parameter methods, nonlinear regression, etc). In many respects the family of econometric models available is far more flexible than other models. For example, lagged effects can be incorporated, observations weighted, ARIMA residual models subsumed, information from separate sections pooled and parameters allowed to vary in econometric models, to mention a few.

One of the major benefits of building an econometric model to be used in forecasting is that the structure or the process that generates the data must be properly identified and appropriate causal paths must be determined. Explicit structure identification makes the source of errors in the forecast easier to identify in econometric models than in other types of models.

Changes in structures can be detected through the use of econometric models and outliners in the historical data are easily eliminated or their influence properly weighted. Also, changes in the factors affecting the variables in question can easily be incorporated in the forecast generated from an econometric model.

Often, fairly reliable econometric models may be constructed with less observations than required for time series models. In the case of pooled regression models, just a few observations for several cross-sections are sufficient to support a model used for predictions.

However, care must be taken in estimating the model to satisfy the underlying assumptions of the techniques which are described in many of the reference works listed at the end of this Recommendation. For example the number of independent variables which can be used is limited by the amount of data available to estimate the model. Also, independent variables which are correlated to one another should be avoided. Sometimes correlation between the variables can be avoided by using differenced or detrended data or by transformation of the variables.

## 6 Descending and ascending methods

### 6.1 *Choice of model*

The object is to make forecasts for the traffic between countries. For this to be a sensible procedure, it is necessary that the traffic between the countries should not be too small, so that the forecasts may be accurate. A method of this type is usually denoted as "ascending".

Alternatively, when there is a small amount of traffic between the countries in question, it is better to start out with forecasting the traffic for a larger group of countries. These forecasts are often used as a basis for forecasts for the traffic to each country. This is done by a correction procedure to be described in more detail below. Methods of this type are called "descending". The following comments concern the preference of one method to another.

Let $\sigma_T$ be the standard deviation of the forecasts between a country and a group of countries, and $\sigma_{Ii}$ be the standard deviation of the forecasts between the originating country and the country in the group.

$$\text{If } \sigma_T < \left[ \sum (\sigma_{Ii}^2) \right]^{1/2};$$

it is preferable to use a descending procedure provided that the method of disaggregating the forecast to the individual countries does not introduce a significantly large additional error. The inequality is an approximate expression where the second order moments are ignored.

In many situations it is possible to use a more advanced forecasting model on the aggregated level. Also, the data on an aggregated level may be more consistent and less influenced by stochastic changes compared to data on a lower level. Hence, in most cases the inequality stated above will be satisfied for small countries.

### 6.2 *Ascending method*

As outlined in § 6.1 the ascending method is defined as a procedure for making separate forecasts of the traffic between different countries directly. If the inequality given in § 6.1 is not satisfied, which may be the case for large countries, it is sufficient to use the ascending method. Hence, one of the forecasting models mentioned in § 5 can be used to make traffic forecasts to different countries.

### 6.3. *Descending procedure*

In most cases the descending procedure is recommended for making forecasts of international traffic from a small country. In § C.2 a detailed example of such a forecasting procedure is given.

The first step in the procedure is to find a forecasting model on the aggregated level which may be a rather sophisticated model. Let $X_T$ be the traffic forecasts on the aggregated level and $\sigma_T$ the estimated standard deviation of the forecasts.

The next step is to develop separate forecasting models of traffic to different countries. Let $\hat{X}_{Ii}$ be the traffic forecasts to the $i^{th}$ country and $\hat{\sigma}_{Ii}$ the standard deviation. Now, the separate forecasts $[\hat{X}_{Ii}]$ have to be corrected by taking into account the aggregated forecasts $\hat{X}_T$. We know that in general

$$\hat{X}_T \neq \sum_i \hat{X}_{Ii}$$

Let the corrections of $[\hat{X}_{Ii}]$ be $[X_i]$ while the corrected aggregated forecast should be $X = \sum X_i$.

The procedure for finding $[X_i]$ is described in § B.3.

## 7 Discontinuities in traffic growth

### 7.1 *Examples of discontinuities*

It may be difficult to assess in advance the magnitude of a discontinuity. The influence of the factors which cause discontinuities often is spread over a transitional period, the discontinuity is then not so obvious. Furthermore, discontinuities arising, for example, from the introduction of international subscriber dialling are difficult to identify accurately, because changes in the method of working are usually associated with other changes (e.g. tariff reductions).

An illustration of the bearing of discontinuities on traffic growth can be observed in the graphs of Figures 3/E.506, 4/E.506 and 5/E.506.

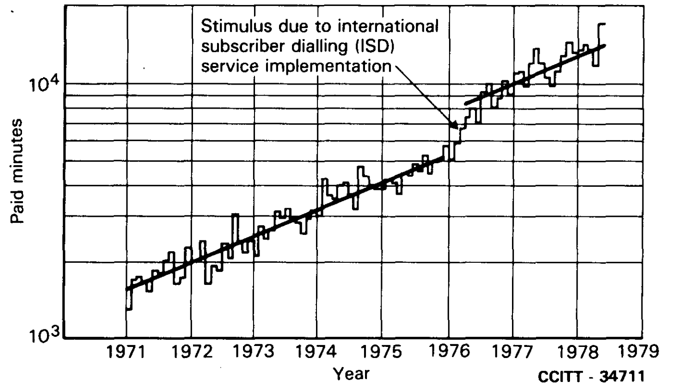



FIGURE 4/E.506

**Outgoing telephone paid-minutes from Australia to Sweden**

Discontinuities representing the doubling and even more of traffic flow are known. It may also be noted that changes could occur in the growth trend after discontinuities.

In short-term forecasts it may be desirable to use the trend of the traffic between discontinuities, but for long-term forecasts it may be desirable to use a trend estimate which is based on long-term observations, including previous discontinuities.

In addition to random fluctuations due to unpredictable traffic surges, faults, etc., traffic measurements are also subject to systematic fluctuations, due to daily or weekly traffic flow cycles, influence of time differences, etc.

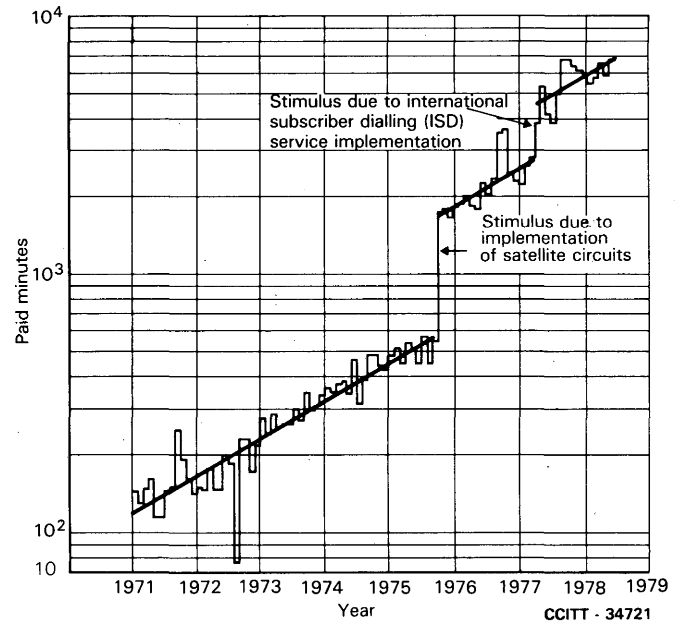



FIGURE 5/E.506

**Outgoing telephone paid-minutes from Australia to Sri Lanka**

7.2 *Introduction of explanatory variables*

Identification of explanatory variables for an econometric model is probably the most difficult aspect of econometric model building. The explanatory variables used in an econometric model identify the main sources of influence on the variable one is interested in.

Economic theory is the starting point for variable selection. More specifically, demand theory provides the basic framework for building the general model. However, the description of the structure or the process generating the data often dictate what variables enter the set of explanatory variables. For instance, technological relationships may need to be incorporated in the model in order to appropriately define the structure.

Although there are some criteria used in selecting explanatory variables (e.g., $\bar{R}^2$, Durbin-Watson (D-W) statistic, root mean square error (RMSE), ex-post forecast performance, explained in the references), statistical problems and/or availability of data (either historical or forecasted) limit the set of potential explanatory variables and one often has to revert to proxy variables. And, unlike pure statistical models, econometric models admit explanatory variables, not on the basis of statistical criteria alone but, also, on the premise that causality is, indeed, present.

A completely specified econometric model will capture turning points, and discontinuities in the dependent variable will not be present unless, of course, the parameters of the model change drastically in a very short time period. Discontinuities in the growth of telephone traffic are indications that the underlying market or technological structure have undergone large changes.

Sustained changes in the growth of telephone demand can either be captured through varying parameter regression or through the introduction of a variable that appears to explain the discontinuity (e.g., the introduction of an advertising variable if advertising is judged to be the cause of the structural change). Once-and-for-all, or step-wise discontinuities, cannot be handled by the introduction of explanatory changes: dummy variables can resolve this problem.

7.3 *Introduction of dummy variables*

In econometric models, qualitative variables are often relevant. To measure the impact of qualitative variables, dummy variables are used in econometric models. The dummy variable technique uses the value 1 for the presence of the qualitative attribute that has an impact on the dependent variable and 0 for the absence of the given attribute.

Thus, dummy variables are appropriate to use in the case where a discontinuity in the dependent variable has taken place. A dummy variable, for example, would take the value of zero during the historical period when calls are operator handled and one for the period for which direct dial service is available.

Dummy variables are often used to capture seasonal effects in the dependent variable or when one needs to eliminate the effect of an outliner on the parameters of a model, such as a large jump in telephone demand due to a postal strike or a sharp decline due to facility outages associated with severe weather conditions.

Indiscriminate use of dummy variables should be discouraged for two reasons:

1) dummy variables tend to absorb all the explanatory power during discontinuities, and

2) they result in a reduction in the degrees of freedom present.

## 8 Accuracy in forecasting

### 8.1 *General*

In this section methods for testing the significance of the parameters and also methods for calculating confidence intervals are presented for some of the forecasting models given in § 5. In particular the methods relating to regression analysis and time series analysis will be discussed.

All econometric forecasting models presented here are described as regression models. Also the simple models given in § 5 can be described as regression models.

The exponential model of Equation (5-1)

$$Z_t = A e^{Bt} \cdot u \tag{8-1}$$

may be transformed to a linear form

$$\ln Z_t = \ln A + Bt + \ln u \tag{8-2}$$

or

$$Y_t = \beta_0 + \beta_1 X_1 + a \tag{8-3}$$

where

$Y_t = \ln Z_t$

$\beta_0 = \ln A$

$\beta_1 = B$

$X_l = t$

$a = \ln u$ (white noise).

The parabolic model

$$Y_t = A + Bt + Ct^2 + a_t \tag{8-4}$$

already has a linear form. The exogenous variables $t$ and $t^2$ in the model may be denoted by $X_1$ and $X_2$.

A regression model in a general form is given by

$$Y_t = \bar{\beta}_0 + \bar{\beta}_1 X_{1t} + \ldots + \bar{\beta}_k X_{kt} + a_t \qquad t = 1, 2, \ldots \tag{8-5}$$

The endogenous variable $Y$ is described by a linear sum of exogenous variables $[X_i]$ and the white noise factor $a$ (also called error term) which is assumed to be normally distributed with expectation zero and variance $\sigma^2$. The $[X_i]$ variables may be different economic explanatory variables. Hence, an observation $Y_t$ at time $t$ can be expressed by the actual values $[X_{ti}]$ of the exogenous variables at time $t$ and the white noise or error term.

8.2 *Test of significance of the parameters*

One way to evaluate the forecasting model is to analyse the impact of different exogenous variables. After estimating the parameters in the regression model, the significance of the parameters have to be tested.

In the example of an econometric model in Annex C, the estimated values of the parameters are given. Below these values the estimated standard deviation is given in parentheses. As a rule of thumb, the parameters are considered as significant if the absolute value of the estimates exceeds twice the estimated standard deviation. A more accurate way of testing the significance of the parameters is to take into account the distributions of their estimators.

Also, the multiple correlation coefficient (or coefficient of determination) may be used as a criterion for the fitting of the equation.

The multiple correlation coefficient, $R^2$, is given by:

$$R^2 = \frac{\sum_{i=1}^{N} (\hat{Y}_i - \overline{Y})^2}{\sum_{i=1}^{N} (Y_i - \overline{Y})^2} \tag{8-6}$$

If the multiple correlation coefficient is close to 1 the fitting is satisfactory. However, a high $R^2$ does not imply an accurate forecast.

In time series analysis, the discussion of the model is carried out in another way. As pointed out in § 5, the number of autoregressive and moving average parameters in an ARIMA model is determined by an identification procedure based on the structure of the autocorrelation and partial autocorrelation function.

The estimation of the parameters and their standard deviations is performed by an iterative nonlinear estimation procedure. Hence, by using a time series analysis computer program, the estimates of the parameters can be evaluated by studying the estimated standard deviations in the same way as in regression analysis.

An overall test of the fitting is based on the statistic

$$Q_{N-d} = \sum_{i=1}^{N} r_i^2 \tag{8-7}$$

where $r_i$ is the estimated autocorrelation at lag $i$ and $d$ is the number of parameters in the model. When the model is adequate, $Q_{N-d}$ is approximately chi-square distributed with $N - d$ degrees of freedom. To test the fitting, the value $Q_{N-d}$ can be compared with fractiles of the chi-square distribution.

8.3 *Validity of exogenous variables*

Econometric forecasting models are based on a set of exogenous variables which explain the development of the endogenous variable (the traffic demand). To make forecasts of the traffic demand, it is necessary to make forecasts of each of the exogenous variables. It is very important to point out that an exogenous variable shall not be included in the forecasting model if the prediction of the variable is less confident than the prediction of the traffic demand.

Suppose that the exact development of the exogenous variable is known which, for example, is the case for the simple models where time is the explanatory variables. If the model fitting is good and the white noise is normally distributed with expectation equal to zero, it is possible to calculate confidence limits for the forecasts. This is easily done by a computer program.

On the other hand, the values of most of the explanatory variables can usually not be predicted exactly. The confidence of the prediction will then decrease with the number of periods. Hence, the explanatory variables will cause the confidence interval of the forecasts to increase with the number of the forecast periods. In these situations it is difficult to calculate a confidence interval around the forecasted values.

If the traffic demand can be described by an autoregressive moving average model, no explanatory variables are included in the model. Hence, if there is no lack of it in the model, the confidence limits of the forecasting values can be calculated. This is done by a time series analysis program package.

### 8.4 *Confidence intervals*

Confidence intervals, in the context of forecasts, refer to statistical constructs of forecast bounds or limits of prediction. Because statistical models have errors associated with them, parameter estimates have some variability associated with their values. In other words, even if one has identified the correct forecasting model, the influence of endogenous factors will cause errors in the parameter estimates and the forecast. Confidence intervals take into account the uncertainty associated with the parameter estimates.

In causal models, another source of uncertainty in the forecast of the series under study are the predictions of the explanatory variables. This type of uncertainty cannot be handled by confidence intervals and is usually ignored, even though it may be more significant than the uncertainty associated with coefficient estimates. Also, uncertainty due to possible outside shocks is not reflected in the confidence intervals.

For a linear, static regression model, the confidence interval of the forecast depends on the reliability of the regression coefficients, the size of the residual variance, and the values of the explanatory variables. The 95% confidence interval for a forecasted value $Y_{N+1}$ is given by:

$$Y_{N+1}^F - 2S_f \leqslant Y_{N+1} \leqslant Y_{N+1}^F + 2S_f \tag{8-8}$$

where $Y_{N+1}^F$ is the forecast one period out and $S_f$ is the standard error of the forecast.

This says that we expect, with a 95% probability, that the actual value of the series at time $N+1$ will fall within the limits given by the confidence interval assuming that there are no errors associated with the forecast of the explanatory variables.

## 9 Methods for evaluation of forecasting models

### 9.1 *Forecasts of levels versus forecasts of changes*

Many econometric models are estimated using levels of the dependent and independent variables. Since economic variables move together over time, high coefficients of determination are obtained. The collinearity among the levels of the explanatory variables does not present a problem when a model is used for forecasting purposes alone, given that the collinearity pattern in the past continues to exist in the future. However, when one attempts to measure structural coefficients (e.g., price and income elasticities) the collinearity of the explanatory variables (known as multicollinearity) renders the results of the estimated coefficients unreliable.

To avoid the multicollinearity problem and generate benchmark coefficient estimates and forecasts, one may use changes of the variables (first difference or first log difference which is equivalent to a percent change) to estimate a model and forecast from that model. Using changes of variables to estimate a model tends to remove the effect of multicollinearity and produce more reliable coefficient estimates by removing the common effect of economic influences on the explanatory variables.

By generating forecasts through levels of and changes in the explanatory variables, one may be able to produce a better forecast through a reconciliation process. That is, the models are adjusted so that the two sets of forecasts give equivalent results.

### 9.2 *Ex-post forecasting*

Ex-post forecasting is the generation of a forecast from a model estimated over a sub-sample of the data beginning with the first observation and ending several periods prior to the last observation. In ex-post forecasting, actual values of the explanatory variables are used to generate the forecast. Also, if forecasted values of the explanatory variables are used to produce an ex-post forecast, one can then measure the error associated with incorrectly forecasted explanatory variables.

The purpose of ex-post forecasting is to evaluate the forecasting performance of the model by comparing the forecasted values with the actuals of the period after the end of the sub-sample to the last observation. With ex-post forecasting, one is able to assess forecast accuracy in terms of:

1) percent deviations of forecasted values from actual values,
2) turning point performance,
3) systematic behaviour of deviations.

Deviations of forecasted values from actual values give a general idea of the accuracy of the model. Systematic drifts in deviations may provide information for either respecifying the model or adjusting the forecast to account for the drift in deviations. Of equal importance in evaluating forecast accuracy is turning point performance, which is how well the model is able to forecast changes in the movement of the dependent variable. More criteria for evaluating forecast accuracy are discussed below.

### 9.3 *Forecast performance criteria*

A model whose purpose is only to forecast, is evaluated in terms of its ability to project changes in the future accurately. While adequate model specification is also judged by the Durbin-Watson statistic

$$\text{D-W} = \frac{\sum_{t=2}^{N} (U_t - U_{t-1})^2}{\sum_{t=1}^{N} U_t^2} \qquad (9\text{-}1)$$

(where $U$ are the residuals of the regression), forecast accuracy is evaluated in terms of other criteria. To judge a model's ability to forecast accurately, one usually performs ex-post analyses and uses either the root mean square error (RMSE) or Theil's inequality coefficient ($U$). The root mean square error of the forecast is defined as:

$$\text{RMSE} = \left[\frac{\sum (Y_p - Y_a)^2}{N}\right]^{1/2} \qquad (9\text{-}2)$$

where,

$Y_p$ are the predicted values of the dependent variable,

$Y_a$ are the actual values of the dependent variable, and

$N$ is the number of periods predicted.

Theil's inequality coefficient is defined as follows:

$$U = \left[\sum \frac{(Y_p - Y_a)^2}{Y_a^2}\right]^{1/2} \qquad (9\text{-}3)$$

Theil's $U$ is preferred as a measure of forecast accuracy because the error between forecasted and actual values can be broken down to errors due to:

1) central tendency,
2) unequal variation between predicted and realized changes, and
3) incomplete covariation of predicted and actual changes.

This decomposition of prediction errors can be used to adjust the model so that the accuracy of the model can be improved.

Another quality that a forecasting model must possess is ability to capture turning points. That is, a forecast must be able to change direction in the same time period that the actual series under study changes direction. If a model is estimated over a long period of time which contains several turning points, ex-post forecast analysis can generally detect a model's inability to trace closely actuals that display turning points.

## 10 Choice of forecasting model

Although the choice of a forecasting model is usually guided by its forecasting performance, other considerations must receive attention. Thus, the length of the forecast period, the functional form, and the forecast accuracy of the explanatory variables of an econometric model must be considered.

The length of the forecast period affects the decision to use one type of a model versus another, along with historical data limitations and the purpose of the forecasting model. For instance, ARIMA models may be appropriate forecasting models for short-term forecasts when stability is not an issue, when sufficient historical data are available, and when causality is not of interest. Also, when the structure that generates the data is difficult to identify, one has no choice but to use a forecasting model which is based on historical data of the variable of interest.

The functional form of the model must also be considered in a forecasting model. While it is true that a more complex model may reduce the model specification error, it is also true that it will, in general, considerably increase the effect of data errors. The model form should be chosen to recognize the trade-off between these sources of error.

Availability of forecasts for explanatory variables and their reliability record is another issue affecting the choice of a forecasting model. A superior model using explanatory variables which may not be forecasted accurately can be inferior to an average model whose explanatory variables are forecasted accurately.

When market stability is an issue, econometric models which can handle structural changes should be used to forecast. When causality matters, simple models or ARIMA models cannot be used as forecasting tools. Neither can they be used when insufficient historical data exist. Finally, when the purpose of the model is to forecast the effects associated with changes in the factors that influence the variable in question, time series models may not be appropriate (with the exception, of course, of transfer function and multiple time series models).

# ANNEX A

(to Recommendation E.506)

**Composite forecasting strategy**

### A.1 *Introduction*

This annex describes a method for forecasting international telephone traffic based on monthly paid-minutes and a number of conversion factors. It demonstrates the method by examining the factors and showing their utility.

The method is seen to have two main features:

1) Monthly paid-minutes exchanged continuously between Administrations for accounting purposes provide a large and continuous volume of data, and graphic and economic methods can be used for forecasting them.

2) Traffic conversion factors are relatively stable, when compared with traffic growth and change slowly since they are governed by customers' habits and network performance. By separately considering the paid minutes and the traffic conversion factors, we gain an insight into the nature of traffic growth which cannot be obtained by circuit occupancy measurements alone. Because of the stability of the conversion factors, these may be measured using relatively small samples, thus contributing to the economy of the procedure.

### A.2 *Basic procedure*

#### A.2.1 *General*

The composite forecasting strategy is carried out for each stream, for each direction and generally for each service category. Essentially, it requires a forecast of monthly paid-minutes to be made, to which are applied forecasts of various conversion factors.

The estimated mean offered busy-hour traffic (in Erlangs) is derived from the monthly paid-minutes using the formula:

$$A = Mdh/60e$$

where

- $A$ is the estimated mean traffic in Erlangs offered in the busy hour,
- $M$ is the total monthly paid-minutes,
- $d$ is the day/month ratio, i.e., the ratio of average weekday paid-time to monthly paid-time,
- $h$ is the busy-hour/day ratio, i.e., the ratio of the busy-hour paid-time to the average daily paid-time,
- $e$ is the efficiency factor, i.e., the ratio of busy-hour paid-time to busy-hour occupied-time.

A.2.2 *Monthly paid-minutes (M)*[1)]

The starting point for the composite strategy is paid minutes. Sudden changes in subscriber demand, for example, resulting from improvements in transmission quality, have a time constant of the order of several months, and on this basis paid minutes accumulated over monthly intervals appear to be optimum in terms of monitoring traffic growth. A longer period (e.g. annually) tends to mask significant changes, whereas a shorter period (e.g. daily) not only increases the amount of data, but also increases the magnitude of fluctuations from one period to the next. A further advantage of the one-month period is that monthly paid-minute figures are exchanged between Administrations for accounting purposes and consequently historical records covering many years are normally readily available.

It should be recognized, however, that accounting information exchanges between Administrations often take place after the event, and it may take some time to reach full adjustments (e.g. collect call traffic).

A.2.3 *Day/month ratio (d)*

This ratio is related to the amount of traffic carried on a typical weekday compared with the total amount of traffic carried in a typical month. It is convenient to regard a typical month as having 30.42 days (365/12), including 21.73 weekdays and 8.69 weekend days (i.e. Saturdays plus Sundays).

Hence $1/d = 21.73 + 8.69 \times r$,

where

$$r = \frac{\text{average non-weekday traffic}}{\text{average weekday traffic}}$$

The relative amount of non-weekday traffic is very sensitive to the relative amount of social contact between origin and destination. (Social calls, are, in general, made more frequently on weekends.) Since changes in such social contact would be very slow, $r$ or $d$ are expected to be the most stable conversion factors, which in general vary only within relatively narrow limits. However, tariff policies such as reduced weekend rates can have a significant effect on $r$ and $d$. Some typical values are shown in Table A-1/E.506.

When $r$ is in the region of 1, the Sunday traffic may exceed the typical weekday level. If this is the case, consideration should be given to dimensioning the route to cater for the additional weekend (Sunday) traffic or adopting a suitable overflow routing arrangement.

TABLE A-1/E.506

| Social contact | Typical weekend/weekday traffic ratio, $r$ | Day-to-month ratio, $d$ |
|---|---|---|
| Low | 0.2 | 0.0426 |
| Medium | 0.5 | 0.0384 |
| High | 1.3 | 0.0303 |

1) In a situation where only yearly paid-minutes are available, this may be converted to $M$ by a suitable factor.

A.2.4 *Busy-hour/day ratio (h)*

The relative amount of average weekday traffic in the busy hour primarily depends on the difference between the local time at origin and destination. Moderately successful attempts have been made to predict the diurnal distribution of traffic based on this information together with supposed "degree of convenience" at origin and destination. However, sufficient discrepancies exist to warrant measuring the diurnal distribution, from which the busy-hour/day ratio may be calculated.

Where measurement data is not available, a good starting point is Recommendation E.523. From the theoretical distributions found in Recommendation E.523, one finds variations in the busy-hour/day ratio from 10% for 0 to 2 hours time difference and up to 13.5% for 7 hours time difference. If it is decided to use standard rate paid-minute information for estimating busy hour erlangs rather than total paid-minutes it will be necessary to use modified values of $d$ and $h$.

A.2.5 *Efficiency factor (e)*

The efficiency factor (ratio of busy-hour paid time to busy-hour occupied time, $e$) converts the paid time into a measure of total circuit occupancy. It is therefore necessary to include all occupied circuit time in the measurement of this ratio, and not merely circuit time taken up in establishing paid calls. For example, the measurement of total circuit occupied time should include the occupied time for paid calls (time from circuit seizure to circuit clearance) and, in addition, the occupied time for directory inquiry calls, test calls, service calls, ineffective attempts and other classes of unpaid traffic handled during the busy hour.

There is a tendency for the efficiency to change with time. In this regard, efficiency is mainly a function of operating method (manual, semi-automatic, international subscriber dialling), the B-subscriber's availability, and the quality of the distant network.

Forecasts of the efficiency can be made on the basis of extrapolation of past trends together with adjustments for planned improvements.

The detailed consideration of efficiency is also an advantage from an operational viewpoint in that it may be possible to identify improvements that may be made, and quantify the benefits deriving from such improvements.

It should be noted that the practical limit for $e$ is generally about 0.8 to 0.9 for automatic working.

A.2.6 *Mean offered busy hour traffic (A)*

It should be noted that $A$ is the mean offered busy-hour traffic expressed in Erlangs.

A.2.7 *Use of composite forecasting*

In the case of countries with lower traffic volumes and manual operation, the paid-time factors ($d$ and $h$) would be available from analysis of call vouchers (dockets). For derivation of the efficiency $e$, the manual operator would have to log the busy-hour occupied time as well as the paid time during the sampling period.

In countries using stored-program controlled exchanges with associated manual assistance positions, computer analysis may aid the composite forecasting procedure.

One consequence of the procedure is that the factors $d$ and $h$ give a picture of subscriber behaviour, in that unpaid time (inquiry calls, test calls, service calls, etc.) are not included in the measurement of these factors. The importance of deriving the efficiency, $e$ during the busy hour, should also be emphasized.

A.3 *Alternative traffic-based implementation*

As described above, the composite forecasting strategy is implemented as an accounting-based procedure. However, it may be more practical for some Administrations to measure $d$ and $h$ based on occupied time, derived from available call recording equipment.

A.4 *Summary*

The composite forecasting strategy isolates a very volatile aspect of traffic behaviour, namely growth, from traffic characteristics.

By isolating growth from traffic characteristics, attention is focused on a number of significant aspects of traffic behaviour. These aspects are expressed in a number of conversion factors. These factors are seen as being most useful for those Administrations using direct Erlang forecasting because of the insight they give into future traffic behaviour.

Where Administrations lack the equipment and procedures enabling these factors to be measured continuously, they may be determined from a sample of all vouchers (dockets) and a measurement of busy-hour traffic (occupied time).

If a number of Administrations each build up a separate data base of conversion factors for their streams, some of the conversion factors can be compared bilaterally and shared among the Administrations. Furthermore, smaller Administrations can make use of comparable conversion factors and gain a better insight into traffic forecasting, even if their measurement resources are limited at present.

ANNEX B

(to Recommendation E.506)

**Description of forecasting procedures**

B.1 *Estimation of autoregressive parameters*

The empirical autocorrelation at lag $k$ is given by:

$$r_k = \frac{v_k}{v_0}$$

where

$$v_k = \frac{1}{N-1} \sum_{t=1}^{N-k} (X_t - \overline{X})(X_{t+k} - \overline{X})$$

and

$$\overline{X} = \frac{1}{N} \sum_{t=1}^{N} X_t$$

$N$ is the total number of observations.

The relation between $[r_k]$ and the estimates $[\hat{\Phi}_k]$ of $[\Phi_k]$ is given by the Yule-Walker equations:

$$r_1 = \hat{\Phi}_1 + \hat{\Phi}_2 r_1 + \dots + \hat{\Phi}_p r_{p-1}$$
$$r_2 = \hat{\Phi}_1 r_1 + \hat{\Phi}_2 r_2 + \dots + \hat{\Phi}_p r_{p-2}$$
$$\vdots$$
$$r_p = \hat{\Phi}_1 r_{p-1} + \hat{\Phi}_2 r_{p-2} + \dots + \hat{\Phi}_p$$

Hence the estimators $[\hat{\Phi}_k]$ can be found by solving this system of equations.

For computations, an alternative to directly solving the equations is the following recursive procedure. Let $[\hat{\Phi}_{k,j}]_j$ be estimators of the parameters at lag $j = 1, 2, \ldots, k$ given that the total number of parameters are $k$. The estimators $[\hat{\Phi}_{k+1,j}]_j$ are then found by

$$\hat{\Phi}_{k+1,\,k+1} = \frac{r_{k+1} \sum_{j=1}^{k} \hat{\Phi}_{k,j}\, r_{k+1-j}}{1 - \sum_{j=1}^{k} \hat{\Phi}_{k,j}\, r_j}$$

$$\hat{\Phi}_{k+1,j} = \hat{\Phi}_{k,j} - \hat{\Phi}_{k+1,\,k+1}\, \hat{\Phi}_{k,\,k-j+1} \qquad j = 1, 2, \ldots, k$$

Defining $\hat{\Phi}_{p,j} = \hat{\Phi}_j$, $j = 1, 2, \ldots, p$, the forecast of the traffic demand at time t+1 is expressed by:

$$X_{t+1} = \hat{\Phi}_1 X_t + \hat{\Phi}_2 X_{t-1} + \ldots + \hat{\Phi}_p X_{t-p}.$$

B.2 *Forecasting with ARIMA models*

The forecast $l$ time units ahead is given by:

$$\begin{aligned}\hat{X}_t(l) = \hat{\Phi}_1 [X_{t+l-1}] + \hat{\Phi}_2 [X_{t+l-2}] \\ + \ldots + \hat{\Phi}_p [X_{t+l-p}] \\ + [a_{t+l}] - \hat{\theta}_1 [a_{t+l-1}] \\ - \hat{\theta}_2 [a_{t+l-2}] - \ldots - \hat{\theta}_q [a_{t+l-q}],\end{aligned}$$

where $[\hat{X}_j] = \begin{cases} \hat{X}_t (j-t) & \text{si } j > t \\ X_j & \text{si } j < t \end{cases}$

$$[a_j] = \begin{cases} 0 & \text{si } j > t \\ X_j - \hat{X}_j & \text{si } j < t, \end{cases}$$

which means that $[X_j]$ is defined as a forecast when $j > t$ and otherwise as an actual observation and that $[a_j]$ is defined as 0 when $j > t$ since white noise has expectation 0. If the observations are known ($j \leqslant t$), then $[a_j]$ is equal to the residual.

B.3 *Description of a top down procedure*

Let

$\hat{X}_T$ be the traffic forecast on an aggregated level,

$\hat{X}_{Ii}$ be the traffic forecast to country $i$,

$\hat{\sigma}_T$ the estimated standard deviation of the aggregated forecast,

$\hat{\sigma}_{Ii}$ the estimated standard deviation of the forecast to country $i$.

Since

$$\hat{X}_T \neq \sum_i \hat{X}_{Ii}$$

it is necessary to find a correction $[X_i]$ of $[\hat{X}_{Ii}]$ such that

$$X = \sum X_i.$$

The corrections $X_i$ may be found by minimizing the expression

$$Q = \alpha_0(\hat{X}_T - X)^2 + \sum_i \alpha_i(X_i - \hat{X}_{Ii})^2$$

subject to

$$X = \sum_i X_i$$

where $\alpha$ and $[\alpha_i]$ are chosen to be

$$\alpha_0 = \frac{1}{\hat{\sigma}_T^2} \text{ and } \alpha_i = \frac{1}{\sigma_{Ii}^2} \qquad i = 1, 2, \ldots$$

The solution of the optimization problem gives the values $[X_i]$:

$$\hat{X}_i = \hat{X}_{Ii} - \hat{\sigma}_{Ii}^2 \frac{\sum_i \hat{X}_{Ii} - \hat{X}_T}{\sum_i \hat{\sigma}_{Ii}^2 + \hat{\sigma}_T^2}$$

A closer inspection of the data base may result in other expressions for the coefficients $[\alpha_i]$, $i = 0, 1, \ldots$ On some occasions, it will also be reasonable to use other criteria for finding the corrected forecasting values $[\hat{X}_i]$. This is shown in the top down example in § C.2.

