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CONSULTATIVE COMMITTEE

SERIES E: OVERALL NETWORK OPERATION, TELEPHONE SERVICE, SERVICE OPERATION AND HUMAN FACTORS

Traffic engineering – Measurement and recording of traffic

TRAFFIC INTENSITY MEASUREMENT PRINCIPLES

Reedition of CCITT Recommendation E.500 published in the Blue Book, Fascicle II.3 (1988)

NOTES

1 CCITT Recommendation E.500 was published in Fascicle II.3 of the *Blue Book*. This file is an extract from the *Blue Book.* While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Recommendation E.500

TRAFFIC INTENSITY MEASUREMENT PRINCIPLES

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.

1.2 This Recommendation gives the principles for measuring carried traffic and bids on circuit groups and exchanges. The number of bids and preferably also carried traffic intensity should also be determined by individual relations (destinations). Data so obtained are applied both for operation and planning. Recommendation E.501 gives methods for estimating offered traffic from carried traffic measurements. Recommendation E.502 describes exchange requirements for traffic measurements both in national and international exchanges. Recommendation E.525 describes the traffic data analysis. Recommendation E.506 gives methods for forecasting future traffic requirements. The remainder of the E.500 Series of Recommendations describes how to utilize this data base in the operation and planning of telephone networks.

The measurements required for network management as described in the E.410 Series are generally similar to those described in this Recommendation. They will usually require a variable and shorter reporting interval.

2 Definitions

A measurement of the amount of traffic carried is the average Erlang value during a certain period of time (e.g. 15 min., 1 hour).

A measurement of the number of bids is a count of this entity during a certain period of time.

Measurements are taken continuously during the day or with exclusion of known low traffic periods. The set of days at which measurement has been taken is called the *measurement days.*

In the **yearly continuous measurement** the measurement days are post-selected from a base period with a length of the whole year. The post-selected days include the peak intensity values measured during the base period.

In the **yearly non-continuous measurement** the measurement days are scheduled (pre-selected) from a base period of a few months. The pre-selected days include the high load days of expectation or of earlier observations.

A traffic profile is defined to be *stable* when the individual daily traffic profiles differ only little in shape and traffic volume between each other.

A traffic profile is defined to be *unstable* when the individual daily traffic profiles differ in shape or traffic volume between each other.

3 Overview

Circuit group dimensioning is based on a congestion objective, on the traffic intensity values at high load time and on the forecast value of intensity until the next augmentation of circuits. Intensity is measured during a daily busy hour and averaged over a number of days, to avoid exceptional values.

If traffic measurements are taken every day of the year (yearly continuous measurements), the required averages can be calculated directly as described in § 4. If traffic measurements are taken only during a limited number of days in the year (yearly non-continuous measurements), the equivalent traffic loads may be estimated using the procedures given in § 5.

The busy hour concept is an important aspect of teletraffic engineering and may be applied in a number of ways. In the E.500 Series of Recommendations the busy hour traffic used is an average of several days with, in some cases, an allowance for day to day variations (Recommendation E.521).

Within the busy hour, traffic is considered to be stationary and thus the recorded intensity is the mean value during the busy hour.

The recommended standard method of calculating the daily average requires *continuously* measuring all quarter hours for *all* days concerned and selecting the busiest hour in the average profile for all days. This method is called the Time-Consistent Busy Hour (TCBH) and is described in detail in § 6. This method is most valuable in situations of stable traffic profiles. The daily continuous measurements provide the data necessary for confirming profile stability.

Another method of arriving at the representative average busy hour also involves *continuously* measuring all quarter hours, but only the busiest hour of *each day is* retained for averaging. This method is called the Average Daily Peak Hour (ADPH) and is described in detail in § 6 together with the relation of ADPH results to TCBH results.

The advantages of ADPH are that it requires less data storage and manipulation than TCBH and that it gives a more representative value in the situation of unstable traffic profiles.

In some situations Administrations do not measure traffic *continuously* over the day, but only for the hour or few hours expected to be busiest. This method is called the Fixed Daily Measurement Period (FDMP) or Fixed Daily Measurement Hour (FDMH) and is described in detail in § 7 together with the relation of FDMP results to TCBH results.

The advantage of FDMP is that it requires less measurement resources than TCBH or ADPH. The disadvantage is that in individual situations the difference between FDMP and TCBH results may vary widely.

In some network situations significant savings can be made by multihour dimensioning (e.g. cluster engineering, time zone differences). This requires daily continuous measurements.

4 Yearly continuous measurements

Traffic statistics should be measured for the significant period of each day of the whole year. The significant period may in principle be 24 hours of the day.

The 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 network dimensioning 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 circuits groups operated automatically or semiautomatically.

4.1 *Normal and high load levels*

Teletraffic performance objectives and dimensioning practices generally set objectives for two sets of traffic load conditions.

A normal traffic load can be considered the typical operating condition of a network for which subscribers service expectations should be met.

A high traffic load can be considered a less frequently encountered operating condition of a network for which normal subscriber expectations would not be met but for which a reduced level of performance should be achieved to prevent excessive repeat calling and spread of network congestion.

In order to estimate normal and high load levels, offered traffic intensity values should, where necessary, be estimated from daily carried traffic measurements. Estimation procedures are presented in Recommendation E.501.

Normal and high loads are defined in Table 1/E.500.

TABLE 1/E.500

Circuit groups		
Parameter	Normal load	High load
Carried traffic intensity	Mean of the 30 highest working 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.

Exchanges		
Parameter	Normal load	High load
Carried 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 bids	Mean of the same 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.

5 Yearly non-continuous measurements

5.1 *Introduction*

This method consists in taking 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 yearly 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.

Table 2/E.500 shows the results of a study carried out on circuit groups within a large metropolitan network [1]. The errors shown are the under-estimates resulting if average busy hour carried traffic intensity is measured over a pre-defined two-week period of the year, rather than the actual busiest two-week period. (The pre-defined period was, in fact, the peak period of the preceding year.)

The error averages 7.6% more or less, depending on circuit group size. Had an Administration wished to estimate the true peak two-week intensity with 90% confidence, starting with the pre-defined two-week measurements, the latter would have had to be increased by amounts ranging from about 14% for large circuit groups, up to about 31% for small ones. (The magnitude of these corrections indicates how inadequate a two-week sample can be as a basis for network planning.)

TABLE 2/E.500

Weighted mean error and the upper limit of the intensity error class for a cumulative proportion of circuit groups, categorized according to traffic intensity

	Total	Low < 10 Erl	Medium 10-100 Erl	High > 100 Erl
Circuits groups	2728	1056	1564	110
Weighted mean error of the intensity value	7.6%	13.7%	7.8%	5.2%
Cumulative proportion of circuit groups				
50%	7.9%	12.9%	6.9%	3.9%
80%	16.9%	22.9%	17.9%	7.9%
90%	23.9%	30.9%	23.9%	13.9%
95%	31.9%	37.9%	34.9%	17.9%
98%	41.9%	47.9%	40.9%	26.9%

5.2 *Estimation method*

An approximate statistical method for estimating normal and high load levels from limited sample measurements is provided below.

5.2.1 *Principle of estimation method*

Measurements are taken on a limited sample of days, and the mean *(M)* and standard deviation *(S)* of the daily 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.

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

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 the 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).

5.2.2 *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 preselected. This period should include all days which are potential candidates for being among the 30 highest days (but excluding recurring exceptional days – see § 4).

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.

5.2.3 *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 reliability of the estimate is poor.

5.2.4 *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 [2].

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 then prefer to use different values for the factors, if they have obtained more precise information from special measurement studies.