If, on the other hand, the variance of the top forecast $\hat{X}_T$ is fairly small, the following procedure may be chosen:

The corrections $[X_i]$ is found by minimizing the expression

$$Q' = \sum_i \alpha_i (X_i - X_{Ii})^2$$

subject to

$$X_T \geqslant \sum_i X_i$$

If $\alpha_i$, $i = 1, 2, \ldots$ is chosen to be the inverse of the estimated variances, the solution of the optimization problem is given by

$$\hat{X}_i = \hat{X}_{Ii} - \hat{\sigma}_{Ii}^2 \frac{\sum_i \hat{X}_{Ii} - \hat{X}_T}{\sum_i \hat{\sigma}_{Ii}^2}$$

ANNEX C

(to Recommendation E.506)

**Examples of forecasting models**

C.1 *Example of an econometric model*

To illustrate the workings of an econometric model, we have chosen the model of United States billed minutes to Brazil. This model was selected among alternative models for three reasons:

a) to demonstrate the introduction of explanatory variables,

b) to point out difficulties associated with models used for both the estimation of the structure and forecasting purposes, and

c) to show transformations may affect the results.

The demand of United States billed minutes to Brazil ($MIN$) is estimated by a log-linear equation which includes United States billed messages to Brazil ($MSG$), a real telephone price index ($RPI$), United States personal income in 1972 prices ($YP72$), and real bilateral trade between the United States and Brazil ($RTR$) as explanatory variables. This model is represented as:

$$\ln(MIN)_t = a + b_1 \ln(MSG)_t + b_2 \ln(RPI)_t + b_3 \ln(YP72)_t + b_4 \ln(RTR)_t + U_t$$

where $U_t$ is the error term of the regression and where, $b_1 > 0$, $b_2 < 0$, $b_3 > 0$ and $b_4 > 0$ are expected values.

Using ridge regression to deal with severe multicollinearity problems, we estimate the equation over the 1971:1 (i.e. first quarter of 1971) to 1979:4 interval and obtain the following results:

$$\ln(MIN)_t = -3.489 + \underset{(0.035)}{0.619} \ln(MSG)_t - \underset{(0.095)}{0.447} \ln(RPI)_t + \underset{(0.269)}{1.166} \ln(YP72)_t + \underset{(0.084)}{0.281} \ln(RTR)_t$$

$$\bar{R}^2 = 0.985,\ SER = 0.083,\ D\text{-}W = 0.922,\ k = 0.10$$

where $\bar{R}^2$ is the adjusted coefficient of determination, $SER$ is the standard error of the regression, $D$-$W$ is the Durbin-Watson statistic, and $k$ is the ridge regression constant. The values in parentheses under the equation are the estimated standard deviation of the parameters $b_1$, $b_2$, $b_3$, $b_4$.

The introduction of messages as an explanatory variable in this model was necessitated by the fact that since the mid-seventies transmission quality has improved and completion rates have risen while, at the same time, the strong growth in this market has begun to dissipate. Also, the growth rates for some periods could not have been explained by rate activity on either side or real United States personal income. The behaviour of the message variable in the minute equation was able to account for all these factors.

Because the model serves a dual purpose – namely, structure estimation and forecasting – at least one more variable is introduced than if the model were to be used for forecasting purposes alone. The introduction of additional explanatory variables results in severe multicollinearity and necessitates employing ridge regression which lowers $\bar{R}^2$ and the Durbin-Watson statistic. Consequently, the predictive power of the model is reduced somewhat.

The effect of transforming the variables of a model are shown in the ex-post forecast analysis performed on the model of United States billed minutes to Brazil. The deviations using levels of the variables are larger than those of the logarithms of the variables which were used to obtain a better fit (the estimated RMSE for the log-linear regression model is 0.119 827). The forecast results in level and logarithmic form are shown in Table C-1/E.506.

TABLE C-1/E.506

| | Logarithms | | | Levels | | |
|---|---|---|---|---|---|---|
| | Forecast | Actual | % deviation | Forecast | Actual | % deviation |
| 1980: 1 | 14.858 | 14.938 | –0.540 | 2 836 269 | 3 073 697 | – 7.725 |
| 2 | 14.842 | 14.972 | –0.872 | 2 791 250 | 3 180 334 | –12.234 |
| 3 | 14.916 | 15.111 | –1.296 | 3 005 637 | 3 654 092 | –17.746 |
| 4 | 14.959 | 15.077 | –0.778 | 3 137 698 | 3 529 016 | –11.089 |
| 1981: 1 | 15.022 | 15.102 | –0.535 | 3 341 733 | 3 621 735 | – 7.731 |
| 2 | 14.971 | 15.141 | –1.123 | 3 175 577 | 3 762 592 | –15.601 |
| 3 | 15.395 | 15.261 | 0.879 | 4 852 478 | 4 244 178 | 14.333 |
| 4 | 15.405 | 15.302 | 0.674 | 4 901 246 | 4 421 755 | 10.844 |
| 1982: 1 | 15.365 | 15.348 | 0.110 | 4 709 065 | 4 630 238 | 1.702 |
| 2 | 15.326 | 15.386 | –0.387 | 4 528 947 | 4 807 901 | – 5.802 |

C.2 *Example of a descending modelling method*

The model for forecasting telephone traffic from Norway to the European countries is divided into two separate parts. The first step is an econometric model for the total traffic from Norway to Europe. Thereafter, we apply a model for breakdown of the total traffic on each country.

C.2.1 *Econometric model*

With an econometric model we try to explain the development in telephone traffic, measured in charged minutes, as a function of main explanatory variables. Because of the lack of data for some variables, such as tourism, these variables have had to be omitted in the model.

The general model may be written:

$$X_t = e^K \cdot GNP_t^a \cdot P_t^b \cdot A_t^c \cdot e^{u_t} (t = 1, 2, \ldots, N) \tag{C-1}$$

where:

$X_t$ is the demand for telephone traffic from Norway to Europe at time $t$ (charged minutes).

$GNP_t$ is the gross national product in Norway at time $t$ (real prices).

$P_t$ is the index of charges for traffic from Norway to Europe at time $t$ (real prices).

$A_t$ is the percentage direct-dialled telephone traffic from Norway to Europe (to take account of the effect of automation). For statistical reasons (i.e. impossibility of taking logarithm of zero) $A_t$ goes from 1 to 2 instead of from 0 to 1.

$K$ is the constant.

$a$ is the elasticity with respect to *GNP*.

$b$ is the price elasticity.

$c$ is the elasticity with respect to automation.

$u_t$ is the stocastic variable, summarizing the impact of those variables that are not explicitly introduced in the model and whose effects tend to compensate each other (expectation of $u_t = 0$ and var $u_t = \sigma^2$).

By applying regression analysis (OLSQ) we have arrived at the coefficients (elasticities) in the forecasting model for telephone traffic from Norway to Europe given in Table C-2/E.506 (in our calculations we have used data for the period 1951-1980).

TABLE C-2/E.506

| Coefficients | Estimated values | $t$ statistics |
|---|---|---|
| K | – 16.095 | – 4.2 |
| a | 2.799 | 8.2 |
| b | – 0.264 | – 1.0 |
| c | 0.290 | 2.1 |

The $t$ statistics should be compared with the Student's Distribution with $N - d$ degrees of freedom, where $N$ is the number of observations and $d$ is the number of estimated parameters. In this example, $N = 30$ and $d = 4$.

The model "explains" 99.7% of the variation in the demand for telephone traffic from Norway to Europe in the period 1951-1980.

From this logarithmic model it can be seen that:

– an increase in GNP of 1% causes an increase in the telephone traffic of 2.80%,
– an increase of 1% in the charges, measured in real prices, causes a decrease in the telephone traffic of 0.26%, and
– an increase of 1% in $A_t$ causes an increase in the traffic of 0.29%.

We now use the expected future development in charges to Europe, in GNP, and in the future automation of traffic to Europe to forecast the development in telephone traffic from Norway to Europe from the equation:

$$X_t = e_t^{-16.095} \cdot GNP_t^{2.80} \cdot P_t u^{-0.26} \cdot A_t^{0.29} \qquad \text{(C-2)}$$

C.2.2 *Model for breakdown of the total traffic from Norway to Europe*

The method of breakdown is first to apply the trend to forecast the traffic to each country. However, we let the trend become less important the further into the period of forecast we are, i.e. we let the trend for each country converge to the increase in the total traffic to Europe. Secondly, the traffic to each country is adjusted up or down, by a percentage that is equal to all countries, so that the sum of the traffic to each country equals the forecasted total traffic to Europe from equation (C-2).

Mathematically, the breakdown model can be expressed as follows:

*Calculation of the trend for country i:*

$$R_{it} = b_i + a_i \cdot t, \qquad i = 1, \ldots, 34 \qquad t = 1, \ldots, N \qquad \text{(C-3)}$$

where

$R_{it} = \dfrac{X_{it}}{X_t}$, i.e country $i$'s share of the total traffic to Europe.

$X_{it}$ is the traffic to country $i$ at time $t$

$X_t$ is the traffic to Europe at time $t$

$t$ is the trend variable

$a_i$ and $b_i$ are two coefficients specific to country $i$; i.e. $a_i$ is country $i$'s trend. The coefficients are estimated by using regression analysis, and we have based calculations on observed traffic for the period 1966-1980.

*The forecasted shares* for country $i$ is then calculated by

$$R_{it} = R_{iN} + a_i \cdot (t - N) \cdot e^{-\frac{t-5}{40}} \qquad \text{(C-4)}$$

where $N$ is the last year of observation, and e is the exponential function.

The factor $e^{-\frac{t-5}{40}}$ is a correcting factor which ensures that the growth in the telephone traffic to each country will converge towards the growth of total traffic to Europe after the adjustment made in Equation (C-6).

To have the sum of the countries' shares equal one, it is necessary that

$$\sum_i R_{it} = 1 \qquad \text{(C-5)}$$

This we obtain by setting the adjusted share, $\tilde{R}_{it}$, equal to

$$\tilde{R}_{it} = R_{it} \frac{1}{\sum_i R_{it}} \qquad \text{(C-6)}$$

Each country's forecast traffic is then calculated by multiplying the total traffic to Europe, $X_t$, by each country's share of the total traffic:

$$X_{it} = \tilde{R}_{it} \times X_t \qquad \text{(C-7)}$$

### C.3 *Models for forecasting telephone traffic from Norway to the other continents*

We have applied the same method that we have used for Europe when forecasting telephone traffic from Norway to the other continents. However, the econometric models for forecasting the total traffic to each continent are different. The method of breakdown of the traffic on countries is that used for European countries.

#### C.3.1 *Econometric model for traffic to North America*

For traffic to North America we have used the same explanatory variables that we have used for Europe. By applying regression analysis, we have arrived at the coefficients in Table C-3/E.506 for the forecasting model for telephone traffic from Norway to North America (we have based our calculations on data for the period 1961-1980):

TABLE C-3/E.506

| Coefficients | Estimated values | *t* statistics |
|---|---|---|
| K | −43.167 | −2.6 |
| a | 5.084 | 4.1 |
| b | − 0.315 | −0.6 |
| c | 0.637 | 4.2 |

We then have $R^2 = 0.995$. The model may be written:

$$X_t = e^{-43.2} \cdot GNP_t^{5.08} \cdot P_t^{-0.31} \cdot A_t^{0.64} \quad \text{(C-8)}$$

where

$X_t$ is the telephone traffic to North America at time $t$,

$GNP_t$ is the gross national product at time $t$,

$P_t$ is the index of charges, measured in real prices to North-America at time $t$, and

$A_t$ is the percentage direct-dialled telephone traffic.

Equation (C-8) is now used – together with expected future development in charges to North America, the future development in the Norwegian GNP and future development in the automation of telephone traffic from Norway to North America – to forecast the development in telephone traffic from Norway to North America.

#### C.3.2 *Econometric model for telephone traffic from Norway to Central and South America, Africa, Asia, and Oceania.*

For telephone traffic from Norway to these continents we have used the same explanatory variables and estimated coefficients. Instead of gross national product, our analysis has shown that for the traffic to these continents the number of telephone stations within each continent are a better and more significant explanatory variable.

After using cross-section/time-series simultaneous estimation we have arrived at the coefficients in Table C-4/E.506 for the forecasting model for telephone traffic from Norway to these continents (for each continent we have based our calculations on data for the period 1961-1980):

TABLE C-4/E.506

| Coefficients | Estimated values | $t$ statistics |
|---|---|---|
| Charges | −1.930 | −5.5 |
| Telephone stations | 2.009 | 4.2 |
| Automation | 0.5 | – |

We then have $R^2 = 0.96$. The model may be written:

$$X_t^k = e^K \cdot (TS_t^k)^{2.009} \cdot (P_t^k)^{1.930} \cdot (A_t^k)^{0.5} \qquad \text{(C-9)}$$

where

$X_t^k$ is the telephone traffic to continent $k$ ($k$ = Central America, ..., Oceania) at time $t$,

$e^K$ is the constant specific to each continent. For telephone traffic from Norway to:

| | | |
|---|---|---|
| Central America: | $K^1$ | $= -11.025$ |
| South America: | $K^2$ | $= -12.62$ |
| Africa: | $K^3$ | $= -11.395$ |
| Asia: | $K^4$ | $= -15.02$ |
| Oceania: | $K^5$ | $= -13.194$ |

$TS_t^k$ is the number of telephone stations within continent $k$ at time $t$,

$P_t^k$ is the index of charges, measured in real prices, to continent $k$ at time $t$, and

$A_t^k$ is the percentage direct-dialled telephone traffic to continent $k$.

Equation (C-9) is now used – together with the expected future development in charges to each continent, future development in telephone stations on each continent and future development in automation of telephone traffic from Norway to the continent – to forecast the future development in telephone traffic from Norway to the continent.

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## SECTION 3

# DETERMINATION OF THE NUMBER OF CIRCUITS IN MANUAL OPERATION

**Recommendation E.510** [1)]

## DETERMINATION OF THE NUMBER OF CIRCUITS IN MANUAL OPERATION

**1** The quality of an international manual demand service should be defined as the percentage of call requests which, during the average busy hour (as defined later under § 3) cannot be satisfied immediately because no circuit is free in the relation considered.

By *call requests satisfied immediately* are meant those for which the call is established by the same operator who received the call, and within a period of two minutes from receipt of that call, whether the operator (when she does not immediately find a free circuit) continues observation of the group of circuits, or whether she makes several attempts in the course of this period.

Ultimately, it will be desirable to evolve a corresponding definition based on the *average speed* of establishing calls in the busy hour, i.e. the average time which elapses between the moment when the operator has completed the recording of the call request and the moment when the called subscriber is on the line, or the caller receives the advice *subscriber engaged*, *no reply*, etc. But for the moment, in the absence of information about the operating time in the European international service, such a definition cannot be established.

**2** The number of circuits it is necessary to allocate to an international relation, in order to obtain a given grade of service, should be determined as a function of the *total holding time* of the group in the busy hour.

The total holding time is the product of the number of calls in the busy hour and a factor which is the sum of the average call duration and the average operating time.

These durations will be obtained by means of a large number of observations made during the busy hours, by agreement between the Administrations concerned. If necessary, the particulars entered on the tickets could also serve to determine the average duration of the calls.

The average call duration will be obtained by dividing the total number of minutes of conversation recorded by the recorded number of effective calls.

The average operating time will be obtained by dividing the total number of minutes given to operating (including ineffective calls) by the number of effective calls recorded.

**3** The number of calls in the busy hour will be determined from the average of returns taken during the busy hours on a certain number of busy days in the year.

Exceptionally busy days, such as those which occur around certain holidays, etc., will be eliminated from these returns. The Administrations concerned should plan, whenever possible, to put additional circuits into service for these days.

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1) This Recommendation dates from the XIIIth Plenary Assembly of the CCIF (London, 1946) and has not been fundamentally revised since. It was studied under Question 13/II in the Study Period 1968-1972 and was found to be still valid.

In principle, these returns will be taken during the working days of two consecutive weeks, or during ten consecutive working days. If the monthly traffic curve shows only small variations, they will be repeated twice a year only. They will be taken three or four times a year or more if there are material seasonal variations, so that the average established is in accordance with all the characteristic periods of traffic flow.

**4** The total occupied time thus determined should be increased by a certain amount determined by agreement between the Administrations concerned according to the statistics of traffic growth during earlier years, to take account of the probable growth in traffic and the fact that putting new circuits into service takes place some time after they are first found to be necessary.

**5** The total holding time of the circuits thus obtained, in conjunction with a suitable table (see Table 1/E.510), will enable the required number of circuits to be ascertained.

**6** In the international manual telephone service, the following Tables A and B should be used as a basis of minimum allocation:

Table A corresponds to about 30% of calls failing at the first attempt because of all circuits being engaged and to about 20% of the calls being deferred.

Table B, corresponding to about 7% of calls deferred, will be used whenever possible.

These tables do not take account of the fact that the possibility of using secondary routes permits, particularly for small groups, an increase in the permissible occupation time.

TABLE 1/E.510

**Capacity of circuit groups**

(See Supplement No. 2 at the end of this fascicle)

| Number of circuits | Table A | | Table B | |
|---|---|---|---|---|
| | Percentage of circuit usage | Minutes of circuit usage possible in the busy hour | Percentage of circuit usage | Minutes of circuit usage possible in the busy hour |
| 1 | 65.0 | 39 | – | – |
| 2 | 76.7 | 92 | 46.6 | 56 |
| 3 | 83.3 | 150 | 56.7 | 102 |
| 4 | 86.7 | 208 | 63.3 | 152 |
| 5 | 88.6 | 266 | 68.3 | 205 |
| 6 | 90.0 | 324 | 72.0 | 259 |
| 7 | 91.0 | 382 | 74.5 | 313 |
| 8 | 91.7 | 440 | 76.5 | 367 |
| 9 | 92.2 | 498 | 78.0 | 421 |
| 10 | 92.6 | 556 | 79.2 | 475 |
| 11 | 93.0 | 614 | 80.1 | 529 |
| 12 | 93.4 | 672 | 81.0 | 583 |
| 13 | 93.6 | 730 | 81.7 | 637 |
| 14 | 93.9 | 788 | 82.3 | 691 |
| 15 | 94.1 | 846 | 82.8 | 745 |
| 16 | 94.2 | 904 | 83.2 | 799 |
| 17 | 94.3 | 962 | 83.6 | 853 |
| 18 | 94.4 | 1020 | 83.9 | 907 |
| 19 | 94.5 | 1078 | 84.2 | 961 |
| 20 | 94.6 | 1136 | 84.6 | 1015 |

*Note* – Tables A and B can be extended for groups comprising more than 20 circuits by using the values given for 20 circuits.

## SECTION 4

# DETERMINATION OF THE NUMBER OF CIRCUITS IN AUTOMATIC AND SEMIAUTOMATIC OPERATION

**Recommendation E.520**

## NUMBER OF CIRCUITS TO BE PROVIDED IN AUTOMATIC AND/OR SEMIAUTOMATIC OPERATION, WITHOUT OVERFLOW FACILITIES

This Recommendation refers to groups of circuits used:

- in automatic operation;
- in semiautomatic operation;
- in both automatic and semiautomatic operations on the same group of circuits.

### 1 General method

1.1 The CCITT recommends that the number of circuits needed for a group should be read from tables or curves based on the classical Erlang B formula (see Supplements Nos. 1 and 2 at the end of this fascicle which refers to full availability groups). Recommended methods for traffic determination are indicated in Recommendation E.500.

For *semi-automatic operation* the loss probability *p* should be based on 3% during the mean busy hour.

For *automatic operation* the loss probability *p* should be based on 1% during the mean busy hour.

Semiautomatic traffic using the same circuits as automatic traffic is to be added to the automatic traffic and the same parameter value of $p = 1\%$ should be used for the total traffic.

The values of 3% and 1% quoted above refer to the Erlang B formula and derived tables and curves. The 3% value should not be considered as determining a grade of service because with semiautomatic operation there will be some smoothing of the traffic peaks; it is quoted here only to determine the value of the parameter *p* (loss probability) to use in the Erlang B tables and curves.

1.2 In order to provide a satisfactory grade of service both for the mean busy-hour traffic and for the traffic on exceptionally busy days, it is recommended that the proposed number of circuits should, if necessary, be increased to ensure that the loss probability shall not exceed 7% during the mean busy hour for the average traffic estimated for *the five busiest days* as specified in Recommendation E.500.

1.3 For *small groups of long intercontinental circuits* with automatic operation some relaxation could be made in respect to loss probability. It is envisaged that such circuits would be operated on a both-way basis and that a reasonable minimum for automatic service would be a group of six circuits. A table providing relaxation in Annex A is based on a loss probability of 3% for six circuits, with a smooth progression to 1% for 20 circuits. The general provision for exceptional days remains unchanged.

For exceptional circumstances in which very small groups (less than six intercontinental circuits) are used for automatic operation, dimensioning of the group should be based on the loss probability of 3%.

## 2 Time differences

Time differences at the two terminations of intercontinental circuits are likely to be much more pronounced than those on continental circuits. In order to allow for differences on groups containing both-way circuits it will be desirable to acquire information in respect to traffic flow both during the mean busy hour for both directions and during the mean busy hour for each direction.

It is possible that in some cases overflow traffic can be accepted without any necessity to increase the number of circuits, in spite of the fact that this overflow traffic is of a peaky nature. Such circumstances may arise if there is no traffic overflowing from high-usage groups during the mean busy hour of the final group.

## 3 Both-way circuits

3.1 With the use of both-way circuits there is a danger of simultaneous seizure at both ends; this is particularly the case on circuits with a long propagation time. It is advisable to arrange the sequence of selection at the two ends so that such double seizure can only occur when a single circuit remains free.

When all the circuits of a group are operated on a both-way basis, time differences in the directional mean busy hours may result in a total mean busy-hour traffic flow for the group which is not the sum of the mean busy-hour traffic loads in each direction. Furthermore, such differences in directional mean busy hour may vary with seasons of the year. However, the available methods of traffic measurement can determine the traffic flow during mean busy hour for this total traffic.

3.2 Some intercontinental groups may include one-way as well as both-way operated circuits. It is recommended that in all cases the one-way circuits should be used, when free, in preference to the both-way circuits. The number of circuits to be provided will depend upon the one-way and total traffic.

The total traffic will need to be determined for:

a) each direction of traffic;

b) both-way traffic.

This determination is to be made for the busy hour or the busy hours corresponding to the two cases a) and b) above.

In the cases where the number of one-way circuits is approximately equal for each direction, no special procedure is necessary, and the calculation can be treated as for a simple two-group grading [1].

If the number of one-way circuits is quite different for the two directions, some correction may be needed for the difference in randomness of the flow of calls from the two one-way circuit groups to the both-way circuit group. The general techniques for handling cases of this type are quoted in Recommendation E.521.

## ANNEX A

(to Recommendation E.520)

Table A-1/E.520 may be applied to small groups of long intercontinental circuits. The values in column 2 are suitable for a random offered traffic with full availability access.

The table is based on 1% loss probability for 20 circuits and increases progressively to a loss probability of 2% at 9 circuits and 3% at 6 circuits (loss probabilities for these three values being based on the Erlang loss formula: see Supplement No. 1). The traffic flow values obtained from a smoothing curve coincide very nearly with those determined by equal marginal utility theory, i.e. an improvement factor of 0.05 Erlang for an additional circuit.

For groups requiring more than 20 circuits the table for loss probability of 1%, mentioned in Supplement No. 1, should be used.

TABLE A-1/E.520

| Number of circuits | Traffic flow (in erlangs) | | |
|---|---|---|---|
| | Offered | Carried | Encountering congestion |
| (1) | (2) | (3) | (4) |
| 6 | 2.54 | 2.47 | 0.08 |
| 7 | 3.13 | 3.05 | 0.09 |
| 8 | 3.73 | 3.65 | 0.09 |
| 9 | 4.35 | 4.26 | 0.09 |
| 10 | 4.99 | 4.90 | 0.09 |
| 11 | 5.64 | 5.55 | 0.10 |
| 12 | 6.31 | 6.21 | 0.10 |
| 13 | 6.99 | 6.88 | 0.10 |
| 14 | 7.67 | 7.57 | 0.10 |
| 15 | 8.37 | 8.27 | 0.11 |
| 16 | 9.08 | 8.96 | 0.11 |
| 17 | 9.81 | 9.69 | 0.11 |
| 18 | 10.54 | 10.42 | 0.11 |
| 19 | 11.28 | 11.16 | 0.12 |
| 20 | 12.03 | 11.91 | 0.12 |

**Reference**

[1] TÅNGE (I.): Optimal use of both-way circuits in cases of unlimited availability, *TELE*, English Edition, No. 1, 1956.

## Recommendation E.521

### CALCULATION OF THE NUMBER OF CIRCUITS IN A GROUP CARRYING OVERFLOW TRAFFIC

A calculation of the number of circuits in a group carrying overflow traffic should be based on this Recommendation and on Recommendation E.522 dealing with high-usage groups.

The objective grade of service used is that the average blocking during the busy-hour of the 30 busiest days of the year will not exceed 1%.

To determine the number of circuits in a group carrying overflow traffic, three traffic parameters are required: the average traffic offered to the group, the weighted peakedness factor, and the level of day-to-day traffic variations.

The level of day-to-day traffic variations indicates the degree to which the daily busy-hour traffic deviates from the overall mean traffic, and is determined by the sample variance of the 30 busy-hour traffic.

The peakedness factor indicates the degree to which the variability of the traffic deviates from pure chance traffic within a single hour, and in statistical terms is the variance-to-mean ratio of the distribution of simultaneous overflow traffic.

### 1 Determination of the level of day-to-day traffic variations

Let $M_1, M_2, \ldots, M_{30}$ denote the 30 busy-hour loads of the traffic offered to the final group. Determine the mean traffic $M$ of the daily traffic by

$$M = \frac{1}{30} \sum_{j=1}^{30} M_j$$

Determine the sample variance $V_d$ of the daily traffic by

$$V_d = \frac{1}{29} \sum_{j=1}^{30} (M_j - M)^2$$

Determine the point $(M, V_d)$ on Figure 1/E.521; $M$ on the horizontal axis, and $V_d$ on the vertical axis.

i) If the point $(M, V_d)$ is below the bottom curve, the level of variation is *No.*

ii) If the point is between the lower two curves, the level of variation is *Low.*

iii) If the point is between the upper two curves, the level of variation is *Medium.*

iv) If the point is above the highest curve, the level of variation is *High.*

Default procedures: if the data are not available to compute the variance $V_d$ use the following guidelines:

a) If no more than 25 per cent of the traffic offered to the final group is overflow from other groups, assume the level of day-to-day variation is Low.

b) Otherwise, assume a Medium level of variation.

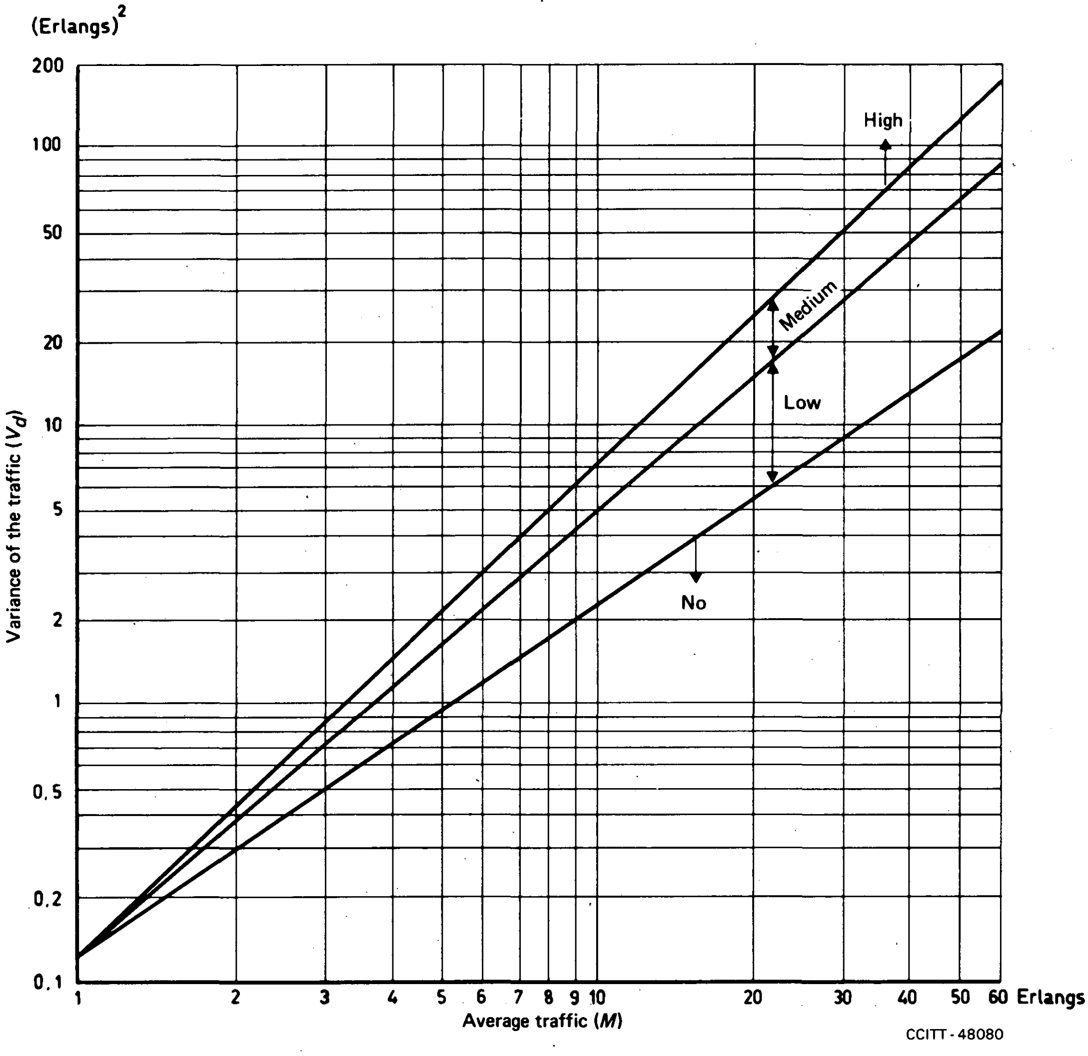


FIGURE 1/E.521

**Determination of the level of day-to-day traffic variation**

## 2 Determination of peakedness factor $z$

Peakedness factors depend principally upon the number of high-usage circuits over which random traffic has access. When the number of such high-usage circuits does not exceed 30, the actual peakedness of the traffic overflowing from a high-usage group will be only slightly below the maximum peakedness values[1), 2)]. The maximum peakedness values are given in Table 1/E.521.

TABLE 1/E.521

**Maximum peakedness factor $z_i$**

| Number of high-usage circuits ($n_i$) | Peakedness factor ($z_i$) | Number of high-usage circuits ($n_i$) | Peakedness factor ($z_i$) |
|---|---|---|---|
| 1 | 1.17 | 16 | 2.44 |
| 2 | 1.31 | 17 | 2.49 |
| 3 | 1.43 | 18 | 2.55 |
| 4 | 1.54 | 19 | 2.61 |
| 5 | 1.64 | 20 | 2.66 |
| 6 | 1.73 | 21 | 2.71 |
| 7 | 1.82 | 22 | 2.76 |
| 8 | 1.90 | 23 | 2.81 |
| 9 | 1.98 | 24 | 2.86 |
| 10 | 2.05 | 25 | 2.91 |
| 11 | 2.12 | 26 | 2.96 |
| 12 | 2.19 | 27 | 3.00 |
| 13 | 2.26 | 28 | 3.05 |
| 14 | 2.32 | 29 | 3.09 |
| 15 | 2.38 | 30 | 3.14 |

For more than 30 circuits, the peakedness of the traffic overflowing from a high-usage group $i$ of $n_i$ circuits is given by

$$z_i = 1 - \beta_i + \frac{A_i}{n_i + 1 + \beta_i - A_i}$$

where

$A_i$ is the mean (random) traffic offered to the $n_i$ circuits and

$\beta_i$ is the traffic overflowing. The overflow traffic $\beta_i$ is found by employing the standard Erlang loss formula $E_{1,\,n_i}(A_i)$:

$$\beta_i = A_i E_{1,\,n_i}(A_i).$$

The weighted mean peakedness factor $z$, is then calculated from:

$$z = \frac{\sum_{i=1}^{h} \beta_i z_i}{\sum_{i=1}^{h} \beta_i}$$

for the $h$ parcels of traffic being offered to the final group.

Note that for the traffic directly offered to the final group, the peakedness factor is $z_i = 1$.

---

1) Tables giving:
- the exact mean of the overflow traffic, and
- the difference between variance and mean of the overflow

have been computed and are set out in [1].

2) Curves giving the exact mean and variance of overflow traffic are given in [2]. See also a more detailed description of the method in [3] and [4].

## 3 Determination of the mean traffic offered to the final group and the number of circuits required

3.1 For planning future network requirements, the traffic overflowing to a final group should be determined theoretically from forecasts of traffics offered to the high-usage groups.

The mean traffic overflowing to the final group from a high-usage group is determined in two steps:

i) the "single-hour" overflow traffic $\beta_i$ overflowing from $n_i$ circuits is given as above by

$$\beta_i = A_i E_{i,\,n_i}(A_i),$$

when $A_i$ is the forecast of traffic offered to the $i^{\text{th}}$ high-usage group;

ii) the average overflow traffic $\bar{\beta}_i$ overflowing from the $n_i$ circuits is then determined by adjusting the single-hour traffic $\beta_i$ for the effect of day-to-day traffic variations.

$$\bar{\beta}_i = r_i \, \beta_i$$

The adjustment factor $r_i$ is given in Table 2/E.521; it is a function of:

- the offered traffic $A_i$,
- the traffic $A_i E_{i,\,n_i - 1}(A_i) - \beta_i$ carried by the last trunk $i$, and
- the level of day-to-day variations of the traffic offered to the high-usage group.

This level can be determined using the method described in § 1 above, but applying it to measurements of traffic offered to the high-usage group. If such measurements are not available a *medium* level can be used.

The mean traffic offered to the final group is then the sum of all $\bar{\beta}_i$ over the $h$ parcels of traffic:

$$M = \sum_{i=1}^{h} \bar{\beta}_i$$

It can be assumed that the level of day-to-day traffic variations on the final group remains constant over the forecast time period.

Using the level of day-to-day traffic variation as determined in § 1 above on the final group and the peakedness factor of § 2 above, the appropriate table of Tables 3/E.521 to 6/E.521 is used to derive the number of circuits required.

*Note 1* – This method of calculation of the mean traffic offered to the final group is valid only if the overflow traffic due to blocking encountered in the exchange in the attempts to connect to a high-usage, is negligible.

*Note 2* – Table 3/E.521 differs slightly from the previous tables published by CCITT, although in Table 3.1/E.521 there is no allowance for day-to-day variations. The new table takes into account a systematic bias in the measurement procedure that is based on a finite period of time (1 hour), instead of an infinite period as was assumed in the previous table [5].

*Note 3* – Tables 4/E.521, 5/E.521 and 6/E.521 are based on the calculation of the average blocking from the formula:

$$\bar{\beta} = \int B(m)\, f(m) dm,$$

where

$B(m)$ is the single-hour expected blocking and

$f(m)$ is the density distribution of day-to-day traffic ($m$), assuming a Pearson Type III distribution:

$$\left[ f(m) = \frac{(M/V)^{(M^2/V_d)}}{\gamma^{(M^2/V^d)}} m^{[(M^2/V_d) - 1]} e^{-M_m/V_d} \right]$$

$M$ and $V_d$ are the mean and day-to-day variance of the traffic as calculated [5] in § 1 above.

TABLE 2 /E.521

**Overflow adjustment for high-usage trunk groups**

Factor $r_i$

| Offered traffic $A_i$ | Last trunk traffic | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Low daily variation | | | | | Medium daily variation | | | | | High daily variation | | | | |
| | 0.25 | 0.3 | 0.4 | 0.5 | 0.6 | 0.25 | 0.3 | 0.4 | 0.5 | 0.6 | 0.25 | 0.3 | 0.4 | 0.5 | 0.6 |
| 3 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| 5 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.2 | 1.2 | 1.1 | 1.1 | 1.0 |
| 7 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.2 | 1.2 | 1.1 | 1.1 | 1.0 | 1.4 | 1.3 | 1.2 | 1.1 | 1.1 |
| 10 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.3 | 1.2 | 1.2 | 1.1 | 1.1 | 1.5 | 1.4 | 1.3 | 1.2 | 1.1 |
| 15 | 1.2 | 1.1 | 1.1 | 1.1 | 1.0 | 1.5 | 1.4 | 1.2 | 1.2 | 1.1 | 1.8 | 1.6 | 1.4 | 1.3 | 1.1 |
| 20 | 1.2 | 1.2 | 1.1 | 1.1 | 1.0 | 1.6 | 1.5 | 1.3 | 1.2 | 1.1 | 2.0 | 1.8 | 1.5 | 1.3 | 1.2 |
| 25 | 1.3 | 1.2 | 1.2 | 1.1 | 1.1 | 1.8 | 1.6 | 1.4 | 1.3 | 1.1 | 2.3 | 2.0 | 1.7 | 1.4 | 1.2 |
| 30 | 1.3 | 1.3 | 1.2 | 1.1 | 1.1 | 1.8 | 1.7 | 1.4 | 1.3 | 1.2 | 2.4 | 2.1 | 1.7 | 1.5 | 1.3 |

TABLE 3/E.521

**Single-hour capacity, in Erlangs, as a function of the number of trunks and of the peakedness factor**

*Parameters:* – Blockage 0.01;
– *No* allowance for day-to-day variation;
– Weighted mean peakedness factor.

| Number of trunks required | 1.0 | 1.2 | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | 3.4 | 3.8 | 4.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.06 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.22 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.53 | 0.33 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 0.94 | 0.69 | 0.50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 1.42 | 1.14 | 0.89 | 0.67 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 1.97 | 1.64 | 1.36 | 1.08 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 2.56 | 2.19 | 1.86 | 1.58 | 1.31 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 3.19 | 2.81 | 2.44 | 2.11 | 1.81 | 1.53 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | 3.83 | 3.42 | 3.03 | 2.67 | 2.36 | 2.03 | 1.75 | 1.50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | 4.53 | 4.08 | 3.67 | 3.28 | 2.92 | 2.58 | 2.28 | 2.00 | 1.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 5.22 | 4.75 | 4.31 | 3.89 | 3.53 | 3.17 | 2.83 | 2.53 | 2.25 | 1.97 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | 5.94 | 5.44 | 4.97 | 4.56 | 4.14 | 3.78 | 3.42 | 3.08 | 2.78 | 2.47 | 2.22 | 0.0 | 0.0 | 0.0 |
| 13 | 6.67 | 6.14 | 5.64 | 5.19 | 4.81 | 4.39 | 4.03 | 3.67 | 3.33 | 3.03 | 2.72 | 0.0 | 0.0 | 0.0 |
| 14 | 7.42 | 6.86 | 6.36 | 5.89 | 5.44 | 5.03 | 4.67 | 4.28 | 3.94 | 3.61 | 3.28 | 2.69 | 0.0 | 0.0 |
| 15 | 8.17 | 7.58 | 7.06 | 6.58 | 6.11 | 5.69 | 5.31 | 4.92 | 4.56 | 4.19 | 3.86 | 3.22 | 0.0 | 0.0 |
| 16 | 8.94 | 8.33 | 7.78 | 7.28 | 6.81 | 6.36 | 5.94 | 5.56 | 5.17 | 4.81 | 4.44 | 3.81 | 3.19 | 0.0 |
| 17 | 9.72 | 9.08 | 8.50 | 8.00 | 7.50 | 7.06 | 6.61 | 6.19 | 5.81 | 5.42 | 5.06 | 4.39 | 3.75 | 3.44 |
| 18 | 10.50 | 9.83 | 9.25 | 8.72 | 8.22 | 7.75 | 7.31 | 6.86 | 6.44 | 6.06 | 5.69 | 4.97 | 4.31 | 4.00 |
| 19 | 11.31 | 10.61 | 10.00 | 9.44 | 8.92 | 8.44 | 7.97 | 7.53 | 7.11 | 6.72 | 6.33 | 5.58 | 4.89 | 4.58 |
| 20 | 12.08 | 11.39 | 10.78 | 10.19 | 9.67 | 9.14 | 8.67 | 8.22 | 7.81 | 7.39 | 6.97 | 6.22 | 5.50 | 5.17 |
| 21 | 12.89 | 12.19 | 11.53 | 10.94 | 10.39 | 9.86 | 9.39 | 8.92 | 8.47 | 8.06 | 7.64 | 6.86 | 6.11 | 5.78 |
| 22 | 13.72 | 13.00 | 12.31 | 11.69 | 11.14 | 10.61 | 10.08 | 9.61 | 9.17 | 8.72 | 8.31 | 7.50 | 6.75 | 6.39 |
| 23 | 14.53 | 13.78 | 13.08 | 12.47 | 11.89 | 11.36 | 10.81 | 10.33 | 9.86 | 9.42 | 8.97 | 8.17 | 7.39 | 7.00 |
| 24 | 15.36 | 14.58 | 13.89 | 13.22 | 12.64 | 12.08 | 11.56 | 11.03 | 10.56 | 10.11 | 9.67 | 8.83 | 8.03 | 7.64 |
| 25 | 16.19 | 15.39 | 14.67 | 14.00 | 13.39 | 12.83 | 12.28 | 11.78 | 11.28 | 10.81 | 10.36 | 9.50 | 8.69 | 8.31 |
| 26 | 17.03 | 16.22 | 15.47 | 14.81 | 14.17 | 13.58 | 13.03 | 12.50 | 12.00 | 11.53 | 11.06 | 10.19 | 9.36 | 8.94 |
| 27 | 17.86 | 17.03 | 16.28 | 15.58 | 14.94 | 14.33 | 13.78 | 13.22 | 12.72 | 12.22 | 11.75 | 10.86 | 10.03 | 9.61 |
| 28 | 18.69 | 17.86 | 17.08 | 16.36 | 15.72 | 15.11 | 14.53 | 13.97 | 13.44 | 12.94 | 12.47 | 11.56 | 10.69 | 10.28 |
| 29 | 19.56 | 18.69 | 17.89 | 17.17 | 16.50 | 15.86 | 15.28 | 14.72 | 14.19 | 13.67 | 13.19 | 12.28 | 11.39 | 10.94 |
| 30 | 20.39 | 19.53 | 18.72 | 17.97 | 17.28 | 16.64 | 16.06 | 15.47 | 14.92 | 14.42 | 13.92 | 12.97 | 12.08 | 11.64 |
| 31 | 21.25 | 20.36 | 19.53 | 18.78 | 18.08 | 17.42 | 16.81 | 16.22 | 15.67 | 15.14 | 14.64 | 13.69 | 12.78 | 12.33 |
| 32 | 22.11 | 21.19 | 20.36 | 19.58 | 18.89 | 18.22 | 17.58 | 17.00 | 16.42 | 15.89 | 15.36 | 14.39 | 13.47 | 13.03 |
| 33 | 22.97 | 22.06 | 21.19 | 20.39 | 19.67 | 19.00 | 18.36 | 17.75 | 17.19 | 16.64 | 16.11 | 15.11 | 14.17 | 13.72 |
| 34 | 23.83 | 22.89 | 22.00 | 21.22 | 20.47 | 19.81 | 19.14 | 18.53 | 17.94 | 17.39 | 16.86 | 15.86 | 14.89 | 14.42 |
| 35 | 24.69 | 23.75 | 22.83 | 22.03 | 21.28 | 20.58 | 19.92 | 19.31 | 18.69 | 18.14 | 17.61 | 16.58 | 15.61 | 15.14 |
| 36 | 25.58 | 24.58 | 23.69 | 22.86 | 22.11 | 21.39 | 20.72 | 20.08 | 19.47 | 18.89 | 18.36 | 17.31 | 16.31 | 15.83 |
| 37 | 26.44 | 25.44 | 24.53 | 23.69 | 22.92 | 22.19 | 21.50 | 20.86 | 20.25 | 19.67 | 19.11 | 18.06 | 17.06 | 16.56 |
| 38 | 27.31 | 26.31 | 25.36 | 24.53 | 23.72 | 23.00 | 22.31 | 21.64 | 21.03 | 20.44 | 19.86 | 18.81 | 17.78 | 17.28 |
| 39 | 28.19 | 27.17 | 26.22 | 25.36 | 24.56 | 23.81 | 23.11 | 22.44 | 21.81 | 21.19 | 20.64 | 19.53 | 18.50 | 18.00 |
| 40 | 29.08 | 28.03 | 27.06 | 26.19 | 25.39 | 24.61 | 23.89 | 23.22 | 22.58 | 21.97 | 21.39 | 20.28 | 19.25 | 18.72 |
| 41 | 29.94 | 28.89 | 27.92 | 27.03 | 26.19 | 25.44 | 24.69 | 24.03 | 23.36 | 22.75 | 22.17 | 21.06 | 19.97 | 19.47 |
| 42 | 30.83 | 29.75 | 28.78 | 27.86 | 27.03 | 26.25 | 25.53 | 24.81 | 24.17 | 23.53 | 22.94 | 21.81 | 20.72 | 20.19 |
| 43 | 31.72 | 30.64 | 29.61 | 28.72 | 27.86 | 27.08 | 26.33 | 25.61 | 24.94 | 24.31 | 23.69 | 22.56 | 21.47 | 20.94 |
| 44 | 32.61 | 31.50 | 30.47 | 29.56 | 28.69 | 27.89 | 27.14 | 26.42 | 25.75 | 25.11 | 24.50 | 23.33 | 22.22 | 21.69 |
| 45 | 33.50 | 32.39 | 31.33 | 30.42 | 29.53 | 28.72 | 27.94 | 27.22 | 26.56 | 25.89 | 25.28 | 24.08 | 22.97 | 22.42 |
| 46 | 34.39 | 33.25 | 32.19 | 31.25 | 30.39 | 29.56 | 28.78 | 28.03 | 27.33 | 26.69 | 26.06 | 24.86 | 23.72 | 23.17 |
| 47 | 35.28 | 34.14 | 33.08 | 32.11 | 31.22 | 30.39 | 29.58 | 28.86 | 28.14 | 27.47 | 26.83 | 25.64 | 24.47 | 23.92 |
| 48 | 36.17 | 35.00 | 33.94 | 32.97 | 32.06 | 31.22 | 30.42 | 29.67 | 28.94 | 28.28 | 27.64 | 26.42 | 25.25 | 24.69 |
| 49 | 37.06 | 35.89 | 34.81 | 33.81 | 32.92 | 32.06 | 31.25 | 30.47 | 29.75 | 29.08 | 28.42 | 27.19 | 26.00 | 25.44 |
| 50 | 37.97 | 36.78 | 35.67 | 34.67 | 33.75 | 32.89 | 32.08 | 31.31 | 30.58 | 29.89 | 29.22 | 27.97 | 26.78 | 26.19 |

TABLE 4/E.521

**Single-hour capacity, in Erlangs, as a function of the number of trunks and of the peakedness factor**

*Parameters:* – Blockage 0.01;
– *Low* day-to-day variation allowance;
– Weighted mean peakedness factor.

| Number of trunks required | 1.0 | 1.2 | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | 3.4 | 3.8 | 4.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.06 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.22 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.53 | 0.33 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 0.94 | 0.69 | 0.50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 1.39 | 1.14 | 0.89 | 0.67 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 1.89 | 1.64 | 1.36 | 1.08 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 2.44 | 2.14 | 1.86 | 1.58 | 1.31 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 3.03 | 2.69 | 2.42 | 2.11 | 1.81 | 1.53 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | 3.64 | 3.28 | 2.97 | 2.67 | 2.36 | 2.03 | 1.75 | 1.50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | 4.25 | 3.89 | 3.56 | 3.22 | 2.92 | 2.58 | 2.28 | 2.00 | 1.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 4.92 | 4.53 | 4.17 | 3.83 | 3.50 | 3.17 | 2.83 | 2.53 | 2.25 | 1.97 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | 5.58 | 5.17 | 4.78 | 4.44 | 4.08 | 3.78 | 3.42 | 3.08 | 2.78 | 2.47 | 2.22 | 0.0 | 0.0 | 0.0 |
| 13 | 6.25 | 5.81 | 5.42 | 5.06 | 4.69 | 4.36 | 4.03 | 3.67 | 3.33 | 3.03 | 2.72 | 0.0 | 0.0 | 0.0 |
| 14 | 6.94 | 6.50 | 6.08 | 5.69 | 5.33 | 4.97 | 4.64 | 4.28 | 3.94 | 3.61 | 3.28 | 2.69 | 0.0 | 0.0 |
| 15 | 7.64 | 7.17 | 6.75 | 6.33 | 5.97 | 5.61 | 5.25 | 4.92 | 4.56 | 4.19 | 3.86 | 3.22 | 0.0 | 0.0 |
| 16 | 8.33 | 7.86 | 7.42 | 7.00 | 6.61 | 6.25 | 5.89 | 5.53 | 5.17 | 4.81 | 4.44 | 3.81 | 3.19 | 0.0 |
| 17 | 9.06 | 8.56 | 8.11 | 7.67 | 7.28 | 6.89 | 6.53 | 6.17 | 5.81 | 5.42 | 5.06 | 4.39 | 3.75 | 3.44 |
| 18 | 9.81 | 9.28 | 8.81 | 8.36 | 7.94 | 7.56 | 7.17 | 6.81 | 6.44 | 6.06 | 5.69 | 4.97 | 4.31 | 4.00 |
| 19 | 10.53 | 10.00 | 9.50 | 9.06 | 8.61 | 8.22 | 7.83 | 7.44 | 7.08 | 6.72 | 6.33 | 5.58 | 4.89 | 4.58 |
| 20 | 11.28 | 10.72 | 10.22 | 9.75 | 9.31 | 8.89 | 8.50 | 8.11 | 7.72 | 7.36 | 6.97 | 6.22 | 5.50 | 5.17 |
| 21 | 12.03 | 11.44 | 10.94 | 10.44 | 10.00 | 9.56 | 9.17 | 8.78 | 8.39 | 8.03 | 7.64 | 6.86 | 6.11 | 5.78 |
| 22 | 12.78 | 12.19 | 11.67 | 11.17 | 10.69 | 10.25 | 9.83 | 9.44 | 9.06 | 8.67 | 8.31 | 7.56 | 6.75 | 6.39 |
| 23 | 13.53 | 12.94 | 12.39 | 11.89 | 11.42 | 10.94 | 10.53 | 10.11 | 9.72 | 9.33 | 8.94 | 8.19 | 7.39 | 7.00 |
| 24 | 14.31 | 13.69 | 13.14 | 12.61 | 12.11 | 11.67 | 11.22 | 10.81 | 10.39 | 10.00 | 9.61 | 8.86 | 8.03 | 7.64 |
| 25 | 15.08 | 14.44 | 13.86 | 13.33 | 12.83 | 12.36 | 11.92 | 11.50 | 11.08 | 10.67 | 10.28 | 9.50 | 8.67 | 8.31 |
| 26 | 15.86 | 15.22 | 14.61 | 14.08 | 13.56 | 13.08 | 12.61 | 12.19 | 11.75 | 11.36 | 10.94 | 10.17 | 9.33 | 8.94 |
| 27 | 16.64 | 15.97 | 15.36 | 14.81 | 14.28 | 13.81 | 13.33 | 12.89 | 12.44 | 12.03 | 11.64 | 10.83 | 10.00 | 9.61 |
| 28 | 17.42 | 16.75 | 16.14 | 15.56 | 15.03 | 14.53 | 14.06 | 13.58 | 13.14 | 12.72 | 12.31 | 11.50 | 10.67 | 10.28 |
| 29 | 18.22 | 17.53 | 16.89 | 16.31 | 15.78 | 15.25 | 14.78 | 14.31 | 13.86 | 13.42 | 13.00 | 12.19 | 11.36 | 10.94 |
| 30 | 19.00 | 18.31 | 17.67 | 17.06 | 16.50 | 16.00 | 15.50 | 15.03 | 14.56 | 14.11 | 13.69 | 12.86 | 12.06 | 11.64 |
| 31 | 19.81 | 19.08 | 18.44 | 17.83 | 17.25 | 16.72 | 16.22 | 15.72 | 15.28 | 14.83 | 14.39 | 13.56 | 12.75 | 12.33 |
| 32 | 20.61 | 19.89 | 19.19 | 18.58 | 18.00 | 17.47 | 16.94 | 16.47 | 16.00 | 15.53 | 15.11 | 14.25 | 13.44 | 13.03 |
| 33 | 21.39 | 20.67 | 19.97 | 19.36 | 18.78 | 18.22 | 17.69 | 17.19 | 16.72 | 16.25 | 15.81 | 14.94 | 14.14 | 13.72 |
| 34 | 22.22 | 21.47 | 20.75 | 20.11 | 19.53 | 18.97 | 18.42 | 17.92 | 17.44 | 16.97 | 16.53 | 15.67 | 14.83 | 14.42 |
| 35 | 23.03 | 22.25 | 21.56 | 20.89 | 20.28 | 19.72 | 19.17 | 18.67 | 18.17 | 17.69 | 17.22 | 16.36 | 15.56 | 15.11 |
| 36 | 23.83 | 23.06 | 22.33 | 21.67 | 21.06 | 20.47 | 19.92 | 19.39 | 18.89 | 18.42 | 17.94 | 17.08 | 16.25 | 15.81 |
| 37 | 24.64 | 23.86 | 23.14 | 22.44 | 21.83 | 21.25 | 20.67 | 20.14 | 19.64 | 19.14 | 18.67 | 17.78 | 16.94 | 16.50 |
| 38 | 25.47 | 24.67 | 23.92 | 23.25 | 22.61 | 22.00 | 21.44 | 20.89 | 20.36 | 19.89 | 19.42 | 18.50 | 17.64 | 17.19 |
| 39 | 26.28 | 25.47 | 24.72 | 24.03 | 23.39 | 22.78 | 22.19 | 21.64 | 21.11 | 20.61 | 20.14 | 19.22 | 18.33 | 17.89 |
| 40 | 27.11 | 26.28 | 25.53 | 24.81 | 24.17 | 23.53 | 22.94 | 22.39 | 21.86 | 21.36 | 20.86 | 19.94 | 19.06 | 18.61 |
| 41 | 27.92 | 27.08 | 26.31 | 25.61 | 24.94 | 24.31 | 23.72 | 23.14 | 22.61 | 22.11 | 21.61 | 20.67 | 19.78 | 19.31 |
| 42 | 28.75 | 27.92 | 27.11 | 26.39 | 25.72 | 25.08 | 24.47 | 23.92 | 23.36 | 22.83 | 22.33 | 21.39 | 20.47 | 20.03 |
| 43 | 29.58 | 28.72 | 27.92 | 27.19 | 26.50 | 25.86 | 25.25 | 24.67 | 24.11 | 23.58 | 23.08 | 22.11 | 21.19 | 20.75 |
| 44 | 30.42 | 29.56 | 28.75 | 28.00 | 27.31 | 26.64 | 26.03 | 25.44 | 24.89 | 24.33 | 23.83 | 22.86 | 21.92 | 21.44 |
| 45 | 31.25 | 30.36 | 29.56 | 28.81 | 28.08 | 27.44 | 26.81 | 26.22 | 25.64 | 25.11 | 24.58 | 23.58 | 22.64 | 22.17 |
| 46 | 32.08 | 31.19 | 30.36 | 29.61 | 28.89 | 28.22 | 27.58 | 26.97 | 26.42 | 25.86 | 25.33 | 24.33 | 23.36 | 22.89 |
| 47 | 32.92 | 32.03 | 31.17 | 30.42 | 29.69 | 29.00 | 28.36 | 27.75 | 27.17 | 26.61 | 26.08 | 25.06 | 24.11 | 23.64 |
| 48 | 33.75 | 32.83 | 32.00 | 31.22 | 30.47 | 29.81 | 29.14 | 28.53 | 27.94 | 27.39 | 26.83 | 25.81 | 24.83 | 24.36 |
| 49 | 34.58 | 33.67 | 32.81 | 32.03 | 31.28 | 30.58 | 29.94 | 29.31 | 28.72 | 28.14 | 27.58 | 26.56 | 25.56 | 25.08 |
| 50 | 35.44 | 34.50 | 33.64 | 32.83 | 32.08 | 31.39 | 30.72 | 30.08 | 29.50 | 28.92 | 28.36 | 27.31 | 26.31 | 25.83 |

TABLE 5/E.521

**Single-hour capacity, in Erlangs, as a function of the number of trunks and of the peakedness factor**

*Parameters:* – Blockage 0.01;
– *Medium* day-to-day variation allowance;
– Weighted mean peakedness factor.

| Number of trunks required | 1.0 | 1.2 | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | 3.4 | 3.8 | 4.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.06 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.22 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.53 | 0.33 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 0.94 | 0.69 | 0.50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 1.39 | 1.14 | 0.89 | 0.67 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 1.86 | 1.61 | 1.36 | 1.08 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 2.39 | 2.11 | 1.83 | 1.58 | 1.31 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 2.94 | 2.64 | 2.36 | 2.08 | 1.81 | 1.53 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | 3.53 | 3.19 | 2.89 | 2.61 | 2.33 | 2.03 | 1.75 | 1.50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | 4.11 | 3.78 | 3.47 | 3.17 | 2.86 | 2.58 | 2.28 | 2.00 | 1.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 4.72 | 4.39 | 4.03 | 3.72 | 3.42 | 3.14 | 2.83 | 2.53 | 2.25 | 1.97 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | 5.36 | 4.97 | 4.64 | 4.31 | 4.00 | 3.69 | 3.39 | 3.08 | 2.78 | 2.47 | 2.22 | 0.0 | 0.0 | 0.0 |
| 13 | 6.00 | 5.61 | 5.25 | 4.89 | 4.56 | 4.25 | 3.94 | 3.67 | 3.33 | 3.03 | 2.72 | 0.0 | 0.0 | 0.0 |
| 14 | 6.64 | 6.22 | 5.86 | 5.50 | 5.17 | 4.83 | 4.53 | 4.22 | 3.92 | 3.61 | 3.28 | 2.69 | 0.0 | 0.0 |
| 15 | 7.31 | 6.89 | 6.47 | 6.11 | 5.78 | 5.42 | 5.11 | 4.78 | 4.47 | 4.19 | 3.86 | 3.22 | 0.0 | 0.0 |
| 16 | 7.97 | 7.53 | 7.11 | 6.75 | 6.39 | 6.03 | 5.69 | 5.39 | 5.06 | 4.75 | 4.44 | 3.81 | 3.19 | 0.0 |
| 17 | 8.64 | 8.19 | 7.78 | 7.36 | 7.00 | 6.64 | 6.31 | 5.97 | 5.64 | 5.33 | 5.03 | 4.39 | 3.75 | 3.44 |
| 18 | 9.33 | 8.86 | 8.42 | 8.03 | 7.64 | 7.28 | 6.92 | 6.58 | 6.25 | 5.92 | 5.61 | 4.97 | 4.31 | 4.00 |
| 19 | 10.03 | 9.53 | 9.08 | 8.67 | 8.28 | 7.89 | 7.53 | 7.19 | 6.86 | 6.53 | 6.19 | 5.58 | 4.89 | 4.58 |
| 20 | 10.69 | 10.19 | 9.75 | 9.33 | 8.92 | 8.53 | 8.17 | 7.81 | 7.47 | 7.14 | 6.81 | 6.17 | 5.50 | 5.17 |
| 21 | 11.42 | 10.89 | 10.42 | 9.97 | 9.56 | 9.17 | 8.81 | 8.44 | 8.08 | 7.75 | 7.42 | 6.75 | 6.11 | 5.78 |
| 22 | 12.11 | 11.58 | 11.11 | 10.64 | 10.22 | 9.83 | 9.44 | 9.06 | 8.69 | 8.36 | 8.03 | 7.36 | 6.72 | 6.39 |
| 23 | 12.83 | 12.28 | 11.78 | 11.33 | 10.89 | 10.47 | 10.08 | 9.69 | 9.33 | 8.97 | 8.64 | 7.97 | 7.33 | 7.00 |
| 24 | 13.53 | 13.00 | 12.47 | 12.00 | 11.56 | 11.14 | 10.72 | 10.36 | 9.97 | 9.61 | 9.25 | 8.58 | 7.94 | 7.61 |
| 25 | 14.25 | 13.69 | 13.17 | 12.69 | 12.25 | 11.81 | 11.39 | 11.00 | 10.61 | 10.25 | 9.89 | 9.19 | 8.56 | 9.19 |
| 26 | 14.97 | 14.42 | 13.86 | 13.39 | 12.92 | 12.47 | 12.06 | 11.64 | 11.28 | 10.89 | 10.53 | 9.83 | 9.17 | 8.81 |
| 27 | 15.69 | 15.11 | 14.58 | 14.08 | 13.61 | 13.14 | 12.72 | 12.31 | 11.92 | 11.53 | 11.17 | 10.44 | 9.78 | 9.42 |
| 28 | 16.44 | 15.83 | 15.28 | 14.78 | 14.28 | 13.83 | 13.39 | 12.97 | 12.58 | 12.19 | 11.81 | 11.08 | 10.39 | 10.06 |
| 29 | 17.17 | 16.56 | 16.00 | 15.47 | 14.97 | 14.53 | 14.08 | 13.64 | 13.25 | 12.83 | 12.47 | 11.72 | 11.03 | 10.67 |
| 30 | 17.92 | 17.28 | 16.72 | 16.17 | 15.67 | 15.19 | 14.75 | 14.31 | 13.92 | 13.50 | 13.11 | 12.36 | 11.64 | 11.31 |
| 31 | 18.64 | 18.03 | 17.42 | 16.89 | 16.39 | 15.89 | 15.44 | 15.00 | 14.58 | 14.17 | 13.78 | 13.03 | 12.28 | 11.94 |
| 32 | 19.39 | 18.75 | 18.14 | 17.58 | 17.08 | 16.58 | 16.11 | 15.67 | 15.25 | 14.83 | 14.44 | 13.67 | 12.92 | 12.56 |
| 33 | 20.14 | 19.47 | 18.86 | 18.31 | 17.78 | 17.28 | 16.81 | 16.36 | 15.92 | 15.50 | 15.11 | 14.33 | 13.58 | 13.19 |
| 34 | 20.89 | 20.22 | 19.61 | 19.03 | 18.50 | 18.00 | 17.50 | 17.06 | 16.61 | 16.17 | 15.78 | 14.97 | 14.22 | 13.86 |
| 35 | 21.64 | 20.97 | 20.33 | 19.75 | 19.22 | 18.69 | 18.19 | 17.75 | 17.28 | 16.86 | 16.44 | 15.64 | 14.86 | 14.50 |
| 36 | 22.39 | 21.69 | 21.06 | 20.47 | 19.92 | 19.42 | 18.92 | 18.44 | 17.97 | 17.53 | 17.11 | 16.31 | 15.53 | 15.14 |
| 37 | 23.14 | 22.44 | 21.81 | 21.19 | 20.64 | 20.11 | 19.61 | 19.14 | 18.67 | 18.22 | 17.81 | 16.97 | 16.19 | 15.81 |
| 38 | 23.89 | 23.19 | 22.53 | 21.94 | 21.36 | 20.83 | 20.31 | 19.83 | 19.36 | 18.92 | 18.47 | 17.64 | 16.86 | 16.47 |
| 39 | 24.64 | 23.94 | 23.28 | 22.67 | 22.08 | 21.56 | 21.03 | 20.53 | 20.06 | 19.61 | 19.17 | 18.33 | 17.53 | 17.11 |
| 40 | 25.42 | 24.69 | 24.03 | 23.39 | 22.81 | 22.25 | 21.75 | 21.25 | 20.75 | 20.31 | 19.86 | 19.00 | 18.19 | 17.78 |
| 41 | 26.17 | 25.44 | 24.78 | 24.14 | 23.56 | 22.97 | 22.44 | 21.94 | 21.47 | 21.00 | 20.56 | 19.69 | 18.86 | 18.44 |
| 42 | 26.94 | 26.19 | 25.50 | 24.86 | 24.28 | 23.72 | 23.17 | 22.67 | 22.17 | 21.69 | 21.25 | 20.36 | 19.53 | 19.11 |
| 43 | 27.72 | 26.97 | 26.25 | 25.61 | 25.00 | 24.44 | 23.89 | 23.36 | 22.86 | 22.39 | 21.94 | 21.06 | 20.19 | 19.81 |
| 44 | 28.47 | 27.72 | 27.00 | 26.36 | 25.75 | 25.17 | 24.61 | 24.08 | 23.58 | 23.08 | 22.64 | 21.75 | 20.89 | 20.47 |
| 45 | 29.25 | 28.47 | 27.78 | 27.11 | 26.47 | 25.89 | 25.33 | 24.81 | 24.31 | 23.81 | 23.33 | 22.44 | 21.56 | 21.14 |
| 46 | 30.03 | 29.25 | 28.53 | 27.86 | 27.22 | 26.64 | 26.06 | 25.53 | 25.00 | 24.50 | 24.03 | 23.14 | 22.25 | 21.83 |
| 47 | 30.81 | 30.00 | 29.28 | 28.61 | 27.97 | 27.36 | 26.78 | 26.25 | 25.72 | 25.22 | 24.75 | 23.83 | 22.94 | 22.50 |
| 48 | 31.58 | 30.78 | 30.03 | 29.36 | 28.72 | 28.11 | 27.53 | 26.97 | 26.44 | 25.94 | 25.44 | 24.53 | 23.64 | 23.19 |
| 49 | 32.36 | 31.56 | 30.81 | 30.11 | 29.44 | 28.83 | 28.25 | 27.69 | 27.17 | 26.64 | 26.17 | 25.22 | 24.33 | 23.89 |
| 50 | 33.14 | 32.31 | 31.56 | 30.86 | 30.19 | 29.58 | 29.00 | 28.42 | 27.89 | 27.36 | 26.86 | 25.92 | 25.03 | 24.58 |

TABLE 6/E.521

**Single-hour capacity, in Erlangs, as a function of the number of trunks and of the peakedness factor**

*Parameters:* – Blockage 0.01;
– *High* day-to-day variation allowance;
– Weighted mean peakedness factor.

| Number of trunks required | 1.0 | 1.2 | 1.4 | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | 3.4 | 3.8 | 4.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.06 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.22 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 0.53 | 0.33 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 4 | 0.94 | 0.69 | 0.50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 1.36 | 1.14 | 0.89 | 0.67 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6 | 1.86 | 1.61 | 1.36 | 1.08 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7 | 2.36 | 2.08 | 1.83 | 1.58 | 1.31 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8 | 2.89 | 2.61 | 2.33 | 2.06 | 1.81 | 1.53 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 9 | 3.44 | 3.14 | 2.86 | 2.58 | 2.31 | 2.03 | 1.75 | 1.50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | 4.03 | 3.69 | 3.39 | 3.11 | 2.83 | 2.56 | 2.28 | 2.00 | 1.75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 4.61 | 4.25 | 3.94 | 3.64 | 3.36 | 3.08 | 2.81 | 2.53 | 2.25 | 1.97 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12 | 5.19 | 4.83 | 4.50 | 4.19 | 3.89 | 3.61 | 3.33 | 3.06 | 2.78 | 2.47 | 2.22 | 0.0 | 0.0 | 0.0 |
| 13 | 5.81 | 5.42 | 5.08 | 4.78 | 4.44 | 4.17 | 3.86 | 3.58 | 3.31 | 3.03 | 2.72 | 0.0 | 0.0 | 0.0 |
| 14 | 6.42 | 6.03 | 5.67 | 5.33 | 5.03 | 4.72 | 4.42 | 4.14 | 3.83 | 3.58 | 3.28 | 2.69 | 0.0 | 0.0 |
| 15 | 7.03 | 6.64 | 6.28 | 5.92 | 5.61 | 5.28 | 4.97 | 4.69 | 4.39 | 4.11 | 3.83 | 3.22 | 0.0 | 0.0 |
| 16 | 7.67 | 7.25 | 6.86 | 6.53 | 6.19 | 5.86 | 5.56 | 5.25 | 4.94 | 4.67 | 4.36 | 3.81 | 3.19 | 0.0 |
| 17 | 8.31 | 7.86 | 7.47 | 7.11 | 6.78 | 6.44 | 6.11 | 5.81 | 5.50 | 5.22 | 4.92 | 4.36 | 3.75 | 3.44 |
| 18 | 8.94 | 8.50 | 8.11 | 7.72 | 7.36 | 7.03 | 6.69 | 6.39 | 6.08 | 5.78 | 5.47 | 4.89 | 4.31 | 4.00 |
| 19 | 9.58 | 9.14 | 8.72 | 8.33 | 7.97 | 7.64 | 7.31 | 6.97 | 6.64 | 6.33 | 6.03 | 5.44 | 4.89 | 4.58 |
| 20 | 10.22 | 9.78 | 9.36 | 8.94 | 8.58 | 8.22 | 7.89 | 7.56 | 7.22 | 6.92 | 6.61 | 6.00 | 5.44 | 5.14 |
| 21 | 10.89 | 10.42 | 9.97 | 9.58 | 9.19 | 8.83 | 8.50 | 8.14 | 7.83 | 7.50 | 7.19 | 6.58 | 6.00 | 5.69 |
| 22 | 11.53 | 11.06 | 10.61 | 10.22 | 9.83 | 9.44 | 9.08 | 8.75 | 8.42 | 8.08 | 7.78 | 7.17 | 6.56 | 6.25 |
| 23 | 12.19 | 11.72 | 11.28 | 10.83 | 10.44 | 10.06 | 9.69 | 9.36 | 9.00 | 8.67 | 8.36 | 7.72 | 7.14 | 6.83 |
| 24 | 12.86 | 12.36 | 11.92 | 11.47 | 11.08 | 10.69 | 10.31 | 9.94 | 9.61 | 9.28 | 8.94 | 8.31 | 7.69 | 7.39 |
| 25 | 13.53 | 13.03 | 12.56 | 12.11 | 11.69 | 11.31 | 10.94 | 10.56 | 10.22 | 9.89 | 9.56 | 8.92 | 8.28 | 7.97 |
| 26 | 14.19 | 13.69 | 13.22 | 12.75 | 12.33 | 11.94 | 11.56 | 11.19 | 10.83 | 10.47 | 10.14 | 9.50 | 8.86 | 8.56 |
| 27 | 14.89 | 14.36 | 13.86 | 13.42 | 12.97 | 12.58 | 12.19 | 11.81 | 11.44 | 11.08 | 10.75 | 10.08 | 9.44 | 9.14 |
| 28 | 15.56 | 15.03 | 14.53 | 14.06 | 13.64 | 13.22 | 12.81 | 12.42 | 12.06 | 11.69 | 11.36 | 10.69 | 10.03 | 9.72 |
| 29 | 16.25 | 15.69 | 15.19 | 14.72 | 14.28 | 13.86 | 13.44 | 13.06 | 12.69 | 12.33 | 11.97 | 11.31 | 10.64 | 10.31 |
| 30 | 16.92 | 16.36 | 15.86 | 15.36 | 14.92 | 14.50 | 14.08 | 13.69 | 13.31 | 12.94 | 12.58 | 11.89 | 11.22 | 10.92 |
| 31 | 17.61 | 17.06 | 16.53 | 16.03 | 15.58 | 15.14 | 14.72 | 14.33 | 13.94 | 13.56 | 13.19 | 12.50 | 11.83 | 11.50 |
| 32 | 18.31 | 17.72 | 17.19 | 16.69 | 16.22 | 15.78 | 15.36 | 14.94 | 14.56 | 14.19 | 13.83 | 13.11 | 12.44 | 12.11 |
| 33 | 18.97 | 18.42 | 17.86 | 17.36 | 16.89 | 16.44 | 16.00 | 15.58 | 15.19 | 14.81 | 14.44 | 13.72 | 13.06 | 12.69 |
| 34 | 19.67 | 19.08 | 18.53 | 18.03 | 17.56 | 17.08 | 16.67 | 16.25 | 15.83 | 15.44 | 15.08 | 14.36 | 13.67 | 13.31 |
| 35 | 20.36 | 19.78 | 19.22 | 18.69 | 18.22 | 17.75 | 17.31 | 16.89 | 16.47 | 16.08 | 15.69 | 14.97 | 14.28 | 13.92 |
| 36 | 21.06 | 20.47 | 19.89 | 19.36 | 18.89 | 18.42 | 17.97 | 17.53 | 17.11 | 16.72 | 16.33 | 15.61 | 14.89 | 14.53 |
| 37 | 21.75 | 21.14 | 20.58 | 20.06 | 19.56 | 19.08 | 18.61 | 18.19 | 17.78 | 17.36 | 16.97 | 16.22 | 15.50 | 15.14 |
| 38 | 22.44 | 21.83 | 21.25 | 20.72 | 20.22 | 19.72 | 19.28 | 18.83 | 18.42 | 18.00 | 17.61 | 16.86 | 16.14 | 15.78 |
| 39 | 23.17 | 22.53 | 21.94 | 21.39 | 20.89 | 20.39 | 19.94 | 19.50 | 19.06 | 18.64 | 18.25 | 17.50 | 16.75 | 16.39 |
| 40 | 23.86 | 23.22 | 22.64 | 22.08 | 21.56 | 21.06 | 20.58 | 20.14 | 19.72 | 19.31 | 18.89 | 18.11 | 17.39 | 17.00 |
| 41 | 24.56 | 23.92 | 23.33 | 22.75 | 22.22 | 21.75 | 21.25 | 20.81 | 20.36 | 19.94 | 19.53 | 18.75 | 18.00 | 17.64 |
| 42 | 25.28 | 24.61 | 24.00 | 23.44 | 22.92 | 22.42 | 21.92 | 21.47 | 21.03 | 20.58 | 20.19 | 19.39 | 18.64 | 18.29 |
| 43 | 25.97 | 25.31 | 24.69 | 24.14 | 23.58 | 23.08 | 22.58 | 22.14 | 21.67 | 21.25 | 20.83 | 20.03 | 19.28 | 18.89 |
| 44 | 26.67 | 26.03 | 25.39 | 24.81 | 24.28 | 23.75 | 23.25 | 22.78 | 22.33 | 21.92 | 21.47 | 20.67 | 19.89 | 19.53 |
| 45 | 27.39 | 26.72 | 26.08 | 25.50 | 24.94 | 24.44 | 23.94 | 23.44 | 23.00 | 22.56 | 22.14 | 21.33 | 20.53 | 20.17 |
| 46 | 28.08 | 27.42 | 26.78 | 26.19 | 25.64 | 25.11 | 24.61 | 24.14 | 23.67 | 23.22 | 22.78 | 21.97 | 21.17 | 20.81 |
| 47 | 28.81 | 28.14 | 27.47 | 26.89 | 26.33 | 25.81 | 25.28 | 24.81 | 24.33 | 23.89 | 23.44 | 22.61 | 21.81 | 21.44 |
| 48 | 29.53 | 28.83 | 28.19 | 27.58 | 27.00 | 26.47 | 25.97 | 25.47 | 25.00 | 24.56 | 24.11 | 23.28 | 22.47 | 22.08 |
| 49 | 30.22 | 29.53 | 28.89 | 28.28 | 27.69 | 27.17 | 26.64 | 26.14 | 25.67 | 25.19 | 24.75 | 23.92 | 23.11 | 22.72 |
| 50 | 30.94 | 30.25 | 29.58 | 28.97 | 28.39 | 27.83 | 27.31 | 26.81 | 26.33 | 25.86 | 25.42 | 24.58 | 23.75 | 23.36 |

### 3.2 *Computer implementation*

When computer facilities are available, it is possible to automate the use of Tables 3/E.521. For that purpose, numerical algorithms have been developed and are described in [5].

## 4 Example

### 4.1 *Level of day-to-day traffic variations*

If the traffics offered to a final group over the 30 busiest days are given ($M_1$ to $M_{30}$) and if the mean load and variance are calculated to be 10 and 20 respectively, then applying Figure 1/E.521, a *high* level of day-to-day traffic variations should be used.

### 4.2 *Future traffic offered to the final group and peakedness factor*

If the forecast of future traffics indicates that three parcels of traffic will be offered to the final group:

- the overflow from 6 circuits offered 7.8 Erlangs,
- the overflow from 12 circuits offered 10 Erlangs,
- 7 Erlangs offered directly,

then Table 7/E.521 can be developed.

TABLE 7/E.521

| Number of parcels of traffic $i$ | Traffic offered to high-usage groups $A_i$ | Number of high-usage circuits $n_i$ | Single-hour overflow $\beta_i$ | Last trunk traffic | Peakedness factor $z_i$ | $\beta_i z_i$ | Adjustment factor $r_i$ | Average overflow $\bar{\beta}_i = r_i \beta_i$ |
|---|---|---|---|---|---|---|---|---|
| 1 | 7.8 | 6 | 2.95 | 0.69 | 1.73 | 5.1 | 1.0 | 2.95 |
| 2 | 10.0 | 12 | 1.20 | 0.44 | 2.19 | 2.6 | 1.2 | 1.44 |
| 3 | 7.0 | 0 | 7.0 | | 1.0 | 7.0 | 1.0 | 7.00 |
| | | | | | | 14.7 | | |
| | | | $\sum_{i=1}^{h} \beta_i = 11.15$ | | | $z = \frac{\sum_{i=1}^{h} \beta_i z_i}{\sum_{i=1}^{h} \beta_i} = \frac{14.7}{11.15} = 1.3$ | | $M = \sum_{i=1}^{h} \bar{\beta}_i = 11.39$ |

Note that the values of $r_i$ are derived from Table 2/E.521 for *medium* level of day-to-day traffic variations; if the 30 busiest day traffics for each of the high-usage groups were available, a more appropriate level could be used for each group.

Now all the information required is available: using the capacity Table 6/E.521 for *high* level of day-to-day traffic variations, the average traffic offered to the final group $M = 11.39$ and a peakedness factor $z = 1.3$ (from interpolating between $z = 1.2$ and $z = 1.4$), it is calculated that 23 circuits are required.

Note that if the measurements used in § 4.1 above were not available, then to determine the level of day-to-day traffic variations it would have been necessary to use the default procedure of § 1 above.

Overflow traffic offered to the final group = 4.15 Erlangs.

Total traffic offered to the final group = 11.15 Erlangs.

The ratio 4.15/11.15 = 0.37 is higher than 0.25 and hence a *medium* level of day-to-day traffic variations would have been used.

**References**


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**Recommendation E.522**

## NUMBER OF CIRCUITS IN A HIGH-USAGE GROUP

### 1 Introduction

For the economic planning of an alternate routing network the number of circuits in a high-usage group should be determined so that the annual charges for the whole network arrangement are at a minimum. This is done under the constraint that given requirements for the grade of service are fulfilled. In the optimum arrangement, the cost per erlang of carrying a marginal amount of traffic over the high-usage route or over the alternative route is the same.

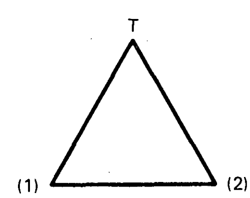


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FIGURE 1/E.522

The optimum number of high-usage circuits, *n*, from one exchange (1) to another exchange (2) is therefore obtained from the following expression when the overflow traffic is routed over a transit exchange T (route 1-T-2, see Figure 1/E.522).

$$F_n(A) = A\,\{E_{1,\,n}(A) - E_{1,\,(n+1)}(A)\} = M \times \frac{\text{annual charge (1-2)}}{\text{annual charge (1-T-2)}}$$

$A$ is the traffic flow offered, for the relation "1-2", in the Erlang loss formula for a full availability group. The expression $F_n(A)$ gives the marginal occupancy[1)] (improvement function) for the high-usage group, if one more circuit were added.

$M$ is the *marginal utilization factor*[2)] *for the final route* "1-T-2" (which has nothing to do with cost ratio), if one additional circuit were provided. The annual charges are marginal charges for adding one additional circuit to route "1-2" and likewise to route "1-T-2".

Planning of an alternate routing network is described in the technical literature (see [1] to [10]).

Annual charge as used in this Recommendation refers to investment costs.

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[1)] Marginal occupancy is often called LTC (last trunk capacity).

[2)] Marginal utilization factor is often called ATC (additional trunk capacity).

## 2 Recommended practical method

### 2.1 *Field of application*

It must be recognized that the conditions applying to alternative routing will vary widely between the continental network and the intercontinental network. Significant differences between the two cases apply to the length and cost of circuits, the traffic flow and the different times at which the busy hours occur. The method described attempts to take account of these factors in so far as it is practicable to do so in any simplified procedure.

### 2.2 *Traffic statistics*

The importance of reliable traffic estimates should be emphasized. Traffic estimates are required for each of the relations in question, for both the busy hour of the relation and for the busy hour of each link of the routes to which the traffic overflows. Since this may be affected by the high-usage arrangements finally adopted, it will be necessary to have traffic estimates for each relation covering most of the significant hours of the day. This applies particularly to the intercontinental network where the final routes carry traffic components with widely differing busy hours.

### 2.3 *Basis of the recommended method*

The method is based on a simplification of the economic dimensioning equations described under 1. Introduction. The simplifying assumptions are:

i) the ratios of the alternative high-usage annual charges are grouped in classes and a single ratio selected as representative for each class. This is acceptable because total network costs are known to be relatively insensitive to changes in the annual charges ratio;

ii) the marginal utilization factor $M$ applicable to the overflow routes is regarded as constant within a range of circuit group sizes;

| Size of group (number of circuits) | Value of $M$ |
|---|---|
| For less than 10 . . . . . . . . . . . | 0.6 |
| For 10 or more . . . . . . . . . . . | 0.8 |

iii) each high-usage group will be dimensioned against the cheapest alternative route to which traffic overflows. (That is, the effect of parallel alternative routes is ignored.)

Where greater precision is required in either network or individual route dimensioning, more sophisticated methods may be employed (see [5] and [7]).

### 2.4 *Determination of cost ratio*

In continental and intercontinental working, the number of circuits to be provided in high-usage circuit groups depends upon the ratio of the annual charges estimated by the Administrations involved. The annual charge ratio (see Table 1/E.522) is defined as:

$$R = \frac{\text{annual charge of one additional circuit on the alternative route}}{\text{annual charge of one additional circuit on the high-usage route}}$$

The "annual charge of one additional circuit on the alternative route" is calculated by summing:

– the annual charge per circuit of each link comprising the alternative route, and

– the annual charge of switching one circuit at each intermediate switching centre.

When a third Administration is involved, it may be necessary to calculate the annual charge for switching at the intermediate centre from the transit switching charge per holding minute[1]. This may be done as follows:

Annual charges for switching = $M \times 60 \times F \times 26 \times 12 \times$ transit switching charge per holding minute.

In the calculation of the conversion factor $F$ from busy hour to day, its dependence on the traffic offered to the high usage route, the overflow probability and the time difference should be taken into account. As a guideline, Table 1/E.522, which is calculated using the standard traffic profiles of Table 1/E.523, may be used.

TABLE 1/E.522

| Offered traffic (erlangs) | Overflow probability (%) | Time difference | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | 1 | 2.6 | 3.2 | 3.7 | 3.8 | 2.7 | 2.3 | 2.3 | 1.7 | 3.2 | 2.4 | 2.2 | 2.0 | 2.7 |
| | 10 | 3.7 | 4.5 | 4.8 | 4.7 | 3.5 | 3.1 | 3.0 | 2.5 | 4.1 | 3.2 | 2.9 | 2.8 | 3.6 |
| | 20 | 4.5 | 5.2 | 5.4 | 5.3 | 4.0 | 3.7 | 3.5 | 3.1 | 4.7 | 3.8 | 3.4 | 3.4 | 4.2 |
| 5 | 30 | 5.1 | 5.8 | 6.0 | 5.8 | 4.6 | 4.2 | 4.0 | 3.7 | 5.1 | 4.3 | 3.9 | 4.0 | 4.8 |
| | 40 | 5.7 | 6.4 | 6.5 | 6.3 | 5.1 | 4.7 | 4.5 | 4.2 | 5.6 | 4.8 | 4.4 | 4.6 | 5.3 |
| | 50 | 6.3 | 6.9 | 7.0 | 6.8 | 5.6 | 5.2 | 5.0 | 4.7 | 6.0 | 5.3 | 5.0 | 5.1 | 5.8 |
| | 1 | 2.1 | 2.6 | 3.3 | 3.5 | 2.5 | 2.1 | 2.1 | 1.4 | 2.8 | 2.0 | 2.0 | 1.8 | 2.4 |
| | 10 | 3.2 | 4.0 | 4.4 | 4.3 | 3.1 | 2.7 | 2.6 | 2.1 | 3.8 | 2.8 | 2.6 | 2.4 | 3.2 |
| | 20 | 4.0 | 4.8 | 5.1 | 4.9 | 3.6 | 3.3 | 3.1 | 2.7 | 4.3 | 3.4 | 3.0 | 3.0 | 3.8 |
| 10 | 30 | 4.7 | 5.4 | 5.6 | 5.4 | 4.2 | 3.8 | 3.6 | 3.3 | 4.8 | 3.9 | 3.4 | 3.6 | 4.4 |
| | 40 | 5.3 | 6.0 | 6.1 | 5.9 | 4.7 | 4.4 | 4.2 | 3.8 | 5.3 | 4.4 | 4.0 | 4.2 | 4.9 |
| | 50 | 5.9 | 6.6 | 6.7 | 6.4 | 5.3 | 4.9 | 4.7 | 4.4 | 5.7 | 5.0 | 4.6 | 4.8 | 5.5 |
| | 1 | 1.6 | 2.0 | 2.8 | 3.1 | 2.2 | 1.8 | 2.0 | 1.2 | 2.4 | 1.7 | 1.8 | 1.6 | 2.1 |
| | 10 | 2.7 | 3.3 | 3.9 | 3.9 | 2.7 | 2.4 | 2.3 | 1.7 | 3.3 | 2.4 | 2.3 | 2.0 | 2.7 |
| | 20 | 3.5 | 4.2 | 4.6 | 4.4 | 3.2 | 2.8 | 2.7 | 2.2 | 3.9 | 3.0 | 2.6 | 2.5 | 3.3 |
| 25 | 30 | 4.2 | 5.0 | 5.2 | 5.0 | 3.7 | 3.4 | 3.2 | 2.8 | 4.4 | 3.5 | 3.0 | 3.1 | 3.9 |
| | 40 | 4.8 | 5.6 | 5.8 | 5.5 | 4.3 | 3.9 | 3.8 | 3.4 | 4.9 | 4.0 | 3.5 | 3.7 | 4.5 |
| | 50 | 5.5 | 6.2 | 6.3 | 6.1 | 4.9 | 4.5 | 4.3 | 4.0 | 5.4 | 4.6 | 4.1 | 4.4 | 5.1 |
| | 1 | 1.3 | 1.7 | 2.4 | 2.9 | 2.1 | 1.6 | 2.0 | 1.1 | 2.1 | 1.5 | 1.6 | 1.4 | 2.0 |
| | 10 | 2.3 | 2.8 | 3.5 | 3.6 | 2.5 | 2.2 | 2.1 | 1.4 | 3.1 | 2.2 | 2.2 | 1.8 | 2.4 |
| | 20 | 3.1 | 3.9 | 4.3 | 4.2 | 3.0 | 2.6 | 2.4 | 1.9 | 3.7 | 2.7 | 2.5 | 2.2 | 3.0 |
| 50 | 30 | 3.9 | 4.7 | 5.0 | 4.8 | 3.4 | 3.1 | 2.9 | 2.5 | 4.2 | 3.3 | 2.8 | 2.8 | 3.6 |
| | 40 | 4.6 | 5.4 | 5.6 | 5.3 | 4.0 | 3.7 | 3.5 | 3.2 | 4.7 | 3.8 | 3.2 | 3.5 | 4.3 |
| | 50 | 5.3 | 6.0 | 6.1 | 5.9 | 4.7 | 4.3 | 4.2 | 3.8 | 5.2 | 4.3 | 3.8 | 4.2 | 4.9 |

*Note* – Linear interpolation may be used to obtain intermediate results.

1) It may be necessary to calculate transit switching charge per holding minute from charge per conversation minute (efficiency factor is described in Recommendation E.506).

The value determined for $R$ should then be employed to select in Table 2/E.522 the precise (or next higher) value of annual charges ratio for use in traffic tables. The value of annual charges ratios may be grouped in the following general sets:

a) Within a single continent or other smaller closely connected land mass involving distances up to 1000 miles, high traffic and frequently one-way operation:

Annual charges ratio: $R$ = 1.5; $\underline{\underline{2.0}}$; 3.0; 4.0; 5.0; 6.0 and 7.0[1)]

b) Intercontinental working involving long distances, small traffic and usually two-way operation:

Annual charges ratio: $R$ = 1.1; $\underline{\underline{1.3}}$; 1.5; 2.0; 3.0; 4.0 and 5.0.[1)]

### 2.5 *Use of method*

High-usage circuit groups carrying random traffic can be dimensioned from Table 2/E.522.

*Step 1* – Estimate the annual charges ratio $R$ as described under 2.4 above. (There is little difference between adjacent ratios.) If this ratio is difficult to estimate, the values underlined in a) and b) of § 2.4 above, should be used.

*Step 2* – Consult Table 2/E.522 to determine the number of high-usage circuits $N$.

*Note* – When two values of $N$ are given the right-hand figure applies to alternative routes of more than 10 circuits, the left-hand figure applies to smaller groups. The left-hand figure is omitted when it is no longer possible for the alternative route to be small.

## 3 24-hour traffic profiles

The traffic value used in the method in § 2 should be the value of traffic offered to the high-usage route during the busy hour of the final route. In the case that some of the busy hours of the circuit groups or links forming an alternative route do not coincide with the busy hour of the relation, the ensuing method should be followed to take 24-hour traffic profiles into account (see [6], [8] and [9]).

The method consists of the following three basic steps:

i) prepare hourly traffic demands for which dimensioning is to be done;

ii) size all circuit groups, high usage and final, for one hourly traffic demand;

iii) iterate the process in step ii) for each additional hourly matrix.

### 3.1 *Preparation of hourly traffic demands*

Each Administration gathers historical traffic data on an hourly basis in accordance with Recommendations E.500 and E.523. Using historical data and information contained in Recommendation E.506, hourly traffic demand forecasts are made, resulting in a series of hourly demands for each exchange to every other exchange.

### 3.2 *Sizing circuit groups for one-hourly traffic demand*

Using the methods in § 2 and Recommendation E.521, trunk group sizes are prepared for the first hourly traffic demand disregarding other hourly traffic demands.

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1) These values are tentative. Ranges and representative values of annual charges ratio require further study.

TABLE 2/E.522

**Number of high-usage circuits for different values of offered traffic, annual charges ratios and sizes of overflow groups**

| Traffic offered during network busy hour (erlangs) | Annual charges ratios | | | | | | | | | Number of circuits if there is no overflow route, for $p = 0.01$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1.1 | 1.3 | 1.5 | 2.0 | 3.0 | 4.0 | 5.0 | 6.0 | 7.0 | |
| | Minimum circuit occupancies for high-usage traffic | | | | | | | | | |
| | 0.545/0.727 | 0.46/0.615 | 0.4/0.53 | 0.3/0.4 | 0.2/0.26 | 0.15/0.2 | 0.12/0.16 | 0.1/0.13 | 0.085/0.114 | |
| | *N*, number of high usage circuits *A/B*, where<br>*A* is for less than 10 circuits in the overflow group ($M = 0.6$)<br>*B* is for 10 or more circuits in the overflow group ($M = 0.8$) | | | | | | | | | |
| 1,5 | 1/0 | 1/0 | 2/1 | 2/2 | 3/2 | 3/3 | 4/3 | 4/3 | 4/4 | 6 |
| 1,75 | 1/0 | 2/1 | 2/1 | 3/2 | 3/3 | 4/3 | 4/4 | 4/4 | 4/4 | 6 |
| 2,0 | 1/0 | 2/1 | 2/2 | 3/2 | 4/3 | 4/4 | 4/4 | 5/4 | 5/5 | 7 |
| 2,25 | 2/0 | 2/1 | 3/2 | 3/3 | 4/4 | 5/4 | 5/4 | 5/5 | 5/5 | 7 |
| 2,5 | 2/0 | 3/1 | 3/2 | 4/3 | 5/4 | 5/5 | 5/5 | 6/5 | 6/5 | 7 |
| 2,75 | 2/1 | 3/2 | 3/2 | 4/3 | 5/4 | 5/5 | 6/5 | 6/6 | 6/6 | 8 |
| 3,0 | 3/1 | 3/2 | 4/3 | 4/4 | 5/5 | 6/5 | 6/6 | 6/6 | 7/6 | 8 |
| 3,5 | 3/1 | 4/2 | 4/3 | 5/4 | 6/5 | 7/6 | 7/6 | 7/7 | 7/7 | 9 |
| 4,0 | 4/2 | 4/3 | 5/4 | 6/5 | 7/6 | 7/7 | 8/7 | 8/7 | 8/8 | 10 |
| 4,5 | 4/2 | 5/3 | 6/4 | 6/6 | 7/7 | 8/7 | 8/8 | 9/8 | 9/8 | 10 |
| 5,0 | 5/3 | 6/4 | 6/5 | 7/6 | 8/7 | 9/8 | 9/9 | 9/9 | 10/9 | 11 |
| 5,5 | 5/3 | 6/5 | 7/5 | 8/7 | 9/8 | 9/9 | 10/9 | 10/10 | 10/10 | 12 |
| 6,0 | 6/3 | 7/5 | 7/6 | 8/7 | 9/9 | 10/9 | 11/10 | 11/10 | 11/11 | 13 |
| 7,0 | 7/4 | 8/6 | 8/7 | 10/8 | 11/10 | 11/11 | 12/11 | 12/12 | 13/12 | 14 |
| 8,0 | 8/5 | 9/7 | 10/8 | 11/10 | 12/11 | 13/12 | 13/13 | 14/13 | 14/13 | 15 |
| 9,0 | /6 | /8 | /9 | /11 | /12 | /13 | /14 | /14 | /15 | 17 |
| 10,0 | /7 | /9 | /10 | /12 | /14 | /15 | /15 | /16 | /16 | 18 |
| 12,0 | /9 | /11 | /12 | /14 | /16 | /17 | /18 | /18 | /19 | 20 |
| 15,0 | /12 | /14 | /16 | /18 | /20 | /21 | /21 | /22 | /22 | 24 |
| 20,0 | /16 | /19 | /21 | /23 | /25 | /27 | /28 | /28 | /29 | 30 |
| 25,0 | /21 | /24 | /26 | /29 | /31 | /33 | /33 | /34 | /35 | 36 |
| 30,0 | /26 | /29 | /31 | /34 | /37 | /38 | /39 | /40 | /41 | 42 |
| 40,0 | /36 | /39 | /42 | /45 | /48 | /50 | /51 | /52 | /52 | 53 |
| 50,0 | /45 | /49 | /52 | /55 | /59 | /61 | /62 | /63 | | 64 |
| 60,0 | /55 | /60 | /62 | /66 | /70 | /72 | /73 | | | 75 |
| 80,0 | /74 | /80 | /83 | /87 | /92 | /94 | /95 | | | 96 |
| 100,0 | /94 | /100 | /103 | /108 | /113 | /116 | | | | 117 |
| 120,0 | /113 | /120 | /124 | /129 | /134 | /137 | Direct final circuit groups are economical within this area. | | | 138 |
| 150,0 | /143 | /150 | /154 | /160 | /166 | /169 | | | | 170 |
| 200,0 | /192 | /200 | /205 | /212 | /219 | | | | | 221 |
| 250,0 | /241 | /250 | /256 | /263 | /271 | | | | | 273 |
| 300,0 | /290 | /300 | /306 | /315 | /323 | | | | | 324 |

### 3.3 *Iterating for each additional hourly traffic matrix*

In sizing the circuit groups for the second hourly traffic demand, the method is provided with the circuit quantities resulting from the previous step, and is constrained solely to increasing circuit group sizes; i.e., if the circuit group sizes for the first hourly traffic demand were greater than for the second hourly demand, then the circuit group sizes for the first hourly traffic demand would be retained.

All additional hourly traffic demands are processed in the same iterative manner. The resulting circuit group sizes then satisfy the traffic demands for all hours being considered (see Annex A for a computational example).

### 3.4 *Processing sequence*

Processing may start with the first hour of traffic demand, however, experiments have indicated that efficiencies of the network can be improved if processing starts with the hour with the smallest total traffic demand. It should be noted that this method gives us suboptimal networks, which may be improved by manual refinements.

## 4 Minimum outlay alternate routing networks

The method below allows Administrations to adjust alternate routing networks to take into account existing revenue accounting divisions.

The method consists of the following steps:

i) Obtain 24-hour traffic profiles in accordance with Recommendations E.500 and E.523;

ii) Compute circuit quantities and costs for a no-overflow network in accordance with Recommendation E.520;

iii) Compute monthly overflow minutes (holding time) at varying percentages of busy-hour overflow. This is done by applying three conversion factors to the busy hour overflow erlangs:

- Ratio of holding minutes to erlangs: a fixed value of 60.
- Daily overflow to busy-hour overflow ratio: a value that depends on the 24-hour traffic profile and the degree of overflow.
- Monthly overflow to daily overflow ratio (Recommendation E.506): a value that depends on the day-to-day pattern within a month and the degree of overflow.

iv) Starting with the network calculated in step ii):

- reduce the high usage circuits by one circuit,
- calculate overflow to final circuit groups,
- dimension final circuit groups in accordance with Recommendation E.521,
- calculate circuit costs and transit charges;

v) Iterate step iv) until the minimum outlay (circuit costs plus transit charges) for terminal administrations is reached (see Annex B for computational example).

## 5 Service considerations

On intercontinental circuits, where both-way operation is employed, a minimum of two circuits may be economical. Service considerations may also favour an increase in the number of direct circuits provided, particularly where the annual charges ratio approaches unity.

Although the dimensioning of high-usage groups is normally determined by traffic flows and annual charges ratios, it is recognized that such groups form part of a network having service requirements relative to the subscriber. The ability to handle the offered traffic with acceptable traffic efficiency should be tempered by the overall network considerations on quality of service.

The quality of service feature, which is of primary importance in a system of high-usage and final circuit groups, is the advantage derived from direct circuits versus multi-link connections. A liberal use of direct high-usage circuit groups, taking into account the economic factors, favours a high quality of service to the subscriber. It is recommended that new high-usage groups should be provided whenever the traffic flow and cost ratios are not conclusive. This practice may result in direct high-usage groups of two circuits or more.

The introduction of high-usage groups improves the overall grade of service and provides better opportunities of handling traffic during surges and breakdown conditions. When high-usage links bypass the main final routes the introduction of high-usage routes can assist in avoiding expenses which might otherwise be incurred in keeping below the maximum number of long-distance links in series. In the future, more measurements of traffic flows may be necessary for international accounting purposes and high-usage circuits should make this easier.

# ANNEX A

(to Recommendation E.522)

## Example of network dimensioning taking into account 24-hour traffic profiles

A.1 *Assumptions* (see also Figure A-1/E.522)

Calculations are performed under the following conditions:

1) Time difference:

   A is 9 hours west of B
   C is 5 hours west of A
   B is 10 hours west of C

2) Traffic profiles:

   24-hour traffic profiles as per Table 1/E.523 are used.

3) Busy hour traffic:

   A-B 50 erlangs
   A-C 10 erlangs
   C-B 70 erlangs

4) Cost ratio:

   $R = 1.3$

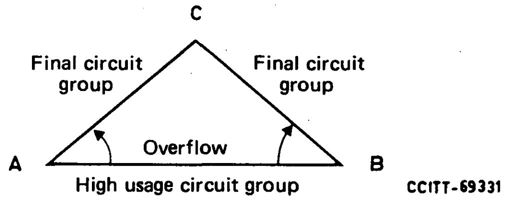


FIGURE A-1/E.522

**Triangular network for numerical examples (Example 1)**

A.2 *Numerical results*

24 hourly traffic demands are processed. The order of processing are from the hour with the smallest total traffic demand to the hour with the largest total traffic demand. Computational results are given in Table A-1/E.522.

TABLE A-1/E.522

**Numerical results**

| Hour | Hourly traffic demand | | | Number of circuits obtained by single hour dimensioning (disregarding lower bounds imposed by the previous iterative stage) | | | Number of circuits obtained considering lower bounds imposed by the previous iterative stage | | | Number of circuits required to meet multiple hourly traffic demands | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A-B | A-C | C-B | A-B | A-C | C-B | A-B | A-C | C-B | A-B | A-C | C-B |
| 6 | 17.50 | 5.00 | 3.50 | 17 | 19 | 17 | 17 | 19 | 17 | 17 | 19 | 17 |
| 7 | 20.00 | 5.00 | 3.50 | 19 | 20 | 18 | 19 | 20 | 18 | 19 | 20 | 18 |
| 5 | 2.50 | 5.00 | 28.00 | 1 | 14 | 41 | 19 | 11 | 39 | 19 | 20 | 39 |
| 4 | 2.50 | 5.00 | 35.00 | 1 | 14 | 49 | 19 | 11 | 47 | 19 | 20 | 47 |
| 8 | 37.50 | 5.00 | 3.50 | 37 | 23 | 22 | 19 | 38 | 37 | 19 | 38 | 47 |
| 9 | 40.00 | 5.00 | 3.50 | 39 | 24 | 23 | 19 | 41 | 40 | 19 | 41 | 47 |
| 3 | 2.50 | 5.00 | 45.50 | 1 | 14 | 61 | 19 | 11 | 59 | 19 | 41 | 59 |
| 18 | 2.50 | 50.00 | 3.50 | 1 | 66 | 12 | 19 | 64 | 9 | 19 | 64 | 59 |
| 10 | 50.00 | 5.00 | 3.50 | 49 | 26 | 25 | 9 | 61 | 59 | 19 | 64 | 59 |
| 19 | 2.50 | 60.00 | 3.50 | 1 | 77 | 12 | 19 | 75 | 9 | 19 | 75 | 59 |
| 20 | 2.50 | 60.00 | 3.50 | 1 | 77 | 12 | 19 | 75 | 9 | 19 | 75 | 59 |
| 22 | 12.50 | 30.00 | 24.50 | 12 | 45 | 39 | 12 | 45 | 39 | 19 | 75 | 59 |
| 2 | 2.50 | 5.00 | 63.00 | 1 | 14 | 80 | 19 | 11 | 78 | 19 | 75 | 78 |
| 17 | 2.50 | 70.00 | 3.50 | 1 | 87 | 12 | 19 | 85 | 9 | 19 | 85 | 78 |
| 1 | 2.50 | 5.00 | 70.00 | 1 | 14 | 87 | 19 | 11 | 85 | 19 | 85 | 85 |
| 23 | 20.00 | 20.00 | 42.00 | 19 | 36 | 60 | 19 | 36 | 60 | 19 | 85 | 85 |
| 11 | 47.50 | 25.00 | 17.50 | 47 | 46 | 38 | 3 | 85 | 77 | 19 | 85 | 85 |
| 21 | 12.50 | 55.00 | 24.50 | 12 | 73 | 39 | 12 | 73 | 39 | 19 | 85 | 85 |
| 12 | 42.50 | 30.00 | 21.00 | 42 | 50 | 41 | 3 | 85 | 76 | 19 | 85 | 85 |
| 16 | 2.50 | 90.00 | 3.50 | 1 | 109 | 12 | 19 | 107 | 9 | 19 | 107 | 85 |
| 0 | 20.00 | 20.00 | 66.50 | 19 | 36 | 87 | 19 | 36 | 87 | 19 | 107 | 87 |
| 13 | 30.00 | 65.00 | 35.00 | 29 | 86 | 54 | 5 | 107 | 76 | 19 | 107 | 87 |
| 15 | 17.50 | 100.00 | 28.00 | 17 | 121 | 44 | 19 | 120 | 43 | 19 | 120 | 87 |
| 14 | 27.50 | 95.00 | 38.50 | 27 | 117 | 57 | 19 | 124 | 64 | 19 | 124 | 87 |

This example relates to an intercontinental network where busy hours of the three traffic relations are widely different among each other. The busy hour of the relation A-C, i.e. hour 15, is a low traffic period for the relations A-B and C-B. The busy hour of the relation C-B, i.e. hour 1, is a low traffic period for the relations A-B and A-C. Similarly, the busy hour of the relation A-B, i.e. hour 10, is a low traffic period for the relations A-C and C-B.

In this case, the single hour dimensioning method, where traffic data during the busy hour of the final circuit group are used for dimensioning, cannot be applied. If the single hour dimensioning method is applied, this results in considerable under-dimensioning.

If all the circuit groups are dimensioned as final, the required number of circuits are 64, 117 and 85 for the circuit groups A-B, A-C and C-B, respectively. About 14% of the total number of circuits is saved by the use of alternate routing.

ANNEX B

(to Recommendation E.522)

**Example of minimum outlay network dimensioning**

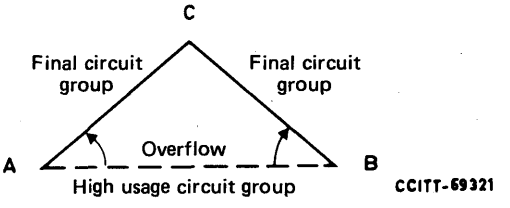


FIGURE B-1/E.522

**Triangular network for numerical example (Example 2)**

B.1 *Assumptions* (see also Figure B-1/E.522)

Calculations are performed under the following conditions:

1) Time difference:

A is 3 hours west of B
A is 3 hours west of C
No time difference between B and C

2) Traffic profiles:

24-hour traffic profiles as per Table 1/E.523 are used.

3) Busy hour traffic:

A-B 16 erlangs
A-C 33 erlangs
C-B 33 erlangs

4) Each Administration monthly cost per circuit:

A-B 1000 units
A-C 1000 units
C-B 800 units

5) Transit charge per holding minute to each terminal Administration:

1/2 unit

6) Conversion factors:

i) Holding minutes/erlangs: 60

ii) Daily overflow/busy hour overflow

This conversion factor ($F$) is calculated according to the guideline given in § 2.4.

iii) Monthly overflow/daily overflow: 26

where medium social contact per Recommendation E.502 is assumed.

7) Grade-of-service (GOS) on final circuit groups: 0.01

B.2 *Numerical results*

Numerical results are shown in Table B-1/E.522. The number of circuits C-B does not increase because of the 24-hour traffic profiles matching. The number of high usage circuits A-B in the minimum outlay network is larger than that in the minimum cost network. The impact of considering transit charges in dimensionings is always in the direction of less overflow.

TABLE B-1/E.522

**Numerical results**

| Network results | | | | Economic results (× 1000 units/month) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Busy-hour overflow probability | Number of circuits | | | Circuit costs | | | Transit charges | | | Total outlay | | |
| | A-B | A-C | C-B | A | B | C | A | B | C | A | B | C |
| 0.0000 | 25 | 45 | 45 | 70 | 61 | 81 | – | – | – | 70.0 | 61.0 | 81.0 |
| 0.0090 | 25 | 45 | 45 | 70 | 61 | 81 | 0.3 | 0.3 | (0.7) | 70.3 | 61.3 | 80.3 |
| 0.0151 | 24 | 45 | 45 | 69 | 60 | 81 | 0.6 | 0.6 | (1.3) | 69.6 | 60.6 | 79.7 |
| 0.0221 | 23 | 45 | 45 | 68 | 59 | 81 | 0.9 | 0.9 | (1.9) | 68.9 | 59.9 | 79.1 |
| 0.0331 | 22 | 46 | 45 | 68 | 58 | 82 | 1.4 | 1.4 | (2.9) | 69.4 | 59.4 | 79.1 |
| 0.0471 | 21 | 46 | 45 | 67 | 57 | 82 | 2.1 | 2.1 | (4.2) | 69.1 | 59.1 | 77.8 |
| 0.0641 | 20 | 46 | 45 | 66 | 56 | 82 | 3.0 | 3.0 | (6.0) | 69.0 | 59.0 | 76.0 |
| | | | | | | | | | | Minimum outlay for A and B | | |
| 0.0861 | 19 | 47 | 45 | 66 | 55 | 83 | 4.2 | 4.2 | (8.4) | 70.2 | 59.2 | 74.5 |
| 0.1121 | 18 | 47 | 45 | 65 | 54 | 83 | 5.7 | 5.7 | (11.5) | 70.7 | 59.7 | 71.5 |
| | | | | | | | | | | Minimum cost network | | |
| 0.142 | 17 | 48 | 45 | 65 | 53 | 84 | 7.6 | 7.6 | (15.1) | 72.6 | 60.6 | 68.9 |
| 0.175 | 16 | 49 | 45 | 65 | 52 | 85 | 9.7 | 9.7 | (19.4) | 74.7 | 61.7 | 65.6 |

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# STANDARD TRAFFIC PROFILES FOR INTERNATIONAL TRAFFIC STREAMS

The worldwide nature of the international telephone network, spanning as it does all possible time zones, has stimulated studies of the traffic streams between countries in different relative time locations. These studies have led to the development of standardized 24-hour traffic profiles which, theoretically based and verified by measurements, would be useful for engineering purposes. In fact, these concepts can be applied to a variety of network situations:

i) variable access satellite working where a large number of traffic streams with possibly differing traffic profiles share the pool of satellite circuits;

ii) combining of traffic streams on groups of terrestrial circuits which may be either high-usage or final choice routes;

iii) detour routing of traffic between origin and destination countries to take advantage of prevailing low load conditions on the detour path.

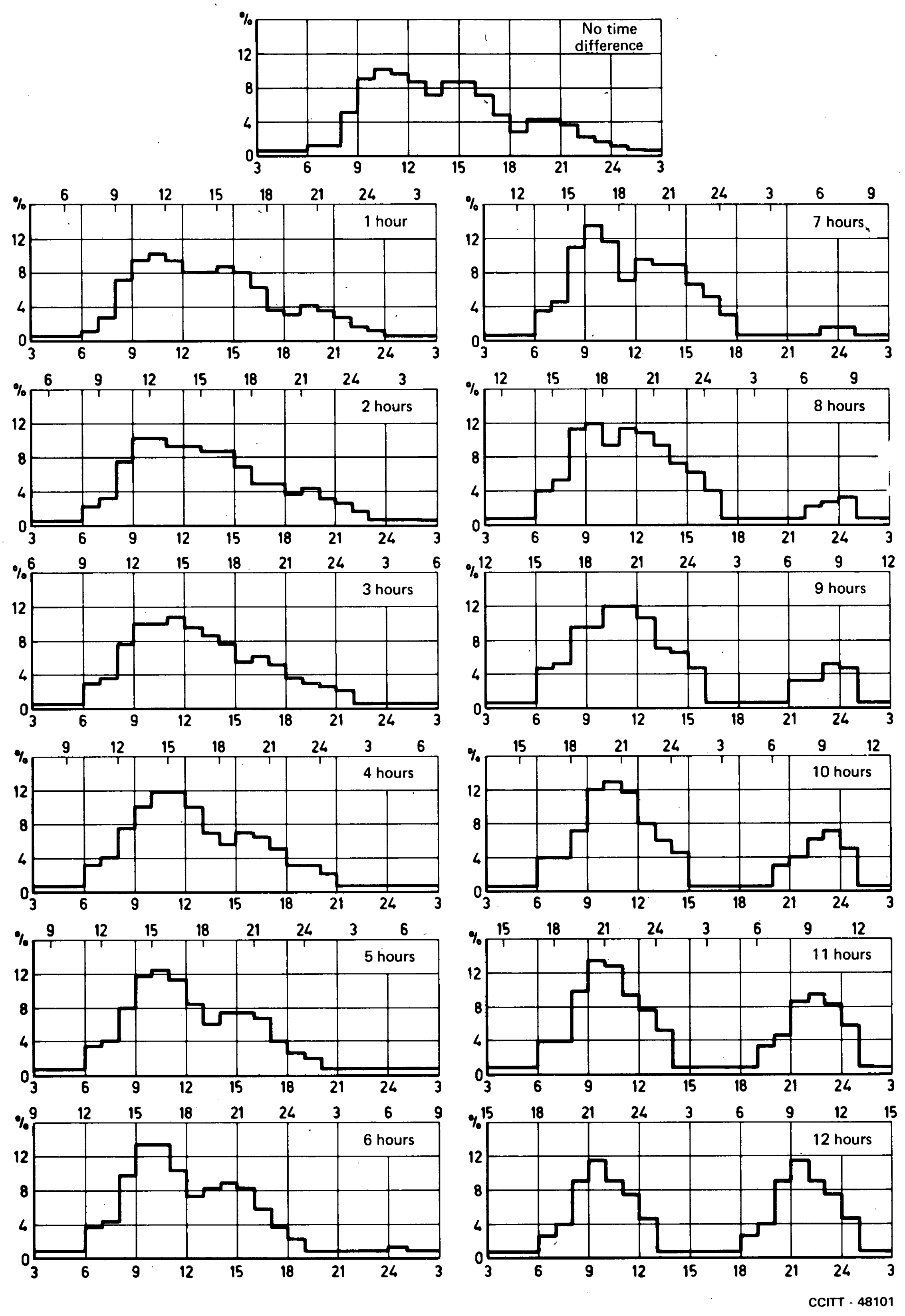
In developing any such applications, account must be taken of the International Routing Plan (Recommendation E.171 [1]) and of accepted accounting principles (Recommendation D.150 [2]).

It must be recognized that the preferred basis for dimensioning consists of traffic profiles based on real traffic. Nevertheless, many countries have found the standard profiles presented in this Recommendation very useful where streams are too small to obtain reliable measurements or where no measurements are available.

For both-way profiles, two equivalent methods of presentation are given in chart and tabular form. In Figure 1/E.523 hour-by-hour traffic volumes are shown in diagrammatically as percentages of the total daily traffic volume; such percentages are particularly convenient for tariff studies. In Table 1/E.523, hourly traffics are expressed as percentages of the busy hour traffic, and this is convenient for engineering purposes. Time zone differences are given in whole hours only. Directional profiles are given in Tables 2/E.523 and 3/E.523.

Although tables are given for both-way and directional traffic streams, it must be emphasized that at this stage only the both-way profiles can be regarded as soundly supported by measurement. The directional profiles are theoretically based and supported by some measurements, but should be used with caution until adequate verification has been achieved.

The theoretical basis for the profiles presented here is contained in Annex A. It depends on a convenience function $f(t)$ which represents the profile of *local* daily traffic, where of course no time zone difference exists. The function $f(t)$ used for computation of the standard profile was derived by mathematical manipulation of measurements of the Tokyo-Oakland and Tokyo-Vancouver streams. Although these results have been supported by other measurements, it leaves open the possibility that the convenience function may vary from one country to another and that, strictly, these should be derived independently and then used to obtain a calculated profile for the international relation. It also seems that the convenience function for the country of destination should be given greater weight than that for the country of origin. These remarks suggest possible refinements, but are not quantified in this Recommendation.




*Note* – The vertical scale gives the hourly traffic volume as a percentage of the daily traffic volume. The horizontal scales show the local times.

FIGURE 1/E.523

**Standard hourly both-way traffic distribution patterns**

TABLE 1/E.523

**Standard hourly bothway traffic patterns**

| Time difference (in hours) between two countries | Local time in the more westerly country: 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | BH % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 5 | 5 | 5 | 5 | 5 | 5 | 10 | 10 | 50 | 90 | 100 | 95 | 85 | 70 | 85 | 85 | 70 | 45 | 25 | 40 | 40 | 35 | 20 | 15 | 10.0 |
| 1 | 5 | 5 | 5 | 5 | 5 | 5 | 10 | 25 | 70 | 95 | 100 | 90 | 80 | 80 | 85 | 80 | 60 | 35 | 30 | 40 | 35 | 25 | 15 | 10 | 10.0 |
| 2 | 5 | 5 | 5 | 5 | 5 | 5 | 20 | 30 | 75 | 100 | 100 | 90 | 90 | 85 | 85 | 65 | 45 | 45 | 35 | 40 | 30 | 25 | 15 | 5 | 10.0 |
| 3 | 5 | 5 | 5 | 5 | 5 | 5 | 25 | 35 | 75 | 100 | 95 | 100 | 95 | 80 | 70 | 50 | 60 | 45 | 35 | 30 | 25 | 15 | 5 | 5 | 10.4 |
| 4 | 5 | 5 | 5 | 5 | 5 | 5 | 25 | 35 | 65 | 85 | 100 | 100 | 85 | 60 | 50 | 60 | 55 | 40 | 25 | 25 | 20 | 5 | 5 | 5 | 11.[illegible] |
| 5 | 5 | 5 | 5 | 5 | 5 | 5 | 25 | 30 | 65 | 95 | 100 | 90 | 70 | 50 | 60 | 60 | 55 | 30 | 20 | 20 | 5 | 5 | 5 | 5 | 12.4 |
| 6 | 10 | 5 | 5 | 5 | 5 | 5 | 25 | 30 | 75 | 100 | 100 | 75 | 55 | 60 | 65 | 60 | 40 | 25 | 15 | 5 | 5 | 5 | 5 | 5 | 13.1 |
| 7 | 10 | 5 | 5 | 5 | 5 | 5 | 25 | 35 | 80 | 100 | 85 | 55 | 70 | 65 | 65 | 50 | 40 | 20 | 5 | 5 | 5 | 5 | 5 | 10 | 13.5 |
| 8 | 25 | 5 | 5 | 5 | 5 | 5 | 35 | 45 | 95 | 100 | 80 | 95 | 90 | 75 | 60 | 50 | 35 | 5 | 5 | 5 | 5 | 5 | 20 | 20 | 11.7 |
| 9 | 40 | 5 | 5 | 5 | 5 | 5 | 35 | 40 | 75 | 80 | 100 | 95 | 85 | 60 | 55 | 35 | 5 | 5 | 5 | 5 | 5 | 25 | 25 | 40 | 12.1 |
| 10 | 40 | 5 | 5 | 5 | 5 | 5 | 35 | 35 | 60 | 95 | 100 | 90 | 65 | 50 | 40 | 5 | 5 | 5 | 5 | 5 | 25 | 30 | 50 | 55 | 12.5 |
| 11 | 40 | 5 | 5 | 5 | 5 | 5 | 30 | 25 | 75 | 100 | 95 | 70 | 55 | 35 | 5 | 5 | 5 | 5 | 5 | 25 | 30 | 65 | 70 | 60 | 12.3 |
| 12 | 40 | 5 | 5 | 5 | 5 | 5 | 20 | 35 | 80 | 100 | 80 | 65 | 40 | 5 | 5 | 5 | 5 | 5 | 20 | 35 | 60 | 100 | 80 | 65 | 11.3 |

*Note 1* – The 24-hour profile of both-way traffic between any two countries is read from left to right from the appropriate row of the table; all time differences can be expressed in the range 0-12 hours. Each entry is expressed as a percentage of the busy hour traffic.

*Note 2* – The *more westerly* country of a traffic relation is the one from which we can proceed eastwards to the other through time zones not exceeding 12 hours.

*Note 3* – For network planning studies, UTC (Universal Coordinated Time) would normally be used so that all traffic streams are processed time consistently. Clearly if the more westerly country is *W* hours ahead of UTC (ignoring the international dateline), then the traffic at 0000-0100 UTC is obtained from the row corresponding to the time difference between the two countries at the column headed *W*. Alternatively, the first entry in the appropriate row gives the relative traffic intensity for the hour (24-*W*) to (25-*W*).

Example: For the traffic stream between the U.K. (UTC + 1 hour) and the central zone of USA (UTC + 18 hours), the time difference is 7 hours and the USA is regarded as the more westerly country, hence $W = 18$. Thus from the table, the traffic during 0000-0100 UTC is 5% of the busy hour traffic, and the busy hour is 1500-1600 UTC.

*Note 4* – The column headed "BH %" gives the busy hour traffic volume as a percentage of the daily traffic volume.

TABLE 2/E.523

**Diurnal distributions of eastbound international telephone traffic**

Local time in the more westerly country

| Time difference (in hours) between two countries | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 10 | 5 | 5 | 5 | 5 | 5 | 10 | 10 | 50 | 90 | 100 | 95 | 85 | 70 | 85 | 85 | 70 | 45 | 25 | 40 | 40 | 35 | 20 | 15 |
| 1 | 5 | 5 | 5 | 5 | 5 | 5 | 10 | 30 | 80 | 95 | 100 | 90 | 80 | 80 | 85 | 80 | 60 | 35 | 30 | 40 | 35 | 25 | 15 | 10 |
| 2 | 5 | 5 | 5 | 5 | 5 | 5 | 25 | 40 | 85 | 100 | 100 | 90 | 90 | 85 | 85 | 60 | 40 | 45 | 35 | 40 | 25 | 20 | 15 | 5 |
| 3 | 5 | 5 | 5 | 5 | 5 | 5 | 40 | 50 | 90 | 100 | 95 | 100 | 95 | 80 | 65 | 40 | 55 | 45 | 35 | 25 | 20 | 10 | 5 | 5 |
| 4 | 5 | 5 | 5 | 5 | 5 | 5 | 35 | 50 | 70 | 85 | 100 | 100 | 85 | 60 | 40 | 50 | 50 | 40 | 25 | 20 | 15 | 5 | 5 | 5 |
| 5 | 5 | 5 | 5 | 5 | 5 | 5 | 30 | 40 | 70 | 95 | 100 | 90 | 65 | 45 | 50 | 50 | 50 | 25 | 20 | 15 | 5 | 5 | 5 | 5 |
| 6 | 10 | 5 | 5 | 5 | 5 | 5 | 40 | 45 | 85 | 100 | 100 | 65 | 45 | 55 | 55 | 50 | 30 | 20 | 15 | 5 | 5 | 5 | 5 | 5 |
| 7 | 10 | 5 | 5 | 5 | 5 | 5 | 40 | 50 | 90 | 100 | 75 | 40 | 60 | 55 | 55 | 40 | 30 | 10 | 5 | 5 | 5 | 5 | 5 | 10 |
| 8 | 25 | 5 | 5 | 5 | 5 | 5 | 55 | 65 | 100 | 100 | 70 | 90 | 85 | 70 | 45 | 35 | 25 | 5 | 5 | 5 | 5 | 5 | 20 | 20 |
| 9 | 50 | 5 | 5 | 5 | 5 | 5 | 40 | 45 | 70 | 75 | 100 | 100 | 85 | 55 | 50 | 35 | 5 | 5 | 5 | 5 | 5 | 25 | 35 | 60 |
| 10 | 65 | 5 | 5 | 5 | 5 | 5 | 45 | 45 | 60 | 95 | 100 | 90 | 60 | 45 | 35 | 5 | 5 | 5 | 5 | 5 | 25 | 30 | 75 | 100 |
| 11 | 65 | 5 | 5 | 5 | 5 | 5 | 40 | 40 | 75 | 90 | 80 | 55 | 40 | 25 | 5 | 5 | 5 | 5 | 5 | 20 | 25 | 80 | 100 | 95 |
| 12 | 55 | 5 | 5 | 5 | 5 | 5 | 20 | 40 | 65 | 70 | 50 | 40 | 20 | 5 | 5 | 5 | 5 | 5 | 20 | 25 | 70 | 100 | 90 | 80 |

*Note* – This table is based on $p = 1.4$, $q = 0.6$ i.e. greater weight is given to the convenience function of the called party (see Annex A).

TABLE 3/E.523

**Diurnal distributions of westbound international telephone traffic**

Local time in the more westerly country

| Time difference (in hours) between two countries | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 10 | 5 | 5 | 5 | 5 | 5 | 10 | 10 | 50 | 90 | 100 | 95 | 85 | 70 | 85 | 85 | 70 | 45 | 25 | 40 | 40 | 35 | 20 | 15 |
| 1 | 5 | 5 | 5 | 5 | 5 | 5 | 10 | 20 | 60 | 95 | 100 | 90 | 80 | 80 | 85 | 80 | 60 | 35 | 30 | 40 | 35 | 25 | 15 | 10 |
| 2 | 5 | 5 | 5 | 5 | 5 | 5 | 15 | 20 | 65 | 100 | 100 | 90 | 90 | 85 | 85 | 70 | 50 | 45 | 35 | 40 | 35 | 30 | 15 | 5 |
| 3 | 5 | 5 | 5 | 5 | 5 | 5 | 10 | 20 | 60 | 100 | 95 | 100 | 95 | 80 | 75 | 60 | 65 | 45 | 35 | 35 | 30 | 15 | 5 | 5 |
| 4 | 5 | 5 | 5 | 5 | 5 | 5 | 15 | 20 | 60 | 85 | 100 | 100 | 85 | 60 | 60 | 70 | 60 | 40 | 25 | 30 | 25 | 5 | 5 | 5 |
| 5 | 5 | 5 | 5 | 5 | 5 | 5 | 20 | 20 | 60 | 95 | 100 | 90 | 75 | 55 | 70 | 70 | 60 | 35 | 20 | 25 | 5 | 5 | 5 | 5 |
| 6 | 10 | 5 | 5 | 5 | 5 | 5 | 10 | 15 | 65 | 100 | 100 | 85 | 65 | 65 | 75 | 70 | 50 | 30 | 15 | 5 | 5 | 5 | 5 | 5 |
| 7 | 10 | 5 | 5 | 5 | 5 | 5 | 10 | 20 | 70 | 100 | 95 | 70 | 80 | 75 | 75 | 60 | 50 | 30 | 5 | 5 | 5 | 5 | 5 | 10 |
| 8 | 20 | 5 | 5 | 5 | 5 | 5 | 15 | 25 | 90 | 100 | 90 | 95 | 95 | 80 | 75 | 65 | 45 | 5 | 5 | 5 | 5 | 5 | 20 | 20 |
| 9 | 25 | 5 | 5 | 5 | 5 | 5 | 30 | 35 | 80 | 85 | 100 | 95 | 85 | 65 | 60 | 35 | 5 | 5 | 5 | 5 | 5 | 20 | 20 | 25 |
| 10 | 10 | 5 | 5 | 5 | 5 | 5 | 25 | 25 | 60 | 95 | 100 | 90 | 70 | 55 | 45 | 5 | 5 | 5 | 5 | 5 | 25 | 30 | 25 | 10 |
| 11 | 15 | 5 | 5 | 5 | 5 | 5 | 10 | 10 | 65 | 95 | 100 | 80 | 65 | 45 | 5 | 5 | 5 | 5 | 5 | 25 | 35 | 40 | 35 | 25 |
| 12 | 20 | 5 | 5 | 5 | 5 | 5 | 20 | 25 | 70 | 100 | 90 | 80 | 55 | 5 | 5 | 5 | 5 | 5 | 20 | 40 | 65 | 70 | 50 | 40 |

*Note* – This table is based on $p = 1.4$, $q = 0.6$ i.e. greater weight is given to the convenience function of the called party (see Annex A).

## ANNEX A

(to Recommendation E.523)

### Mathematical expression for the influence of time differences on the traffic flow

A telephone call is initiated when a person wishes to call someone else, but both parties have to be on the line before the call is established. It is considered that a telephone call is made at a time which tends to be convenient for both the calling and called parties. The *degree of convenience* for making a telephone call is considered to be a periodical function of time *t*, whose period is 24 hours. When the time difference between both parties is zero, the degree of convenience is denoted by $f(t)$, where *t* is local standard time. The graphic shape of the basic function $f(t)$ will be determined by the daily pattern of human activities, and will resemble, or fairly closely coincide with, the hour by hour traffic distribution in the national (or local) telephone network.

It is assumed that the hourly traffic distribution $F_\tau(t)$, when a time difference of τ hours exists between the originating and called locations, is expressed as the geometric mean of convenience functions of two locations τ hours apart:

$$F_{\tau,}(t) = \mathrm{k}\left\{f(t) \cdot f(t+\tau)\right\}^{1/2}$$

where

$$\mathrm{k} = 1/\int_{24\ \text{hours}} \left\{f(t) \cdot f(t+\tau)\right\}^{1/2} dt \qquad \text{(A-1)}$$

The sign of τ is positive when the time at the destination is ahead of, and negative when the time of destination is behind, the reference time.

The distribution of equation (A-1) represents the sum of the outgoing and incoming traffics. Expressions for the one-way hourly traffic distributions can also be obtained by extending the concept of convenience function as follows.

Define convenience functions both for the caller $f_0(t)$ and for the called party $f_i(t)$.Then the one-way traffic distributions of east-bound and west-bound telephone calls, for the case of τ hour time-difference, are similarly expressed as follows:

$$F_{\tau,\,\text{east}}(t) = \mathrm{k}\left\{f_0(t) \cdot f_i(t+\tau)\right\}^{1/2}$$

$$\mathrm{k} = 1/\int_{24\ \text{hours}} \left\{f_0(t) \cdot f_i(t+\tau)\right\}^{1/2} dt \qquad \text{(A-2)}$$

$$F_{\tau,\,\text{west}}(t) = \mathrm{k}\left\{f_i(t) \cdot f_0(t+\tau)\right\}^{1/2}$$

$$\mathrm{k} = 1/\int_{24\ \text{hours}} \left\{f_i(t) \cdot f_0(t+\tau)\right\}^{1/2} dt \qquad \text{(A-3)}$$

where

- *t* is the local standard time of the west station and
- τ is positive.

It is natural that a caller makes a call considering the convenience of the called person, and therefore the convenience function of the called person $f_i$ contributes more than the convenience of the caller $f_0$ to the directional distribution F. They can be written as follows:

$$f_i(t) = k_1 \left\{ f(t) \right\}^p, \qquad f_0(t) = k_2 \left\{ f(t) \right\}^q, \qquad \text{(A-4)}$$

where

$$p > q \quad \text{and} \quad p + q = 2,$$

and where $k_1$ and $k_2$ are normalizing coefficients to ensure that:

$$\int_{24 \text{ hours}} f_i(t)\, dt = 1, \qquad \int_{24 \text{ hours}} f_0(t)\, dt = 1.$$

As to the values of $p$ and $q$ in equation (A-4), it has been found empirically that the convenience of the called side $p$ is considerably larger than that of originating side $q$, and appropriate values are roughly $p = 1.4$ and consequently $q = 0.6$.

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[1] CCITT Recommendation *International routing plan*, Rec. E.171.

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SECTION 5

# GRADE OF SERVICE

**Recommendation E.540**

## OVERALL GRADE OF SERVICE OF THE INTERNATIONAL PART OF AN INTERNATIONAL CONNECTION

**1** The International Routing Plan envisages that international traffic relations may be served by any of the following routing arrangements:

a) direct circuits;

b) transit operation involving one or more transit centres for all connections,

c) direct high-usage circuits with overflow via one or more transit centres.

In principle there would be merit in dimensioning international facilities to provide the same grade of service for all relations, however served. Practical considerations make it advisable to depart from one universal value.

**2** Direct circuit groups are dimensioned, according to Recommendation E.520 on the basis of $p = 1\%$ loss probability during the mean busy hour. An exception is permitted for small groups of very long international circuits for which $p = 3\%$ loss probability is accepted for six or fewer circuits. As the traffic increases the grade of service improves progressively until $p = 1\%$ loss value is reached for 20 circuits.

**3** For the relations served exclusively by transit operation the grade of service will deteriorate with the number of transit centres in the connection. Measurements made on congestion in such circumstances suggest that the overall grade of service for up to six links in tandem is less than twice the congestion of any of the six links in the chain. Hence, for a series of routes, each dimensioned for $p = 1\%$, the overall grade of service should seldom exceed 2%. An East-West type of connection would have the advantage of different busy hours on the various links. Corresponding advantage would not apply to North-South circuits.

In the case of relations served by high-usage circuits the overflow traffic will route over at least two links and, hence, will be subject to the same deterioration of service as in the case for transit traffic. However, a substantial part of the traffic will be connected over the high-usage circuits and the overall grade of service will approximate that of the relations served solely by direct circuits.

It is desirable that at least one high-usage circuit should always be provided between a CT3 and its homing CT1, even though the circuit may not be wholly justified on economic considerations alone. However, such a circuit should not be provided unless there is a measurable amount of traffic which exists, or can be foreseen in the busy hour. The provision of such circuits would improve the transmission as well as the grade of service; these considerations should encourage an increase both in traffic and in the revenue-earning capacity of the circuits provided.

The overall grade of service for the international part of a connection is a contributory factor to the overall grade of service from the calling party in one country to the called party in another.

**Recommendation E.541**

# OVERALL GRADE OF SERVICE FOR INTERNATIONAL CONNECTIONS (SUBSCRIBER-TO-SUBSCRIBER)

## 1 Introduction

1.1 The overall grade of service (subscriber-to-subscriber) on international connections – relating only to the phenomena of congestion in the entire network as a result of the traffic flow – depends on a number of different factors, such as the routing arrangements in the national and international parts of the connection, congestion allowed per switching stage, the methods used to measure traffic and compute the traffic base, and the time differences between the busy hours of the various links involved in the connection.

1.2 The most satisfactory way in which this grade of service could be described would be to give its distribution. The design average grade of service during the busy hour of the complete connection would be the most useful single parameter. However, until such time as continuous traffic measurements are carried out during the busy season in all parts of the network on a routine basis, it is not possible to compute this average grade of service. Therefore, at this stage it cannot be used as a criterion for the dimensioning of the network.

1.3 The only practical way of ensuring an acceptable overall grade of service on international calls is to specify an upper limit on the design loss probability per connecting link in the national network as is done for the links in the international network (see Recommendation E.540).

## 2 General considerations

2.1 Since the success of the international automatic service is highly dependent on the grade of service of all links involved in the connection from subscriber-to-subscriber, it is desirable that the originating and terminating national network involved in the connection has grade of service standards comparable with those of the international network.

2.2 It is especially important that the links in the country of destination should have a good grade of service for handling the traffic, since high congestion in the terminating national network could have serious effects on the international network. High congestion in the network of the country of destination causes added retrials with consequent increased loading on common switching devices as well as increased occupation of the routes with ineffective calls.

## 3 Design objectives

3.1 It is recommended that the links in the national network should be designed for a loss probability[1)] not exceeding 1 per cent per link in the final choice route during its applicable busy hour. It is recognized, however, that in some countries additional congestion is permitted for the internal switching stages of the transit exchanges. It is also recognized that, where this recommended grade of service is not provided for the national service, it may not be economically feasible to provide it for international relations.

3.2 The maximum number of links in tandem used by an international connection is defined by Recommendation E.171 [1].

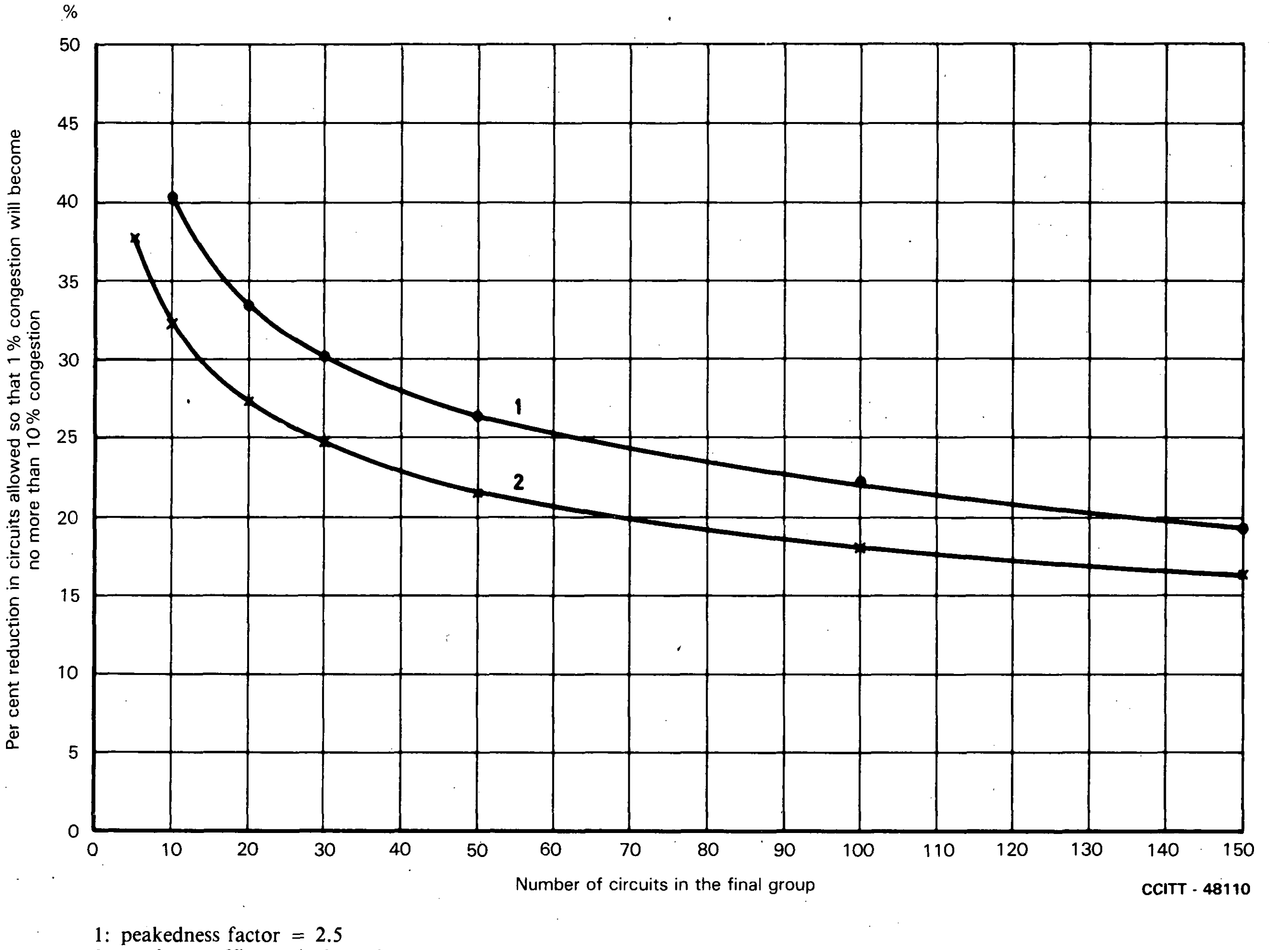
3.3 Although the worst overall grade of service would be approximated by the sum of loss probabilities for individual links connected in tandem, on most calls the overall grade of service will be significantly better.

1) The loss probability mentioned refers to busy hour traffic values as defined in Recommendation E.500.

## 4 Maximum traffic loading

4.1 An acceptable automatic service on a final circuit group is difficult to maintain if the traffic loading on the group exceeds a level corresponding to a calculated Erlang grade of service of 10 per cent. Beyond this traffic loading, service on the route may rapidly deteriorate. This condition will be accentuated under the cumulative effect of repeat attempt calls if these should occur.

4.2 The curves of Figure 1/E.541 indicate the proportionate reduction in circuits that may be tolerated for a short period, 15 minutes for example, under normal busy-hour conditions, on a full-availability circuit group dimensioned for 1 per cent Erlang loss, in accordance with the above traffic overload criterion. Table 1/E.541 gives the figures used to plot the curves.




1: peakedness factor = 2.5
2: random traffic (peakedness factor = 1.0)

FIGURE 1/E.541

**Proportionate reduction in the number of circuits in a final group in the event of a breakdown if the calculated Erlang grade of service is not to exceed 10 per cent**

TABLE 1/E.541

**Percentage reduction in the number of circuits if the calculated Erlang grade of service is not to exceed 10%**

| Number of circuits | If originally operating at 1% congestion, % reduction in circuits allowed to yield 10% congestion | |
|---|---|---|
| | Random traffic (peakedness factor = 1.0) | Peakedness factor = 2.5 |
| 5 | 37.7 | – |
| 10 | 32.3 | 40.2 |
| 20 | 27.2 | 33.3 |
| 30 | 24.8 | 30.1 |
| 50 | 21.7 | 26.5 |
| 100 | 18.3 | 22.4 |
| 150 | 16.7 | 19.7 |

4.3 The curves of Figure 1/E.541 are intended merely as a guide. If the breakdown occurs during an exceptionally busy hour, the permissible proportionate reduction will be less. Conversely, if the breakdown occurs during an hour of light traffic, a higher proportionate reduction in circuits could be tolerated. A higher reduction might also be acceptable after an appropriate oral announcement has been introduced. In the general case, a knowledge of the circuit occupancy will enable an estimate to be made of the prevailing Erlang loss figure with the reduced number of circuits.

The permissible reduction in the case of large groups should not be exceeded; otherwise very serious congestion can result from repeated attempts.

## 5 General notes

*Note 1* – teletraffic implications for international switching and operational procedures under failure of a transmission facility are discussed in Supplement No. 5 of this fascicle.

*Note 2* – alternative routing in the national and in the international networks provides on average a grade of service that is better than that provided in the theoretical final route.

*Note 3* – non-coincidence of traffic peaks in the national and international networks will provide reduction in the overall grade of service compared with the sum of the design grade of service values per link.

*Note 4* – time differences will also improve the resulting grade of service.

*Note 5* – the methods of measuring and calculating the traffic base for provisioning purposes in the national networks may be different in various countries and differ from the methods for the international network given in Recommendation E.500. This means that the national traffic values are not always comparable among themselves or with the values of the international network. Each Administration must estimate how its design traffic level compares with that recommended for the international network.

*Note 6* – the design grade of service value of each link will only apply if the traffic at each switching stage is equal to the forecast. In practice, such a situation will seldom occur. Furthermore, the planning procedure normally is such that the specified grade of service should not be exceeded until the end of the planning period. In a growing network, this means that the circuit groups during almost the whole planning period give a better service than the specified critical standard.

In conclusion, the overall grade of service depends on the accuracy of forecasts made and the planning procedure used, i.e. it depends on the interval between plant additions and on the specific traffic value in future to which the grade of service is related.

### Reference

[1] CCITT Recommendation *International routing plan*, Rec. E.171.

**Recommendation E.543**

## GRADES OF SERVICE IN DIGITAL INTERNATIONAL TELEPHONE EXCHANGES

## 1 Introduction

1.1 The grade of service (GOS) parameters and values to be used as dimensioning standards and as performance objectives for international telephone exchanges are indicated below. Procedures to monitor the actual GOS performance of the exchanges are also recommended.

1.2 The GOS standards for international telephone exchanges defined in this Recommendation assume "fully operative" conditions for the exchange and they are based on the load levels specified in Recommendation E.500.

## 2 Scope of the Recommendation

2.1 The GOS standards are specified for an exchange as a whole, i.e. neither the delay nor the loss parameters are associated solely with the control area or with the connecting network, so that no particular system concept is favoured.

2.2 Although the GOS parameters defined in this Recommendation apply to the digital as well as to the analogue exchanges, the numerical values recommended for these parameters are primarily intended for digital exchanges. The GOS may be too stringent for analogue exchanges and Administrations are advised to make suitable allowances when applying to the analogue exchanges.

Administrations may also consider these GOS values for dimensioning the national transit exchanges so that the end-to-end GOS performance for international connections is maintained at a high level.

## 3 Grade of service parameters

The loss and delay GOS standards are defined as follows:

### 3.1 *Loss grade of service*

**internal loss probability**: for any call attempt, it is the probability that an overall connection cannot be set up between a given incoming circuit and any suitable free outgoing circuit within the switching network.

The loss grade of service is to be met by every pair of incoming and outgoing trunk groups averaged over all inlets of the incoming group.

This approach takes explicit account of the fact that the Administrations will take actions such as the favourable loading of switch blocks in order to balance access to all trunk groups. These actions will minimize the impact of the worst case upon the traffic flow capacity of the switch, by confining the necessary adjustments to localized regions of the switching network.

These actions should ensure that the switching system operates as efficiently as possible within the constraints imposed by this loss standard.

### 3.2 *Delay grade of service in case of channel-associated signalling*

**incoming response delay**: The interval from the instant when an incoming seizure signal has arrived at the incoming side of the exchange to the instant when a proceed-to-send signal is returned to the preceding exchange by the receiving exchange.

The incoming response delay may affect the holding time of the preceding trunks and of the common control equipment in the preceding exchange(s). It may also be perceived by the subscriber as dial-tone delay, in case of special dial tone for international calls in outgoing international exchanges, or may contribute to the post-dialling delay experienced by the subscriber in all other cases. The contribution to post-dialling delay does not necessarily comprise the whole of the incoming response delay.

*Note* – The above definition of incoming response delay does not explicitly mention that it includes receiver attachment delay. However, for the purpose of this Recommendation, it is assumed that receiver attachment delay is a part of the incoming response delay.

3.3 *Delay grade of service in case of any combination of channel-associated and common channel signalling*

**exchange call set-up delay**: The interval from the instant when the address information required for setting up a call is received at the incoming side of the exchange to the instant when the seizing signal or the corresponding address information is sent to the subsequent exchange.

**through-connection delay (end-to-end channel associated or common channel signalling)**: the interval from the instant when the information required for setting up a through-connection in an exchange is available for processing in the exchange to the instant when the switching network through-connection is established between the incoming and outgoing circuits.

**through-connection delay (link-by-link channel associated signalling)**: the interval from the completion of outpulsing to the establishment of a communication path through the exchange between the incoming and the outgoing circuits.

## 4 Grade of service standards

The values shown in Table 1/E.543 are recommended for GOS standards of international digital telephone exchanges. The normal and high load levels are the ones defined in Recommendation E.500.

TABLE 1/E.543

| | Normal load | High load |
|---|---|---|
| Incoming response delay [a) b)] | P(> 0.5 sec.) ⩽ 5% | P(> 1 sec.) ⩽ 5% |
| Exchange call set-up delay [b)] | P(> 0.5 sec.) ⩽ 5% | P(> 1 sec.) ⩽ 5% |
| Through-connection delay [b)] | P(> 0.5 sec.) ⩽ 5% | P(> 1 sec.) ⩽ 5% |
| Internal loss probability [c)] | 0.002 | 0.01 |

a) See Note in § 3.2.

b) The determination of the number of bids for the different devices or exchange modules at normal and high load levels should be made according to Rec. E.500. Circuit group or exchange load levels will be used according to the devices or exchange modules affected.

c) The values of traffic offered to the circuit group and to the switching network of the exchange, to be used for loss probability evaluation, should correspond to the traffic flow levels defined for circuit groups and exchanges, respectively, in Rec. E.500.

In case of differences between exchange and circuit group busy hours it is recommended to use models which can take account of the different traffic values in the different parts of the exchange. For example, models used for dimensioning the auxiliary equipment could take advantage of the differences of busy hour of the different circuit groups using the same auxiliary equipment.

## 5 Measurements to monitor exchange GOS performance

In the context of traffic Administration, monitoring the GOS performance in an exchange is a means of detecting potential problems which can affect the GOS performance of that exchange. By analysing deviations from previously established GOS performance thresholds, problem areas can be detected. After having identified the problems, actions such as load balancing, fault removal, extensions, etc., can be derived from GOS performance monitoring. These actions are not taken on a real-time basis, and consequently the data collection and analysis do not have real-time constraints. The traffic measurements recommended below do not separate the causes of call attempt failure or excessive delay.

When the values of the GOS performance are consistently worse than the GOS standards specified in § 4, it will be necessary to identify the causes of such a situation through the analysis of ad-hoc measurement procedures. Considering the above framework, errors in GOS estimation are only important to the extent that they can generate over- or under-reactions to exchange situations.

For each of the GOS parameters a statistical estimator has been defined. The measurements must be made on a per circuit group and per exchange basis. Eventually, savings could be derived from delay measurements made on the basis of signalling types when several circuit groups share the same auxiliary devices. All measurements described below refer to a specific measurement period.

### 5.1 *Delay measurements*

#### 5.1.1 *Incoming response delay*

The exchange GOS performance with respect to this parameter can be estimated by means of the ratio:

$$p = \frac{B}{A},$$

where

$A$ is the number of call attempts accepted for processing from a given incoming circuit group

$B$ is the number of call attempts out of the set $A$, for which the incoming response delay exceeded the predetermined value $X$

*Note* – In SPC exchanges a certain time may elapse from the moment that the incoming seizure signal appears at the incoming circuit until the moment that the processor accepts the call attempt for processing. Measuring this delay would require external equipment to the call handling processors. The above measurement only provides an indication of the incoming response delay after the call has been accepted for call processing. In the case where this delay is significant, it should be taken into account in dimensioning and should be subtracted from the total time allowed for the incoming response delay.

#### 5.1.2 *Exchange call set-up delay*

The exchange performance with respect to this parameter can be measured by means of the following ratio:

$$q = \frac{D}{C},$$

where

$C$ is the number of call attempts for which sufficient address information has been received at the incoming side of the exchange, which are addressed to a certain outgoing circuit group and for which the seizing signal or the corresponding address information is sent to the subsequent exchange.

$D$ is the number of call attempts already counted in $C$ for which the call set-up delay exceeds the predetermined value, $T$.

#### 5.1.3 *Through-connection delay*

The exchange performance with respect to this parameter can be measured by means of the following ratio:

$$r = \frac{F}{E},$$

where

$E$ (for end-to-end channel associated and common channel signalling) is the number of call attempts for which the required information for setting up a through-connection is available for processing in the exchange for a certain circuit group.

$E$ (for link-by-link channel associated signalling) is the number of call attempts which have completed outpulsing in a certain circuit group.

$F$ is the number of call attempts already counted in $E$ for which the through-connection delay has exceeded the predetermined value $V$.

*Note 1* – The loss of call attempts caused by the exchange itself, premature subscriber release or time-out expiration in an upstream exchange may modify the outcome of the above delay measurements. However, the effect will only be significant under abnormal conditions which should be investigated separately.

*Note 2* – It is recommended that values for $X$, $T$, and $V$ be either 0.5 s (normal load) or 1 s (high load).

*Note 3* – Measuring delays on a per call basis could produce severe cost penalties to the exchange. Since the accuracy requirements from the statistical viewpoint are not very high, call sampling procedures or test calls can be sufficient for GOS monitoring purposes.

5.2 *Loss measurements*

One estimator of this parameter per circuit group is:

$$s = \frac{H}{G},$$

where:

$G$ is the number of call attempts which require a connection from an inlet to the desired outgoing circuit group having at least one free circuit and for which sufficient call handling information was made available to the exchange.

$H$ is the number of those call attempts described by $G$ which failed to build up the required connection.

*Note* – The loss of call attempts caused by premature subscriber release or time-out expiration in an upstream exchange, may modify the outcome of the above measurement.

**Recommendation E.550**

## GRADE-OF-SERVICE AND NEW PERFORMANCE CRITERIA UNDER FAILURE CONDITIONS IN INTERNATIONAL TELEPHONE EXCHANGES

### 1 Introduction

1.1 The grade of service (GOS) seen by a subscriber (blocking and/or delay in establishing calls) is not only affected by the variations in traffic loads but also by the partial or total failures of network components. The concept of customer-perceived grade of service is not restricted to specific fault and restoration conditions. For example, the customer is usually not aware of the fact that a network problem has occurred, and he is unable to distinguish a failure condition from a number of other conditions such as peak traffic demands or equipment shortages due to routine maintenance activity. It is therefore necessary that suitable performance criteria and grades-of-service objectives for international telephone exchanges be formulated that take account of the impact of partial and total failures of the exchange. Further, appropriate definitions, models and measurement and calculation methods need to be developed as part of this activity.

1.2 From the subscriber's point of view, the grade of service should not only be defined by the level of unsatisfactory service but also by the duration of the intervals in which the grade of service is unsatisfactory and by the frequency with which it occurs. Thus, in its most general form the performance criteria should take into account such factors as: frequency and duration of failures, traffic demand at time of failures, number of subscribers affected by the failures and the distortions in traffic patterns caused by the failures.

However, from a practical viewpoint, it will be desirable to start with a simpler criteria that could be gradually developed to account for all the factors mentioned above.

1.3 Total or partial failures within the international part of the network have a much more severe effect than similar failures in the national networks because the failed components in the national networks can be isolated and affected traffic can be rerouted. Failures in the international part of the network may therefore lead to degraded service in terms of increased blocking and delays and even complete denial of service for some time. The purpose of this Recommendation is to set some service objectives for international exchanges so that the subscribers demanding international connections are assured a certain level of service. Subsequently, the proposed performance criteria and grade-of-service levels may be further refined (if necessary) and used for dimensioning of redundant components in international exchanges.

## 2 General considerations

2.1 The new performance criteria being sought involve concepts from the field of "availability" (frequency and duration of failures) and "traffic congestion" (levels of blocking and/or delay). It is therefore necessary that the terminology, definitions and models considered should be consistent with the appropriate CCITT Recommendations on terminology and vocabulary.

2.2 During periods of heavy congestion, caused either by traffic peaks or due to malfunction in the exchange, a significant increase in repeated attempts is likely to occur. Further, it is expected that due to accumulated demands during a period of total failure, the exchange will experience a heavy traffic load immediately after a failure condition has been removed and service restored. The potential effects of these phenomena on the proposed grade of service under failure conditions should be taken into account.

## 3 Scope of the Recommendation

3.1 The recommendations are confined to the failures in a single exchange and their impact on calls within that exchange – network impacts are not covered in these recommendations.

3.2 The recommendations are made from the grade-of-service viewpoint.

3.3 In conformity with Recommendation E.543 for transit exchanges under normal operation, this Recommendation applies primarily to international digital transit exchanges. However, Administrations may consider these recommendations for their national networks.

3.4 The following four classes of exchange failures are covered by this Recommendation:

a) total exchange failure;

b) partial failure resulting in capacity reduction in all traffic flows to the same extent;

c) partial failure in which traffic flows to or from a particular point are restricted or totally isolated from their intended route;

d) intermittent fault affecting a certain proportion of calls.

3.5 The traffic grade of service criteria as defined in Recommendation E.543 are applicable to each of the classes of failures in § 3.4 [with the possible exception of failure class d)]. However, this Recommendation concentrates on the loss grade of service.

## 4 The GOS structure and applicable models

4.1 In this section, the terms "accessible" and "unaccessible" are used in the sense of reliability theory as defined in revised Recommendation G.106. The grade-of-service structure for exchanges under failure conditions can be formulated at the following two conceptual levels from a subscriber's viewpoint.

### 4.1.1 *Instantaneous service accessibility (unaccessibility)*

At this level, one focuses on the probability that the service is accessible (not accessible) to the subscriber *at the instant* he places a demand.

### 4.1.2 *Cumulative service accessibility (unaccessibility)*

At this level, one extends the concept of "downtime" used in availability specifications for exchanges to include the effects of partial failures and traffic overloads over a long period of time.

4.2 Based on the grade-of-service concept outlined in § 4.1, the grade-of-service parameters for exchanges under failure conditions are defined as follows:

4.2.1 **instantaneous exchange unaccessibility** is the probability that the exchange in question cannot perform the required function under stated conditions at the time a request for service is placed.

4.2.2 **cumulative exchange service unaccessibility** is the fraction of time the exchange in question cannot perform the required function under stated conditions over a prespecified observation period.

4.2.3 *Note 1* – The GOS model in the case of instantaneous exchange unaccessibility parallels the concept of the call congestion in traffic theory and it needs to be extended to include the call congestion caused by exchange failures classified in § 3.4. The GOS value can then be assigned on a basis similar to Recommendation E.543 for transit exchanges under normal operation.

*Note 2* – A model for estimating the cumulative exchange unaccessibility is provided in Annex A. Though the model provides a simple and hence attractive approach, some practical issues related to measurement and monitoring and the potential effects of network management controls and scheduled maintenance on the GOS need further study.

*Note 3* – The effect of repeated call attempts during periods of congestion due to traffic overloads or partial exchange failures should be taken into account while specifying these GOS parameters. Moreover, the duration of failure (considered in Annex A) should include the recovery time after restoration, needed to handle accumulated demand.

## 5 GOS values

The actual values or range of values for the GOS parameters recommended in § 4 will be assigned after further study. The assigned values should reflect the subscriber's viewpoint and should be consistent with the overall end-to-end GOS performance standards for the network.

ANNEX A

(to Recommendation E.550)

### A model for cumulative exchange unaccessibility

The model proposes the following expression for cumulative exchange unaccessibility:

$$p = \sum_{i=1}^{N} \lambda_i \tau_i b_i / T$$

where

$p$ is the relative traffic loss due to exchange failures over a given observation period $T$

$N$ is the number of types of failures given in § 3.4

$\lambda_i$ is the frequency of failure type $i$ (for example times/year)

$\tau_i$ is the average duration of failure type i (for example in hours)

$b_i$ is the average proportion of traffic offered which cannot be served within a specified GOS under normal exchange operation due to failure type $i$

$T$ is the observation period (for example 1 year = 24 × 365 hours)

The value assigned to $p$ should be an inverse function of the traffic carrying capacity of the exchange under the normal load (or the total number of circuits served by the exchange) as specified in Table 2/E.500 and the GOS as specified in Recommendation E.543. The exact nature and shape of the inverse function needs further study.

SECTION 6

# DEFINITIONS

## Recommendation E.600

## TERMS AND DEFINITIONS OF TELETRAFFIC ENGINEERING

### 1 Introduction

This Recommendation contains terms and definitions agreed for use in the field of teletraffic engineering. It is to be regarded as open and continually subject to revision, for two reasons:

a) the broadening range of application of teletraffic engineering will require additional definitions, and possibly revision of existing definitions;

b) it is very difficult to produce a perfect and totally consistent set of definitions, and improvements will always be possible.

The Recommendation does not include related terms whose scope is more appropriately defined by experts in other fields (e.g. reliability), and which can already be found in appropriate Recommendations. On the other hand, terms have been retained and redefined, where the meaning in a teletraffic context is significantly different from that of the same word elsewhere, and to change teletraffic usage would be impracticable.

The terms bear an IEV number which has the format 715.XX.YY, where 715 is the number of the teletraffic chapter of the IEV, XX is a subchapter number, and YY is a provisional sequence number in the subchapter. Alternatives for the preferred term are given in parentheses.

### 2 List of terms and definitions of teletraffic

This Recommendation is organized as follows:

715 – Teletraffic, trunking and operating

715.1 *Teletraffic*

10 General theory
11 Calls
12 Delays
13 Traffic
14 Trunks
15 Engineering

715.10 *General theory*

10.02 Communication
10.06 Connection (communication path)
10.08 Loss mode of operation
10.10 Delay mode of operation
10.20 Resource

715.11 *Calls*

11.01 Call
11.06 Bid
11.08 Seizure
11.10 Call attempt
11.12 Call intent
11.13 Call demand
11.14 First call attempt
11.16 Repeated call attempt (reattempt)
11.18 Call string
11.20 Busy
11.22 Release
11.23 Holding-time
11.24 Busy period
11.25 Service-time
11.26 Waiting time
11.27 Delay time
11.28 Blocking (congestion)
11.30 Internal blocking
11.32 External blocking
11.34 Call congestion (probability of loss; loss)
11.36 Time congestion
11.38 Call attempt, abandoned
11.40 Call attempt, lost
11.42 Call attempt, successful
11.44 Call attempt, completed (call attempt, effective)
11.48 Successful call
11.50 Completion ratio (efficiency ratio) answer seizure ratio)
11.54 Call intensity
11.56 Subscriber calling rate
11.58 Subscriber traffic rate

715.12 *Delays*

12.02 Dialling time
12.04 Dial tone delay
12.06 Incoming response delay
12.08 Exchange call set up delay
12.10 Through-connection delay
12.12 Post-dialling delay
12.14 Answering delay

715.13 *Traffic*

13.02 Telecommunications traffic (teletraffic)
13.04 Poisson traffic
13.06 Pure chance traffic
13.08 Peakedness factor
13.10 Smooth traffic
13.12 Peaked traffic
13.14 Traffic offered
13.16 Traffic carried
13.18 Overflow traffic
13.20 Lost traffic
13.22 Traffic volume
13.26 Erlang
13.27 Destination
13.28 Traffic matrix
13.30 Traffic relation (traffic stream; traffic item; parcel of traffic; "point-to-point traffic")
13.32 Equivalent random traffic intensity

715.14 *Circuits*

14.02 Unidirectional
14.04 Bidirectional
14.06 One way
14.08 Both way
14.10 Channel
14.12 Pair of complementary channels
14.14 Trunk = circuit
14.18 Circuit subgroup
14.20 Circuit group
14.22 First choice circuit group
14.24 High usage circuit group
14.26 Final circuit group
14.28 Only route circuit group
14.30 Fully provided circuit group
14.32 Last choice circuit group
14.34 Equivalent random circuit group

715.15 *Engineering*

15.02 Route
15.03 Routing
15.04 Alternative (alternate) route
15.06 Network cluster
15.10 Traffic routing
15.12 Busy hour
15.14 Peak busy hour (bouncing busy hour); post selected busy hour)
15.16 Time consistent busy hour
15.18 Day to busy-hour ratio
15.20 Effective traffic
15.22 Grade of service
15.24 Quality of service
15.26 Originating traffic
15.28 Terminating traffic
15.30 Internal traffic
15.32 Incoming traffic
15.34 Outgoing traffic
15.36 Transit traffic
15.44 Traffic load imbalance
15.46 Traffic distribution imbalance

10.02 **communication**

*F: communication*

*S: comunicación*

Transfer of information according to agreed conventions. The information flow need not be bidirectional.

10.06 **connection (communication path)**

*F: connexion (trajet de communication)*

*S: conexión (trayecto de comunicación)*

A temporary association of channels and other functional units providing means for a communication between two or more devices in, or attached to, a telecommunication network.

10.08 **loss mode of operation**

*F: système avec perte*

*S: modo de operación con pérdida de llamadas*

A mode of operation in a system in which bids which find no suitable resources free and accessible are lost.

10.10 **delay mode of operation**

*F: système avec attente*

*S: modo de operación con espera de llamadas*

A mode of operation in a system in which bids which find no suitable resources free and accessible are permitted to wait until service can begin.

10.20 **resource**

*F: ressource*

*S: organo*

Any physically or conceptually identifiable entity, the possession or use of which can be unambiguously determined.

11.01 **call**

*F: appel*

*S: llamada*

A single continuous connection.

11.06 **bid**

*F: tentative de prise*

*S: tentativa de toma*

A single attempt to obtain the service of a resource of the type under consideration.

*Note 1* – In a network management context, the absence of qualification implies a bid to a circuit-group, a route or a destination.

*Note 2* – A bid may be unsuccessful for reasons other than the unavailability of the resources under consideration, due to other constraints such as the need to seize other types of resources simultaneously.

11.08 **seizure**

*F: prise*

*S: toma*

A successful bid.

11.10 **call attempt**

*F: tentative d'appel*

*S: tentativa de llamada*

A call attempt is always generated by a user. At a given measurement point it is manifested by a single unsuccessful bid, or a successful bid and all subsequent identifiable activity related to the establishment of a connection using the resource seized and ending not later than its release.

11.12 **call intent**

*F: intention d'appel*

*S: intento de llamada*

The desire to establish a call. This would normally be manifested by one or more call attempts. However, this need not necessarily be the case since attempts may be suppressed or delayed by the calling customer's expectation of poor network performance at a particular time.

11.13 **call demand**

*F: demande d'appel*

*S: demanda de llamada*

A call intent that results in at least one call attempt.

11.14 **first call attempt**

*F: première tentative d'appel*

*S: primera tentativa de llamada*

At a given measurement point in the network, a first call attempt is the first attempt of a call demand that reaches that point.

11.16 **repeated call attempt (reattempt)**

*F: tentative d'appel répétée*

*S: tentativa de llamada repetida*

Any of the subsequent call attempts related to a first call attempt.

11.18 **call string**

*F: chaîne d'appel*

*S: cadena de llamada*

All the call attempts related to a single call intent.

11.20 **busy**

*F: occupation, occupé*

*S: ocupado (ocupación)*

Condition of a resource which is in use, following its seizure.

11.22 **release**

*F: libération (fin, relâchement)*

*S: liberación*

The event which is the end of a busy state.

11.23 **holding time (completion time)**

*F: durée d'occupation*

*S: tiempo de ocupación*

The time interval between the seizure of a resource and its next release.

*Note* – Interruptions by higher-priority demands should not be counted as releases.

11.24 **busy period**

*F: période d'occupation ininterrompue*

*S: periodo de ocupación ininterrumpida*

The time interval between the seizure of the last available resource in a pool of resources and the next release and resultant idle state of a resource in that pool.

11.25 **Service time**

*F: temps de service*

*S: tiempo de servicio*

The total accumulated time that a resource attends to a given demand.

*Note* – For hardware resources, service time is generally uninterrupted and coincides with the holding time.

11.26 **Waiting time (queueing time)**

*F: temps de mise en attente*

*S: tiempo de espera (tiempo de cola)*

The interval between the registration of a demand for a resource and the start of the requested action, or the abandonment of the demand if earlier.

11.27 **delay time**

*F: délai d'attente*

*S: tiempo de demora*

The interval between the registration or arrival of a demand for a resource and the completion of the requested action, or the abandonment of the demand if earlier.

11.28 **blocking (congestion)**

*F: encombrement (congestion)*

*S: bloqueo (congestión)*

The state when the immediate establishment of a new connection is impossible owing to the inaccessibility of any of the resources of the system being considered.

*Note 1* – When blocking or congestion is used as an abbreviation for probability of blocking or probability of congestion, it should always be made clear whether it refers to time congestion or call congestion probabilities.

*Note 2* – Blocking does not necessarily result in the loss of a call attempt, because it may be possible to establish the connection after a certain delay or by using alternative resources.

11.30 **internal blocking**

*F: blocage interne*

*S: bloqueo interno*

The condition in which a connection cannot be made between a given inlet and any suitable free outlet owing to the impossibility of establishing a path, within the switching element being considered.

11.32 **external blocking**

*F: blocage externe*

*S: bloqueo externo*

When referring to a switching stage, the condition in which no suitable resource, connected to that switching stage, is accessible.

11.34 **call congestion (probability of loss; loss)**

*F: encombrement d'appel (probabilité de perte, perte)*

*S: congestión (o bloqueo) de llamadas (probabilidad de pérdida, pérdida)*

The probability that a bid to a particular group of resources is blocked.

11.36 **time congestion**

*F: congestion temporelle*

*S: congestión temporal*

The probability that a system is congested at an arbitrary instant of time.

11.38 **call attempt, abandoned**

*F: tentative d'appel abandonnée*

*S: tentativa de llamada abandonada*

A call attempt aborted by the calling party.

11.40 **call attempt, lost**

*F: tentative d'appel perdue*

*S: tentativa de llamada perdida*

A call attempt that is rejected due to an equipment shortage, error or failure in the network.

11.42 **call attempt, successful (call attempt, fully-routed)**

*F: tentative d'appel acheminée*

*S: tentativa de llamada fructuosa (tentativa de llamada totalmente examinada)*

A call attempt, in which the calling station is either switched through to the exchange line terminating unit of the dialled number, or receives busy tone when the dialled number is busy.

*Note* – A successful call attempt does not necessarily result in a successful call.

11.44 **call attempt, completed (call attempt, effective) (call attempt, answered)**

*F: tentative d'appel ayant abouti (tentative d'appel efficace)*

*S: tentativa de llamada completada (tentativa de llamada eficaz)*

A call attempt answered by a called station; in international service this should always be followed by an answer signal.

*Note* – The station reached might not be the one wanted by the caller, due to dialling error or network malfunction.

11.48 **successful call**

*F: appel ayant abouti*

*S: llamada fructuosa*

A call that has reached the wanted number and allows the conversation to proceed.

11.50 **completion ratio (efficiency ratio; answer seizure ratio)**

*F: taux d'efficacité*

*S: relación respuesta/toma (tasa de eficacia)*

The ratio of the number of completed (or effective) call attempts to the total number of call attempts, at a given point of a network.

11.54 **call intensity**

*F: intensité d'appel*

*S: intensidad de llamadas*

The number of call attempts at a given point, over a period of time, divided by the duration of the period.

11.56 **subscriber calling rate**

*F: taux d'appel d'un abonné*

*S: intensidad de llamadas de un abonado*

The call intensity of a subscriber line.

*Note 1* – It should not be used to mean traffic rate.

*Note 2* – It should be made clear whether the rate refers to the originating calling rate, or to the terminating calling rate or to the sum of both.

11.58 **subscriber traffic rate**

*F: trafic d'un abonné*

*S: intensidad de tráfico de un abonado*

The traffic intensity of a subscriber line.

*Note* – It should be made clear whether the rate refers to the originating traffic rate, or to the terminating traffic rate, or to the sum of both.

12.02 **dialling-time**

*F: durée de numérotation*

*S: tiempo de marcación*

Time interval between the reception of dial tone and the end of dialling of the calling subscriber.

12.04 **dial-tone delay**

*F: durée d'attente de tonalité*

*S: periodo de espera del tono de invitación a marcar*

Time interval between subscriber off hook and reception of dial tone.

12.06 **incoming response delay**

*F: durée de présélection*

*S: duración de la preselección*

The interval from the instant when an incoming seizure signal has arrived at the incoming side of the exchange to the instant when the exchange is ready to receive the signalling, or to the instant when a proceed-to-send signal is returned to the preceding exchange by the receiving exchange. This definition is only applicable in case of channel associated signalling.

12.08 **exchange call set-up delay**

*F: durée de sélection d'un commutateur*

*S: tiempo de establecimiento de la comunicación por una central*

The interval from the instant when the address information required for setting up a call is received at the incoming side of the exchange to the instant when the seizing signal or the corresponding address information is sent to the subsequent exchange, or to the instant when the ringing signal is sent to the appropriate user.

12.10 **through-connection delay**

*F: durée d'établissement d'un commutateur*

*S: tiempo de transferencia de la central*

The interval from the instant when the information required for setting-up a through-connection in an exchange is available for processing in the exchange, to the instant when the switching network through-connection is established between the incoming and outgoing circuits.

12.12 **post-dialling delay**

*F: attente après numérotation*

*S: periodo de espera después de marcar*

Time interval between the end of dialling by the subscriber and the reception by him of the appropriate tone or recorded announcement, or the abandon of the call without tone.

12.14 **answering delay**

*F: durée de sonnerie*

*S: demora de respuesta*

Time interval between the setting-up of an end-to-end connection between the calling and called stations, and the detection of an answer signal.

13.02 **telecommunications traffic (teletraffic)**

*F: trafic de télécommunication (télétrafic)*

*S: tráfico de telecomunicación (teletráfico)*

A flow of attempts, calls and messages.

13.04 **poisson traffic**

*F: trafic poissonnien*

*S: tráfico poissoniano*

A traffic that has a Poisson distribution of arrivals.

13.06 **pure chance traffic**

*F: trafic de pur hasard*

*S: tráfico puramente al azar*

A Poisson traffic which has a negative exponential distribution of holding time.

13.08 **peakedness factor**

*F: facteur d'irrégularité*

*S: factor de irregularidad*

The ratio of variance to mean of a traffic.

*Note* – The variance and the mean refer to the number of resources that would be occupied if this traffic was offered to an infinitely large pool of resources.

13.10 **smooth traffic**

*F: trafic régularisé*

*S: tráfico con distribución uniforme*

A traffic that has a peakedness factor less than one.

13.12 **peaked traffic**

*F: trafic survariant*

*S: tráfico con distribución en pico*

A traffic that has a peakedness factor greater than one.

13.14 **traffic offered**

*F: trafic offert*

*S: tráfico ofrecido*

The traffic that would be served by a pool of resources (assumed to be fully operative) sufficiently large to serve that traffic without limitation by the finite size of that pool.

Its usage is as a calculating quantity similar to a traffic intensity.

13.16 **traffic carried (intensity)**

*F: trafic écoulé (intensité)*

*S: tráfico cursado (intensidad)*

The traffic carried by a pool of resources over a given interval of time is equal to the average number of simultaneously busy resources. Traffic carried calculated in this way is expressed in Erlangs.

13.18 **overflow traffic**

*F: trafic de débordement*

*S: tráfico de desbordamiento*

That part of the traffic offered to a pool of resources which is not carried by it, but is offered to additional resources provided to handle such traffic.

13.20 **lost traffic**

*F: trafic perdu*

*S: tráfico perdido*

That part of the traffic offered to a pool of resources which is not carried and has no additional resource provided to handle such traffic.

13.22 **traffic volume**

*F: volume de trafic*

*S: volumen de tráfico*

The traffic carried by a pool of resources over a given interval, multiplied by the duration of the interval. The traffic volume is therefore equal to the sum of the durations of the occupations of the resources. It may be expressed in (for example) Erlang-hours.

13.26 **Erlang**

*F: erlang*

*S: erlang*

The unit of carried traffic intensity, as defined by § 13.16.

13.27 **destination**

*F: destination*

*S: destino*

The location of the called station. This may be specified to whatever accuracy is necessary; in international working the area or country code is usually sufficient.

13.28 **traffic matrix**

*F: matrice de trafic*

*S: matriz de tráfico*

A matrix of which the element at the intersection of row *i* and column *j* gives the traffic which originates at point *i* and is destined for point *j*. The points *i* and *j* may typically be switching centers in a network or the incoming and outgoing circuit groups of a switching center.

*Note* – Additional traffic generated by the normal operation of the system in setting up and controlling the establishment of the calls needs to be taken into account in any design process using this matrix.

13.30 **traffic relation (traffic stream; traffic item; parcel of traffic; point-to-point traffic)**

*F: flux de trafic (trafic point à point, courant de trafic)*

*S: relación de tráfico (corriente de tráfico, elemento de tráfico, lote de tráfico, tráfico de punto a punto)*

The traffic originating at a particular source and intended for a particular destination.

13.32 **equivalent random traffic intensity**

*F: intensité de trafic équivalent*

*S: intensidad de tráfico aleatorio equivalente*

The theoretical pure chance traffic intensity that, when offered to a number of theoretical circuits (equivalent random circuits), produces an overflow traffic with a mean and variance equal to that of a given offered traffic. The equivalent random concept permits traffic theories that do not explicitely recognize peakedness to be used in peakedness engineering (see equivalent random circuit group).

14.02 **unidirectional**

*F: unidirectionnel*

*S: unidireccional*

A qualification which implies that the transmission of information always occurs in one direction.

14.04 **bidirectional**

*F: bidirectionnel*

*S: bidireccional*

A qualification which implies that the transmission of information occurs in both directions.

14.06 **one way**

*F: à sans unique*

*S: en un solo sentido*

A qualification applying to traffic or circuits which implies that the call set-up always occurs in one direction.

14.08 **both way**

*F: à double sens*

*S: en ambos sentidos*

A qualification applying to traffic or circuits which implies that the call set-up occurs in both directions.

*Note* – The amount of the traffic flowing in the two directions are not necessarily equal either in the short term or in the long term.

14.10 **channel**

*F: voie (de communication)*

*S: canal (de transmisión)*

A means of unidirectional communication.

14.12 **pair of complementary channels**

*F: paire de voies complémentaires*

*S: par de canales complementarios*

Two channels, one in each direction, which provide a bidirectional communication.

14.14 **trunk circuit**

*F: circuit*

*S: circuito (entre centrales)*

A pair of complementary channels with associated equipments terminating in two switching centres.

It is said to be a national (international) circuit if it connects exchanges in the same (different) countries.

*Note* – Where there is no ambiguity the prefix "trunk" may be omitted.

14.18 **circuit subgroup**

*F: sous-faisceaux*

*S: subhaz de circuitos*

A number of circuits with similar characteristics (e.g. type of signalling, type of path transmission, etc.).

It is not engineered as a unit, but as a part of a circuit group. Circuit subgroups are provided for reasons of service, protection, equipment limitation, maintenance, etc.

14.20 **circuit group**

*F: faisceau (de circuits)*

*S: haz de circuitos*

A group of circuits which are traffic-engineered as a unit.

14.22 **first choice circuit group**

*F: faisceau de premier choix*

*S: haz de circuitos de primera elección*

With respect to a particular traffic stream, the circuit group to which this stream is first offered.

14.24 **high usage circuit group**

*F: faisceau débordant*

*S: haz de circuitos de gran utilización*

A circuit group that is traffic engineered to overflow to one or more other circuit groups: that is, a circuit group which is deliberately sized so that without these (i.e. overflow routes) it would offer a level of congestion considered unacceptable.

14.26 **final circuit group**

*F: faisceau final*

*S: haz final de circuitos*

A circuit-group which receives overflow traffic and from which there is no possible overflow.

It may also carry first choice parcels of traffic, for which it is said to be fully provided.

14.28 **only route circuit group**

*F: faisceau d'acheminement unique*

*S: haz de circuitos de una ruta única*

A circuit group which is the one and only route for all the parcels of traffic it carries.

It is said to be fully provided for each of these parcels of traffic.

14.30 **fully provided circuit group**

*F: faisceau totalement fourni*

*S: haz de circuitos totalmente provisto*

With respect to a particular parcel of traffic, a circuit group which is the first choice circuit group for this traffic and which is not traffic engineered as a high usage group.

14.32 **last choice circuit group**

*F: faisceau de dernier choix*

*S: haz de circuitos de última elección*

With respect to a particular traffic stream, a circuit group from which there is no possibility of overflow.

14.34 **equivalent random circuit group**

*F: faisceau équivalent*

*S: haz de circuitos aleatorios equivalente*

A number of theoretical circuits used in conjunction with an equivalent random traffic intensity to permit traffic theories that do not explicitly recognize peakedness to be used in peakedness engineering (see equivalent random traffic).

15.02 **route**

*F: voie d'acheminement*

*S: ruta*

A set of circuits or interconnected circuits from one reference point to another such that the routing of any call over this set is wholly controlled from the first-named reference point.

*Note* – The set need not define a single circuit-group, though it frequently does.

15.03 **routing**

*F: acheminement*

*S: encaminamiento*

The particular route or sequence of routes which is used to establish a path for a call.

15.04 **alternative (alternate) route**

*F: voie d'acheminement détourné*

*S: ruta alternativa*

A second, or subsequent choice route between two reference points usually consisting of two or more circuit groups in tandem.

15.06 **network cluster**

*F: faisceau de faisceaux*

*S: agrupación de haces*

A final circuit group and all the high usage circuit groups which have at least one terminus in common with it and for which the final circuit group is in the last choice route.

15.10 **traffic routing**

*F: acheminement de trafic*

*S: encaminamiento de tráfico*

The selection of a route or routes, for a given traffic stream; this term is applicable to the selection of routes by switching systems or operators, or to the planning of routes.

15.12 **busy hour**

*F: heure chargée*

*S: hora cargada*

The busy hour refers to the traffic volume or number of call attempts, and is that continuous 1-hour period lying wholly in the time interval concerned for which this quantity (i.e. traffic volume or call attempts) is greatest.

15.14 **peak busy hour (bouncing busy hour; post selected busy hour)**

*F: heure de pointe*

*S: hora punta*

The busy hour each day; it is usually not the same over a number of days.

15.16 **time consistent busy hour (mean busy hour)**

*F: heure chargée moyenne*

*S: hora cargada media*

The 1-hour period starting at the same time each day for which the average traffic volume or call-attempt count of the exchange or resource group concerned is greatest over the days under consideration.

15.18 **day to busy-hour ratio**

*F: rapport du trafic journalier au trafic à l'heure chargée*

*S: relación del tráfico diario al tráfico en la hora cargada*

The ratio of the 24-hour day traffic volume to the busy hour traffic volume.

*Note* – Busy-hour to day ratio is also used.

15.20 **effective traffic**

*F: trafic efficace*

*S: tráfico eficaz*

The traffic intensity corresponding only to the conversational portion of successful calls.

15.22 **grade of service**

*F: qualité d'écoulement du trafic*

*S: grado de servicio*

A number of traffic engineering parameters used to provide a measure of adequacy of plant under specified conditions; these grade of service parameters may be expressed as probability of loss, probability of delay, etc.

The numerical values assigned to grade of service parameters are called grade of service standards.

The achieved values of grade service parameters under actual conditions are called grade of service performances.

*Note* – When there is no likelihood of ambiguity, the term grade of service may be used as an abbreviation for the term grade of service performance.

15.24 **quality of service**

*F: qualité de service*

*S: calidad de servicio*

A measure of service provided to the subscriber. The characteristics of this measure must be declared when specifying a quality of service, and may include such characteristics as transmission quality, faults, congestion, delays, etc.

15.26 **originating traffic**

*F: trafic de départ*

*S: tráfico de origen*

Traffic generated by sources located within the network considered, whatever its destination.

15.28 **terminating traffic**

*F: trafic d'arrivée*

*S: tráfico de destino*

Traffic destined for sinks located within the network considered, whatever its origin.

15.30 **internal traffic**

*F: trafic interne*

*S: tráfico interno*

Traffic originating and terminating within the network considered.

15.32 **incoming traffic**

*F: trafic entrant*

*S: tráfico entrante*

Traffic entering the network considered, generated by sources outside it, whatever its destination.

15.34 **outgoing traffic**

*F: trafic sortant*

*S: tráfico saliente*

Traffic leaving the network considered, destined for sinks located outside it, whatever its origin.

15.36 **transit traffic**

*F: trafic de transit*

*S: tráfico de tránsito*

Traffic passing through the network considered, generated by sources outside it and destined for sinks outside it.

15.44 **traffic load imbalance**

*F: déséquilibre de trafic*

*S: desequilibrio de la carga de tráfico en las entradas*

Occurs in an exchange when the traffic load is unevenly distributed among similar units.

15.46 **traffic distribution imbalance**

*F: déséquilibre interne de trafic*

*S: desequilibrio de la distribución interna de tráfico*

Occurs in an exchange when the traffic flow of one incoming unit is unevenly distributed among all the outgoing units.

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# PART III

# SUPPLEMENTS TO THE SERIES E RECOMMENDATIONS RELATING TO TELEPHONE NETWORK MANAGEMENT AND TRAFFIC ENGINEERING

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# TABLE OF THE ERLANG FORMULA

## Table of the Erlang loss formula

## (Erlang No. 1 formula, also called Erlang B formula)

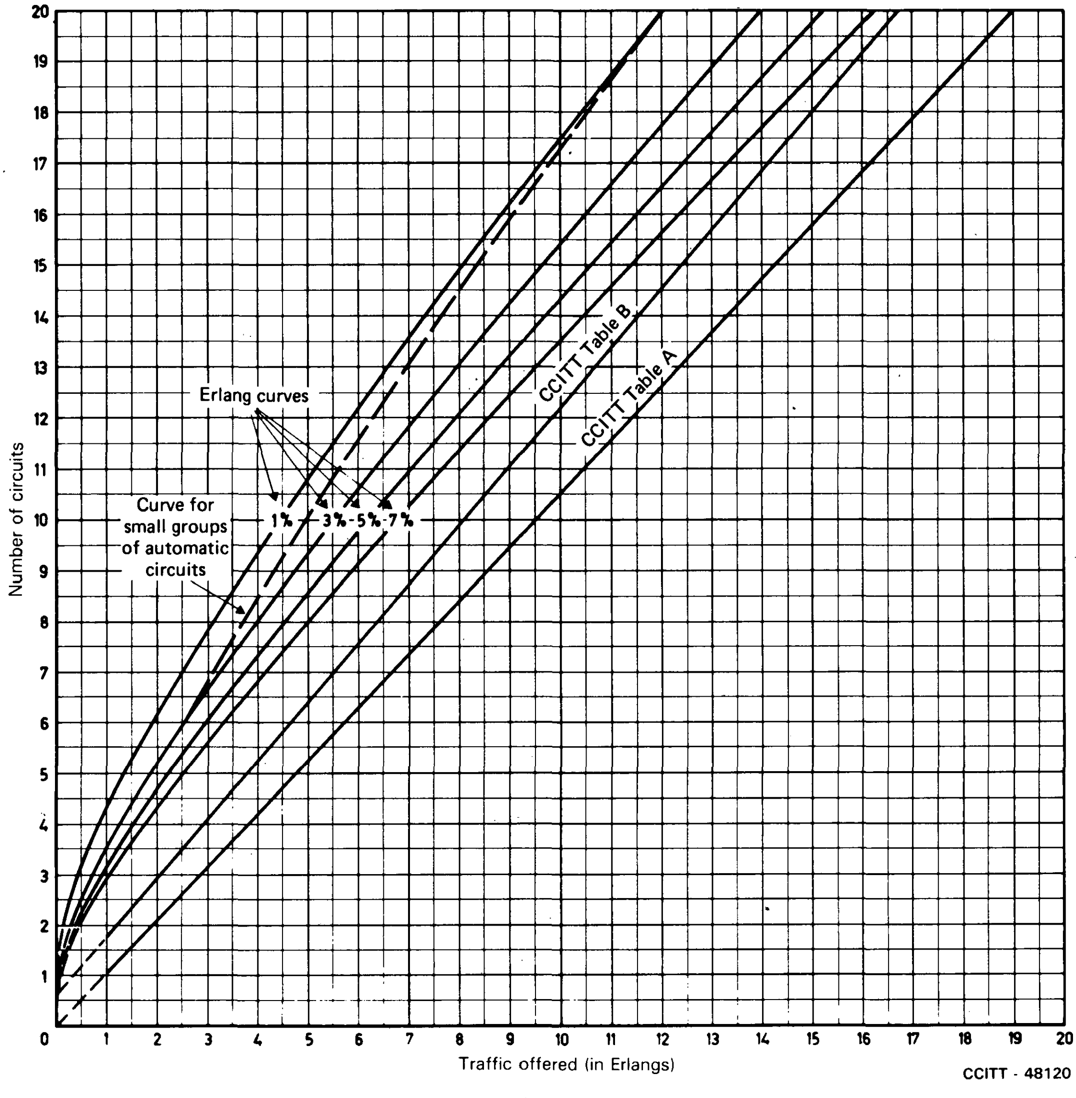
Loss probabilities: 1%, 3%, 5%, 7%.

Let $p$ = the loss probability
$y$ = the traffic offered (in Erlangs)
$n$ = the number of circuits

Formula: $$E_{1,n}(y) = p = \frac{\frac{y^n}{n!}}{1 + \frac{y}{1} + \frac{y^2}{2!} + \ldots + \frac{y^n}{n!}}$$

| $n$ | $p = 1\%$ | $p = 3\%$ | $p = 5\%$ | $p = 7\%$ | $n$ | $p = 1\%$ | $p = 3\%$ | $p = 5\%$ | $p = 7\%$ |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.01 | 0.03 | 0.05 | 0.08 | 51 | 38.80 | 42.89 | 45.53 | 47.72 |
| 2 | 0.15 | 0.28 | 0.38 | 0.47 | 52 | 39.70 | 43.85 | 46.53 | 48.76 |
| 3 | 0.46 | 0.72 | 0.90 | 1.06 | 53 | 40.60 | 44.81 | 47.53 | 49.79 |
| 4 | 0.87 | 1.26 | 1.53 | 1.75 | 54 | 41.50 | 45.78 | 48.54 | 50.83 |
| 5 | 1.36 | 1.88 | 2.22 | 2.50 | 55 | 42.41 | 46.74 | 49.54 | 51.86 |
| 6 | 1.91 | 2.54 | 2.96 | 3.30 | 56 | 43.31 | 47.70 | 50.54 | 52.90 |
| 7 | 2.50 | 3.25 | 3.74 | 4.14 | 57 | 44.22 | 48.67 | 51.55 | 53.94 |
| 8 | 3.13 | 3.99 | 4.54 | 5.00 | 58 | 45.13 | 49.63 | 52.55 | 54.98 |
| 9 | 3.78 | 4.75 | 5.37 | 5.88 | 59 | 46.04 | 50.60 | 53.56 | 56.02 |
| 10 | 4.46 | 5.53 | 6.22 | 6.78 | 60 | 46.95 | 51.57 | 54.57 | 57.06 |
| 11 | 5.16 | 6.33 | 7.08 | 7.69 | 61 | 47.86 | 52.54 | 55.57 | 58.10 |
| 12 | 5.88 | 7.14 | 7.95 | 8.61 | 62 | 48.77 | 53.51 | 56.58 | 59.14 |
| 13 | 6.61 | 7.97 | 8.84 | 9.54 | 63 | 49.69 | 54.48 | 57.59 | 60.18 |
| 14 | 7.35 | 8.80 | 9.73 | 10.48 | 64 | 50.60 | 55.45 | 58.60 | 61.22 |
| 15 | 8.11 | 9.65 | 10.63 | 11.43 | 65 | 51.52 | 56.42 | 59.61 | 62.27 |
| 16 | 8.88 | 10.51 | 11.54 | 12.39 | 66 | 52.44 | 57.39 | 60.62 | 63.31 |
| 17 | 9.65 | 11.37 | 12.46 | 13.35 | 67 | 53.35 | 58.37 | 61.63 | 64.35 |
| 18 | 10.44 | 12.24 | 13.39 | 14.32 | 68 | 54.27 | 59.34 | 62.64 | 65.40 |
| 19 | 11.23 | 13.11 | 14.31 | 15.29 | 69 | 55.19 | 60.32 | 63.65 | 66.44 |
| 20 | 12.03 | 14.00 | 15.25 | 16.27 | 70 | 56.11 | 61.29 | 64.67 | 67.49 |
| 21 | 12.84 | 14.89 | 16.19 | 17.25 | 71 | 57.03 | 62.27 | 65.68 | 68.53 |
| 22 | 13.65 | 15.78 | 17.13 | 18.24 | 72 | 57.96 | 63.24 | 66.69 | 69.58 |
| 23 | 14.47 | 16.68 | 18.08 | 19.23 | 73 | 58.88 | 64.22 | 67.71 | 70.62 |
| 24 | 15.29 | 17.58 | 19.03 | 20.22 | 74 | 59.80 | 65.20 | 68.72 | 71.67 |
| 25 | 16.13 | 18.48 | 19.99 | 21.21 | 75 | 60.73 | 66.18 | 69.74 | 72.72 |
| 26 | 16.96 | 19.39 | 20.94 | 22.21 | 76 | 61.65 | 67.16 | 70.75 | 73.77 |
| 27 | 17.80 | 20.31 | 21.90 | 23.21 | 77 | 62.58 | 68.14 | 71.77 | 74.81 |
| 28 | 18.64 | 21.22 | 22.87 | 24.22 | 78 | 63.51 | 69.12 | 72.79 | 75.86 |
| 29 | 19.49 | 22.14 | 23.83 | 25.22 | 79 | 64.43 | 70.10 | 73.80 | 76.91 |
| 30 | 20.34 | 23.06 | 24.80 | 26.23 | 80 | 65.36 | 71.08 | 74.82 | 77.96 |
| 31 | 21.19 | 23.99 | 25.77 | 27.24 | 81 | 66.29 | 72.06 | 75.84 | 79.01 |
| 32 | 22.05 | 24.91 | 26.75 | 28.25 | 82 | 67.22 | 73.04 | 76.86 | 80.06 |
| 33 | 22.91 | 25.84 | 27.72 | 29.26 | 83 | 68.15 | 74.02 | 77.87 | 81.11 |
| 34 | 23.77 | 26.78 | 28.70 | 30.28 | 84 | 69.08 | 75.01 | 78.89 | 82.16 |
| 35 | 24.64 | 27.71 | 29.68 | 31.29 | 85 | 70.02 | 75.99 | 79.91 | 83.21 |
| 36 | 25.51 | 28.65 | 30.66 | 32.31 | 86 | 70.95 | 76.97 | 80.93 | 84.26 |
| 37 | 26.38 | 29.59 | 31.64 | 33.33 | 87 | 71.88 | 77.96 | 81.95 | 85.31 |
| 38 | 27.25 | 30.53 | 32.62 | 34.35 | 88 | 72.81 | 78.94 | 82.97 | 86.36 |
| 39 | 28.13 | 31.47 | 33.61 | 35.37 | 89 | 73.75 | 79.93 | 83.99 | 87.41 |
| 40 | 29.01 | 32.41 | 34.60 | 36.40 | 90 | 74.68 | 80.91 | 85.01 | 88.46 |
| 41 | 29.89 | 33.36 | 35.58 | 37.42 | 91 | 75.62 | 81.90 | 86.04 | 89.52 |
| 42 | 30.77 | 34.30 | 36.57 | 38.45 | 92 | 76.56 | 82.89 | 87.06 | 90.57 |
| 43 | 31.66 | 35.25 | 37.57 | 39.47 | 93 | 77.49 | 83.87 | 88.08 | 91.62 |
| 44 | 32.54 | 36.20 | 38.56 | 40.50 | 94 | 78.43 | 84.86 | 89.10 | 92.67 |
| 45 | 33.43 | 37.16 | 39.55 | 41.53 | 95 | 79.37 | 85.85 | 90.12 | 93.73 |
| 46 | 34.32 | 38.11 | 40.54 | 42.56 | 96 | 80.31 | 86.84 | 91.15 | 94.78 |
| 47 | 35.22 | 39.06 | 41.54 | 43.59 | 97 | 81.24 | 87.83 | 92.17 | 95.83 |
| 48 | 36.11 | 40.02 | 42.54 | 44.62 | 98 | 82.18 | 88.82 | 93.19 | 96.89 |
| 49 | 37.00 | 40.98 | 43.53 | 45.65 | 99 | 83.12 | 89.80 | 94.22 | 97.94 |
| 50 | 37.90 | 41.93 | 44.53 | 46.69 | 100 | 84.06 | 90.79 | 95.24 | 98.99 |

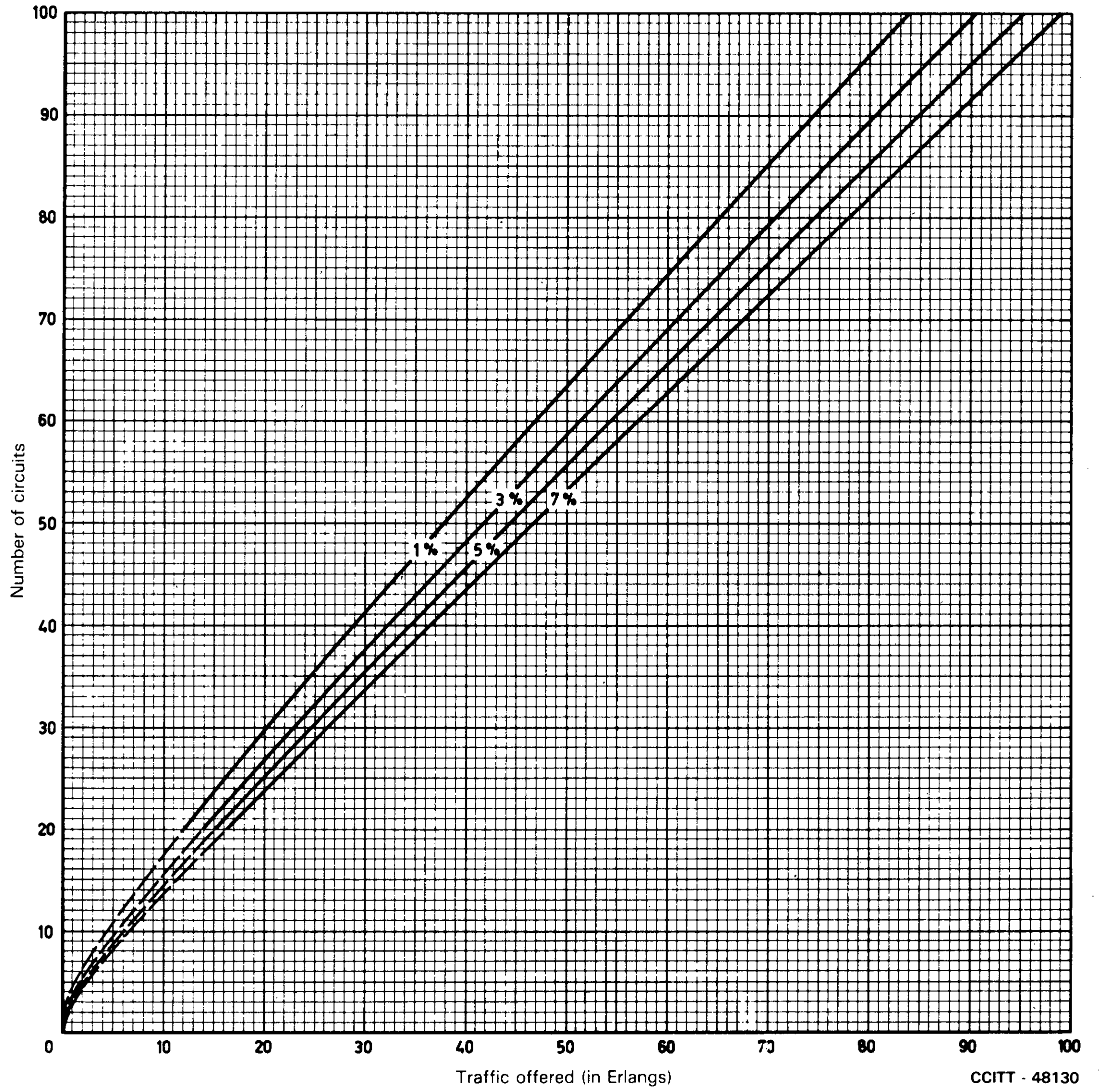
## CURVES SHOWING THE RELATION BETWEEN THE TRAFFIC OFFERED AND THE NUMBER OF CIRCUITS REQUIRED




Relation between the traffic (in Erlangs) offered and the number of circuits required in the case of:
- the curves A and B of Table 1/E.510;
- the Erlang formula ($p$ = 1 %, 3 %, 5 % and 7 %);
- the curve for small groups of automatic circuits (see Annex A to Recommendation E.520).

FIGURE 1

**Number of circuits between 1 and 20**




Relation between the traffic (in Erlangs) offered and the number of circuits required in the case of the Erlang formula for ($p$ = 1 %, 3 %, 5 % and 7 %).

FIGURE 2

**Number of circuits between 1 and 100**

## Supplement No. 3

### INFORMATION ON TRAFFIC ROUTING IN THE INTERNATIONAL NETWORK

(Results from study in 1973-1976 of Question 11/XIII concerning actual connections of international telephone calls

(For the text of this Supplement, see Supplement No. 7, Volume II.2, *Orange Book*, Geneva, 1976)

**Supplement No. 4**

## USE OF COMPUTERS FOR NETWORK PLANNING AND CIRCUIT GROUP DIMENSIONING

(For the text of this Supplement, see Supplement No. 8, Volume II.2, *Orange Book*, Geneva, 1976)

**Supplement No. 5**

## TELETRAFFIC IMPLICATIONS FOR INTERNATIONAL SWITCHING AND OPERATIONAL PROCEDURES RESULTING FROM A FAILURE OF A TRANSMISSION FACILITY

**1** Very considerable changes have occurred in the international network over the past decade. These changes have arisen mainly from:

- the growth in the number of long-distance routes;
- the growth in the number of circuits forming individual long-distance routes;
- the world-wide introduction of international automatic operation;
- technological developments associated with all aspects of the international network: switching unit design, transmission facility design, and routing and operational strategies;
- the integration into the international automatic service of the more isolated geographical areas and of centres having low-capacity international switching units.

**2** The resultant multiplicity of circumstances and situations arising within the international network is now such that it is no longer possible to specify one single criterion for initiating corrective action to counter the loss of a transmission facility. Indeed, the failure of the whole, or part, of a transmission facility may manifest itself in a different manner to each of several Administrations affected by the failure.

**3** Among the many aspects of international switching and operational procedures which can influence the degree of curtailment of service arising from a transmission-facility failure, i.e. which can reduce the ability of part of the international network to carry its designed traffic load successfully, the following are specifically stressed (their order has no particular significance):

- the introduction of fully automatic international operation, which means that the control of the network, formerly completely operator-controlled, now depends directly on subscribers' habits;
- the number of routes that could be affected by failure and their proportion of the total routes on the switching unit to which they are directly connected: the range can be from one whole route to a few circuits in each of many routes, depending on the method of allocating circuits to transmission facilities;
- the influence of any route, for which no alternative transmission facility exists, on the performance of the international switching unit to which it is connected;
- the effect on the grade of service of the switching unit itself due to the loss of a complete route or routes, or parts of several routes, directly connected to it;
- the methods of limiting the effect of failure on service by action within the switching unit or at preceding international or national switching unit, e.g. by code blocking or recorded announcements;
- the cause of the failure, and thus the possible restoration time, relative to the 24-hour traffic profile;
- the effect of a failure on overflow and automatic alternative routing strategies;

- the use of diversity of international switching units;
- the use of diversity of international transmission facilities.

4 Attention is also drawn to four major factors of maintaining continuity of service:
- reliability,
- diversity,
- network management, and
- any redundancy specifically provided to allow restoration of service.

5 Clearly, no practical transmission facility provided will give 100 per cent reliability, so it is inevitable that the other three factors will be involved to varying degrees in maintaining service. The interaction of these four factors will depend largely on the emphasis placed upon each of them by each Administration, thus reinforcing the view that the degree of corrective action that can be taken will depend considerably upon the investment policy (in materials and equipment) and forward-planning objectives of individual Administrations.

6 With respect to diversity, it is recommended that Administrations give consideration to the provision of an adequate number of paths for a particular route, with an adequate level of independence between the paths. Such independence could reduce the effect of a breakdown or other adverse event by confining it, as far as possible, to only one of the paths used by that route.

7 For the further assistance of Administrations in their study of those teletraffic aspects of international switching and operational procedure which influence the degree of curtailment of service and which arise from a transmission facility failure, these factors are included in Question 23/II related to continuity of service, accepted for study during the 1985-1988 Study Period.

**Supplement No. 6**

## NETWORK MANAGEMENT SIGNALS IN SIGNALLING SYSTEM No. 6

### 1 Introduction

CCITT Signalling System No. 6 (S.S. No. 6) can act as a transport mechanism for the transfer of network management signals (NMS). The signals can be transferred between S.S. No. 6 equipped exchanges where agreement on a network management band assignment has been made by Administrations.

This supplement details the use of S.S. No. 6 for the transfer of NMS and gives guidance on typical applications of such signals. Such arrangements would have to be agreed between Administrations on a bilateral or multilateral basis.

### 2 General considerations

The information contained in the NMS need not be limited to S.S. No. 6 circuits or to two S.S. No. 6 equipped international switching centres (ISCs). For example, if multiple ISCs exist in a country it may be desirable to gather this data separately from each ISC at a single location, say a network management centre, before transferring it to other countries via the S.S. No. 6 link. This is particularly attractive if some of the ISCs in a country have S.S. No. 6 capability. In this case NMS may be derived from a range of electrical signals and some interfacing with the S.S. No. 6 system will be required. Furthermore, as detailed below, some delay in transmitting and/or responding to NMS may be desirable. As the S.S. No. 6 links will not have the capability to affect the timing of such signals, this will have to be introduced externally to the system. The interfacing device could also perform this function.

Upon receipt of an NMS, Administrations could display the information in a network management centre and determine the need for manual control actions, or use the signals directly for the automatic control of traffic flow. If automatic control is adopted, then the network management centre should have the ability to ignore the reception of a signal and/or inhibit the transmission of a signal when deemed necessary. Details of control actions are contained in Recommendation E.411.

## 3 Signals to be transmitted

Three types of signals can be transmitted in the S.S. No. 6:

a) *Destination hard to reach NMS*: This information relates to the performance of traffic to a destination. A destination is said to be hard-to-reach (HTR) when the answer-bid-ratio (ABR) to the destination is abnormally low. A HTR code can be a country code, an area (or city) code or an exchange code.

b) *All circuits busy NMS*: This information relates to the availability of circuits. A signal should indicate when all circuits in a route or to a destination are busy, or (preferably) when the remaining idle circuits in a route (or to a destination) are less than a specified number, or when occupancy of a route has exceeded the desired threshold.

c) *switching centre congestion NMS*: This information relates to the switching congestion of an ISC.

## 4 Signal format

Each signal will consist of an initial signal unit (ISU) and one or two subsequent signal units (SSUs) depending on which type of signal is being transmitted. The format of each unit is as shown in Table 1.

TABLE 1

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ISU | Bits: | 11101<br>(1-5)<br>Header code | 0000<br>(6-9)<br>ISU of MUM | XXXXXXX<br>(10-16)<br>Band number | XXXX<br>(17-20)<br>Management information | XXXXXXXX<br>(21-28)<br>Check | | |
| ISU | Bits: | 17-20, Management information<br>0000 Destination hard-to-reach NMS<br>0001 All circuits busy NMS<br>0010 Switching centre congestion NMS<br>0011-1110 Spare<br>1111 Reset band acknowledgement | | | | | | |
| SSU | First SSU<br>Bits: | 00<br>(1-2)<br>Header code | 01<br>(3-4)<br>Length | XXXX<br>(5-8)<br>ISC code | XXXX<br>(9-12)<br>Reason code | XXXX<br>(13-16)<br>D1 | XXXX<br>(17-20)<br>D2 | XXXXXXXX<br>(21-28)<br>Check |
| SSU | Second SSU<br>Bits: | 00<br>(1-2)<br>Header code | 01<br>(3-4)<br>Length | XXXX<br>(5-8)<br>D3 | XXXX<br>(9-12)<br>D4 | XXXX<br>(13-16)<br>D5 | XXXX<br>(17-20)<br>D6 | XXXXXXXX<br>(21-28)<br>Check |

*Note 1* – First SSU bits 5-8 ISC code: this code identifies the ISC (or group of ISCs) within the transmitting Administration to which the network management signal applies. Up to 16 ISCs can be identified.

*Note 2* – First SSU bits 9-12 reason code: this gives the capacity of up to 16 levels of information for each signal and is described in more detail in § 5.

*Note 3* – For switching centre congestion information only the first SSU is required.

*Note 4* – For destination hard-to-reach and all circuits busy information, either one or two SSUs can be used. This will depend on the number of digits required to identify each HTR code or destination busy; bits 13-20 in the first SSU give two digits D1 and D2, while bits 5-20 in the second SSU give another four digits D3 to D6.

*Note 5* – First SSU bits 3-4 length indicator: this will be set at 00 when only one SSU is used and at "01" when two SSUs are required.

## 5 Typical applications

The number of reason codes to be used for each type of signal, and the particular application to which each signal will be put, will be set by bilateral or multilateral agreement. The following gives descriptions of applications of the system which may be developed:

### 5.1 *Destination hard-to-reach NMS*

The reason code given in the first SSU bits (9-12)

0000: ABR below "arbitrary" threshold.

0001 [1]: ABR below "high" threshold.

0010 [1]: ABR below "medium" threshold.

0011 [1]: ABR below "low" threshold.

0100-1111 [1]: Spare.

This network management signal gives scope for identifying problem areas in the international network or selective parts of a national network.

The signal can be regarded as the measure of a poor performance by the originating country to the destination or, alternatively, of all traffic into part of that country's national network.

The poor performance may be as a result of very high congestion and/or poor answer-seizure-ratio on the routes to the destination. In particular, if the answer-seizure-ratio becomes poor, then the circuit group occupancy may also fall and a circuit group threshold alarm may not be initiated. The meaning of the signals could be as follows:

0000 would indicate that all traffic to the destination should cease for the prearranged period (for example 30 s).

0001 would indicate that some transit traffic could be accepted (for example 50% with 50% being code blocked or rerouted via another centre).

This signal would be also repeated at slow intervals (30 s).

0010 would indicate that the service is worse than that of case "0001" and, for example, that only 10% of the bids could be accepted and 90% would be code blocked or rerouted. This signal would be also repeated at slow intervals (30 s).

0011 would indicate that the service was worse than that of case "0010" and, for example, that 100% code blocking of all traffic via this centre should occur. This would be updated, every 2-3 minutes.

The centre receiving this signal would take appropriate action such as diverting the traffic to a recording or using another centre which can successfully complete the calls.

The hard to reach destination is identified by digits D1 to D6 using the full international number. As a minimum, the destination country code must be given and additional digits may be included to indicate congestion within a country. If no trunk code is given, it is implied that the problem relates to the whole of the national network. Special hexadecimal digits have the following meaning:

A [1]: digit 0 in the international number.

B [1]: code 11.

C [1]: code 12.

F [1]: end of number, no further analysis is required. This is to be used where the destination code is defined in fewer than 6 digits.

*Examples*

| D1 | D2 | D3 | D4 | D5 | D6 | Destination |
|---|---|---|---|---|---|---|
| 6 | 1 | 2 | 6 | 3 | A | Sydney, Australia +61 2 630XXXX |
| 1 | 2 | 1 | 2 | 9 | 3 | New York USA +1 212 93XXXXX |
| 7 | C | 3 | A | 3 | F | Moscow USSR code 12, 903 |
| 9 | 1 | 2 | B | F | | Bombay, India, Code 11 operators |
| 8 | 5 | 2 | F | | | Hong Kong national network +852 |

[1] Transmission and/or reception of these signals to be agreed bilaterally.

5.2 *All circuits busy NMS*

The reason code given in the first SSU bits (0-12):

0000: all circuits busy threshold exceeded.

0001 [2]: low levels of congestion.

0010 [2]: medium congestion.

0011 [2]: high congestion.

0100-1111 [2]: spare.

The signal "0000" is generated when a present threshold of circuit occupancy has been exceeded. This could occur, for example, when all direct circuits to the destination are either busy, or, say 95% occupied. Alternatively, the transit centre may generate the signal when congestion is occurring on direct and alternatively routed circuits.

By generating the signal after the threshold has been exceeded on the direct circuits, priority can be given at the transit exchange to locally originated traffic. When this signal is received, it should start a timer and during the timing period, should route traffic via another centre to the wanted destination. If a further signal is received during this timing period, the timer should be reset. When the timer elapses, all traffic controls on this destination should be restored to normal. For example:

a) When all circuits busy is detected, a signal "0000 – stop all traffic signal" is sent. This should start a timer at the receiving end (for instance 30 s).

b) If the transit centre decides that it can handle some transit traffic during the intervening period between transmission of NMS, then it should send selectively to those centres, for which it acts as first choice route to a destination, the second signal "0001 – low level of congestion – block traffic for the next *X* seconds".

c) To the larger centres, which already have direct circuits and may be overflowing via this transit centre, the third signal "0010 – medium level of congestion – block traffic for the next *Y* seconds" (where *Y* is greater than *X*) is sent.

d) The fourth signal "0011 – high level of congestion – block traffic for the next *Z* seconds" (where *Z* is greater than *X*, *Y* or 30 s) would be generated when it can be determined that a transmission failure or very heavy traffic levels will prevent any calls from being switched for a considerable period.

Thus if congestion reoccurred, it would be necessary at time $t = X-1$ s, $Y-1$ s, $Z-1$ s, to send a further signal "0000: All circuits busy – stop traffic" to reset the timers at the receiving end, and to again inhibit traffic for a period as requested by the sending end.

In summary the all-circuits-busy signals mean:

0000: all traffic should stop for up to 30 s.

0001: some transit traffic will be able to be handled shortly (for example 6 to 12 s).

0010: transit traffic will be able to be handled later (for example 12 to 24 s).

0011: lengthy delays exist in handling transit traffic (for example delay calls 1-2 minutes).

Again the digits D1 to D6 are used to identify the destination associated with the circuit group which is experiencing congestion.

5.3 *Switching centre congestion NMS*

This information is coded compactly in one SSU in all calls. Reason codes are as follows:

0000 [2]: moderate congestion – level 1.

0001 [2]: serious congestion – level 2.

0010 [2]: unable to process calls – level 3.

0100-1111 [2]: spare.

---

[2] Transmission and/or reception of these signals to be agreed bilaterally.

The function of this signal is to warn other centres that this particular ISC (as identified by bits 5-8 of the SSU) is experiencing overload. All ISCs, on receiving this NMS should take immediate steps to restrict traffic to this exchange.

The degree of restriction would depend on the level of signal received. For example, "0000 – moderate congestion – level 1" may require the restriction of transit traffic, whereas "0010 – unable to process calls – level 3" would make it necessary to inhibit all traffic (transit and direct routed).

The signals should normally escalate through each congestion level, and should not, for example, pass directly from congestion level 1 to congestion level 3, and vice versa. This will ensure smooth operation when these signals are used to control traffic at the receiving location.

Unless a technical fault is occurring at the exchange which is generating this signal, the signal may be due to heavy calling to a hard-to-reach destination(s).

Once the initial restriction of traffic has been implemented, the network manager should try to ascertain if the cause of the overload is traffic dependent, and, if it is, then take appropriate measures to isolate the offending destination(s).

## 6 Generation of S.S. No. 6 network management signals

Network management signals relating to switching centre congestion should, as a high priority action within the exchange, be generated and presented to S.S. No. 6 signalling links for transmission.

Other signals, such as all circuits busy, should be transmitted as soon as practicable after the detection of either congestion or occupancy exceeding the desired threshold. A similar condition applies to the destination HTR NMS for hard-to-reach destinations.

If the condition still persists, the signals should be retransmitted at regular intervals (e.g. 30 s). In this way, no acknowledgement signal is required to be transmitted by the receiving end. If the signal is not retransmitted after the specified time interval (30 s) has elapsed, the receving ISC will also time-out and will remove any control actions that resulted from the receipt of such a signal.

## 7 Distribution of signals

As each ISC can generate network management signals for all traffic through its exchange, selective analysis should be made before any NMS is distributed to other centres.

The following considerations should be made:

a) All network management signals are a request for action by the preceding ISC. If the preceding ISC cannot react to such a signal, then the signal should not normally be sent.

b) Unless traffic to a hard-to-reach destination has arrived from a previous exchange in the last few minutes, then no "destination HTR" network management signal need be sent to that exchange.

c) "All-circuit-busy" signals may only be sent to those centres which have previously requested the information. This then eliminates unnecessary signals, especially if another ISC does not use this centre for transmitting to the destination.

d) The switching centre congestion signals should be broadcast simultaneously to all centres so that a general reduction in traffic loading on the ISC can take place until the true cause has been identified and the situation remedied.

e) All these network management signals are used to highlight exceptional conditions. Under "normal" conditions, no signals are sent.

The use of timers at the point of generating the signal and at the receipt of the signals minimizes the load on the data link and the ISCs that are sending and receiving signals.

## 8 Reception of S.S. No. 6 network management signals

Although the priority of network management signals in S.S. No. 6 is lower than telephony signals, the signals should be acted upon as soon as possible.

The NMS indicating switching centre congestion should be treated with the highest priority. An urgent indication should be brought to the attention of international network management centre (INMC) staff so that steps can be taken to limit traffic overall into this exchange. (Refer also to Recommendation Q.297).

# GUIDE FOR EVALUATING AND IMPLEMENTING ALTERNATE ROUTING NETWORKS

A systematic procedure consisting of a number of distinct steps is used for the evaluation of alternate routing networks.

These steps are given in the flowchart of Annex A and are provided as guidance. Administrations may wish to expand, delete or change the order of these steps to meet circumstances.

The steps may be grouped into the following six processes:

- Identification of alternate route.
- Preliminary screening.
- Data gathering.
- Evaluation.
- Implementation.
- Monitoring.

## 1 Identification of alternate route

A terminal Administration selects an alternate route.

A tentative agreement is reached with the opposite terminal Administration to use the selected alternate route, and both terminal Administrations reach tentative agreement with the transit Administration to explore the use of its network as an alternate route.

If no tentative agreements are reached, another alternate route is selected or if none is available, the procedure is abandoned.

## 2 Preliminary screening

Using available data, the organizational elements of the terminal Administrations responsible for transmission, routing and call completion, analyse the feasibility of utilizing the alternate route.

If an objection is raised, another alternate route is selected or, if none is available, the procedure is abandoned.

## 3 Data gathering

A questionnaire is issued to all Administrations involved to obtain additional information before an evaluation is made of the proposed alternate route.

The questionnaire can include requests for transmission, routing, call completion rates, traffic profiles, circuit costs, and transit charges.

If there is no response to the questionnaire or if the information provided indicates that the alternate route is unsuitable, another alternate route is selected or, if none is available, the procedure is abandoned.

## 4 Evaluation

The alternate routing network is dimensioned according to Recommendation E.522.

If additional circuits are required on the alternate route, and the required increment exceeds the available capacity, another alternate route is selected. If no other alternate route is available Administrations may choose to retain the selected alternate route and accept a cost disadvantage.

## 5 Implementation

Final negotiations are carried out and approval of all Administrations involved in the alternate route network is sought.

The negotiations would include the reporting procedure and responsibility for recording traffic overflowing to the alternate route.

If final agreement cannot be reached, another alternate route is selected or, if none is available, the procedure is abandoned.

## 6 Monitoring

Traffic volumes and performance data for the alternate route are recorded and exchanged at regular intervals.

# ANNEX A

(to Supplement No. 7)

**Flowchart of evaluation and implementation procedure for alternate routing networks**

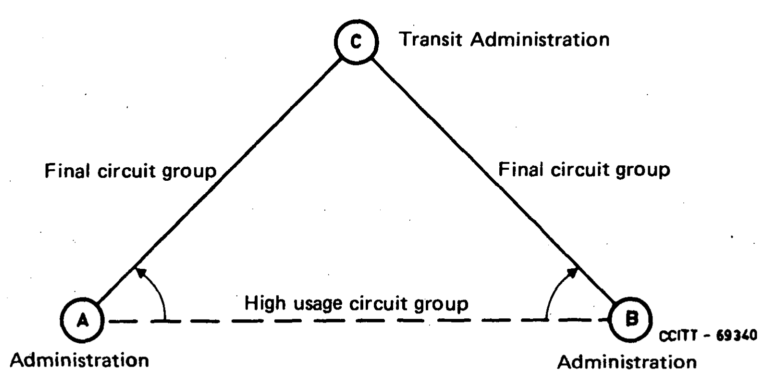
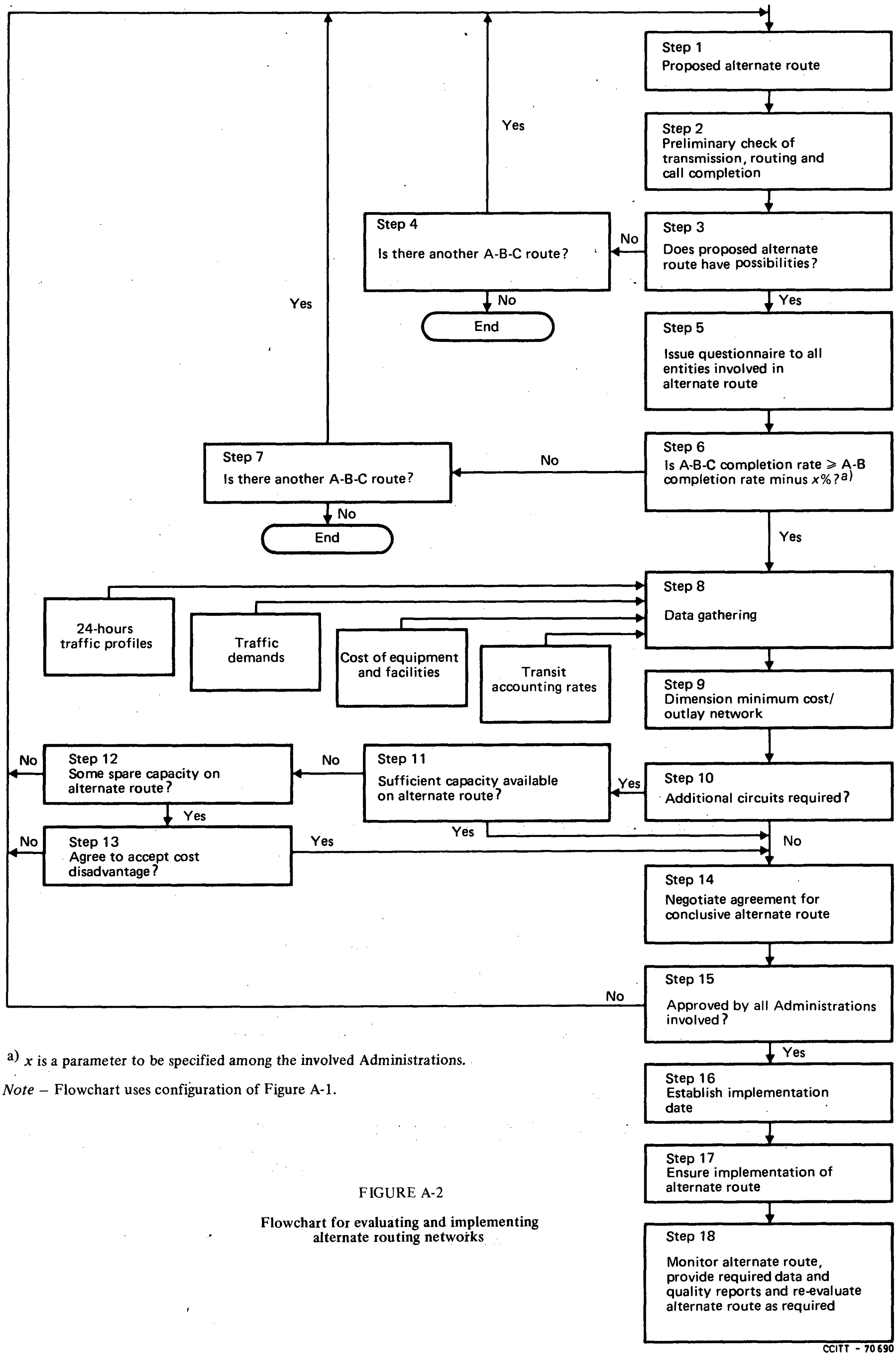



FIGURE A-1

**Alternate routing network**




a) $x$ is a parameter to be specified among the involved Administrations.

*Note* – Flowchart uses configuration of Figure A-1.

FIGURE A-2

Flowchart for evaluating and implementing alternate routing networks

**Supplement No. 8**

# NON-VOICE TRAFFIC ON THE TELEPHONE NETWORK

## 1 Non-voice call characteristics

The present telephone network is capable of providing a bearer service for a range of non-voice service applications. These include:

data (analogue coded),

facsimile,

phototelegraphy,

VF telegraphy.

VF telegraphy is not carried on the public switched telephone network (PSTN). Furthermore, phototelegraphy calls use telephone circuits removed from normal service, as set out in Recommendation E.320. For calls on the PSTN therefore, only data and facsimile services are considered below.

Special considerations may need to be given to the suitability of the telephone network to carry these services because of their particular characteristics which differ from those of voice traffic in the following ways:

a) The transmission of these services is characterized by a continuous power loading, compared to the syllabic bursts found in speech.

b) Non-voice traffic often has a 24-hour traffic profile different from voice traffic, but similar to other non-voice services such as telex.

c) Call holding times are often significantly shorter than voice traffic.

Further information on points b) and c), which was collected in the 1980-1984 Study Period, is contained in Annex A.

## 2 Considerations due to continuous power loading

### 2.1 *Signalling considerations*

Non-voice service signals can interfere with telephone circuit signalling systems and vice versa.

Data or facsimile signals can interfere with signalling systems which use in-band line signalling such as Signalling Systems No. 4, No. 5 and R1. Thus such non-voice calls should use the standardized systems set out in the Series V and T Recommendations since these are designed to prevent interference with the standard signalling systems, either by avoiding the particular signalling frequencies or by operating the guard circuit of the signalling receiver.

Despite the safeguards mentioned above, it may sometimes happen that the signalling receiver is momentarily operated by the carried service signal. In this case the splitting device in the signalling receiver will operate and cause a short discontinuity in the received service signal.

### 2.2 *Transmission considerations*

#### 2.2.1 *Interference to transmission systems*

If the proportion of non-voice calls is large, it can increase the overall power loading in a transmission assembly (group or supergroup). This can cause distortion in the group of signals and/or the operation of power limiters which can adversely affect other calls or services in the same transmission assembly.

In order to economize on the provision of international voice channels, some international transmission systems may be fitted with speech interpolation systems, such as TASI. Circuit gains are realized by exploiting the silent periods normally existing during speech conversations. Continuous non-voice service signals will cause the continuous operation of the speech detectors and give rise to permanent association of the telephone circuit to the transmission channel. This in turn increases the probability of noticeable speech clipping and in severe cases the occurrence of freeze-out where no channel is available. Thus the quality of speech on parallel voice calls can be affected, resulting in a need to reduce the gain advantage of the speech interpolation system.

Information on speech interpolation systems can be found in Supplement No. 2 of Fascicle VI.1.

### 2.2.2 *Interference by transmission systems*

It may be the case that ordinary speech channels do not provide an adequate transmission path for some types of non-voice service, resulting in an unacceptable error performance, or in the worst case not allowing any service at all.

Echo suppressors will not allow the transmission of duplex data unless the tone-disabling signal is first applied and immediately followed by the service signal.

Some types of transmission system do not support higher speed data transmission. In particular adaptive differential pulse code modulation (ADPCM) uses a 32 kbit/s coding technique for the speech channel and may not support higher data speeds, e.g. 9600 bit/s.

## 3 Means to overcome difficulties

If the transmission of non-voice services on the telephone network is found to cause problems due to the above issue, the Administrations concerned should take the following actions:

3.1 It should be established for each bilateral relationship what commercial and regulatory arrangements exist which recognize the need to provide for non-voice services within prescribed quality of service parameters.

3.2 If it is decided by the Administrations concerned that certain services must be supported then two approaches can be taken:

a) only transmission systems allowing reliable performance for non-voice services are used;

b) separate routings are established for the whole or part of the networks, where unreliable transmission would otherwise occur.

3.3 In case b) above, it is necessary to know when subscribers are initiating non-voice calls. There are three methods for achieving this:

i) The subscriber line is known to be one originating only non-voice calls, e.g. it is a facsimile terminal.

ii) The subscriber sends some form of service indication to the network, identifying a non-voice call request.

iii) The subscriber dials or selects a particular prefix before the international (or national) number requesting a non-voice service call.

If these indications are directly available at the exchange where the separate routing is selected then path selection need only combine this indication with the dialled digits. In other cases it is necessary for a suitable signalling system to be employed to carry this indication forward to the special selection point. This may be done using signalling systems including special call categories. In particular a call category "data call" is provided in Signalling Systems R2, No. 6 and No. 7, also No. 5 by bilateral agreement. The separate routing may be continued throughout the network using either "path of entry" indications at the exchanges concerned or the special call category signals within the signalling system. Such special arrangements for non-voice calls may have an impact on charging rates.

## 4 Special provisions for digital telephone networks

When integrated digital telephone networks are provided it is possible to transport data on an end-to-end basis using the digital bit stream rather than analogue modulated signals. When ISDN features are implemented the requirements of both voice and non-voice services will be met. Interim arrangements may exist before the ISDN however, that allow the transmission of data calls.

Compared to the call set-up principles for voice calls, the following arrangements need to be applied:

i) Only compatible digital circuits must be selected, e.g. all circuits use 64 kbit/s transmission.

ii) The digital speech interpolation (DSI) systems may be used, unless they can be disabled.

iii) Any A-law to μ-law convertors must be made transparent to the digital bit stream.

iv) All echo suppressors or cancellors must be disabled.

v) Digital transmission attenuation pads must not be used.

ANNEX A

(to Supplement No. 8)

**Teletraffic characteristics of non-voice traffic**

A.1 *Mean call duration*

There is a very significant difference in call duration between voice and non-voice traffic. The mean call duration of non-voice traffic is within three minutes in most cases, which is about one-half or even one-third of the voice traffic.

A.2 *24-hour profile*

A.2.1 The difference in profile of voice and non-voice traffic becomes apparent when there is a large time difference between the originating and terminating countries.

A.2.2 The peak hour of non-voice traffic comes between 1700 to 1800 hours, i.e. at close of business in the outgoing country.

A.2.3 It seems that the 24-hour profile of non-voice traffic resembles that of the telex traffic (refer to Figure A-1).

A.3 *Observed statistics*

A.3.1 *Observation carried out by United Kingdom:*

a) Around the route busy hour, the semi-automatic measurements produced similar figures to the earlier manual study, i.e. 7% averaged between transmit and receive, giving some further confidence to the study.

b) The profile of non-voice traffic is different between transmit and receive directions. Typically very high levels of non-voice activity in the transmit direction were noted. These high levels occurred between 1730 and 1830 GMT and varied between 56% and 70% on different days. A slightly lower level of activity was detected in the receive direction between 0730 and 0830 GMT varying between 18% and 30%. The route busy hour for all traffic is between 1000 and 1100 GMT. The non-voice traffic was in general low outside the two non-voice busy hours identified above.

c) Although the percentages of non-voice traffic in b) are high, the actual non-voice traffic carried is in general low as both these periods are outside the route busy hour.

d) The destination and source of the non-voice traffic measured has a local time of GMT + 9 hours and the pattern of non-voice traffic would seem to indicate that customers in the United Kingdom are passing data to the destination country at close of business in the United Kingdom.

*Note* – Twenty-four-hour profiles were recorded of traffic to and from a Far East destination. This measurement was continued for 5 days, alternately examining transmit and receive directions, and from the subsequent analysis of this, these conclusions were drawn.

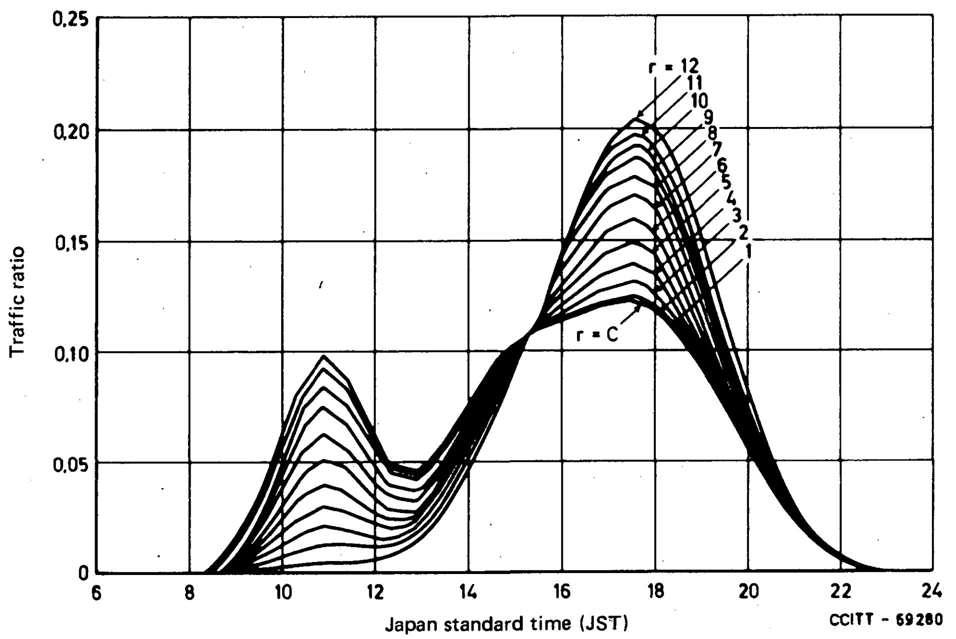
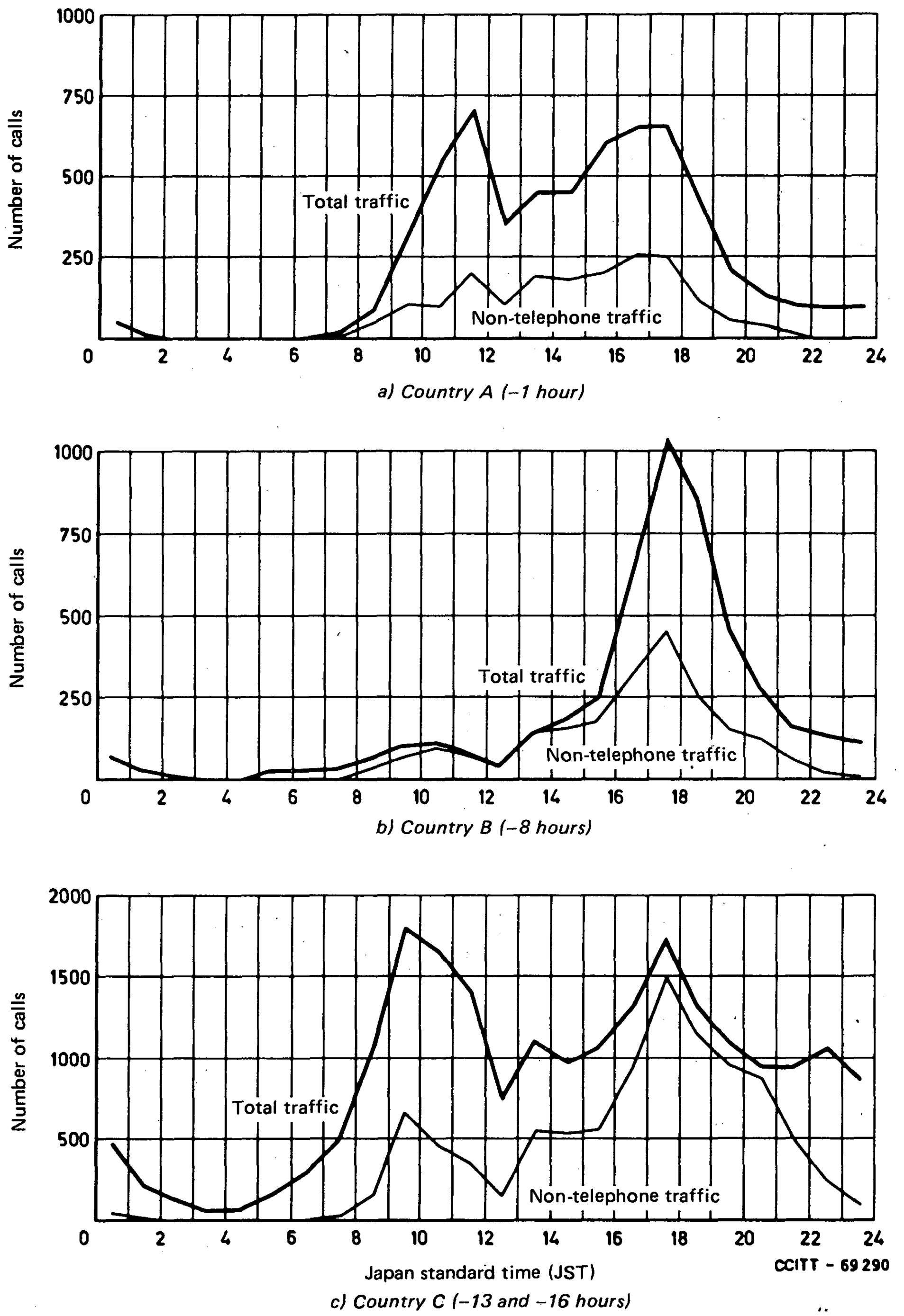



FIGURE A-1

**24-hour traffic profile for telex (theoretical) [1]**

A.3.2 *Observations carried out by KDD are shown in Figures A-2 and A-3.*




*Note 1* – The figures show outgoing traffic from Japan.

*Note 2* – The figures show number of calls, and not the traffic volume.

FIGURE A-2

**24-hour distribution of total calls completed**

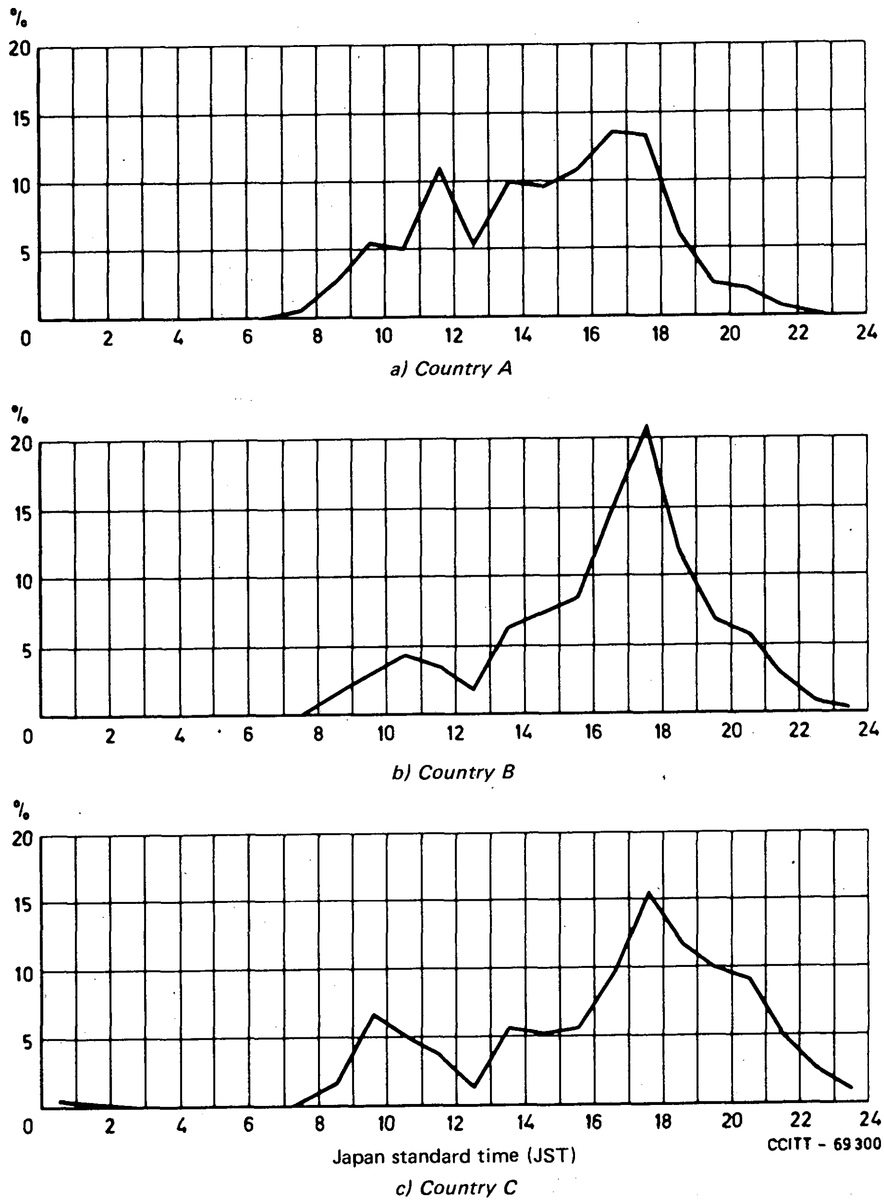



FIGURE A-3

**24-hour profile of non-voice traffic (expressed by concentration ratio)**

### Reference

[1] HATORI (N.), YAMADA (K.): Traffic characteristics of international telex calls, *7th ITC*, No. 443, Stockholm, July 1973.

Printed in Switzerland — ISBN 92-61-02011-9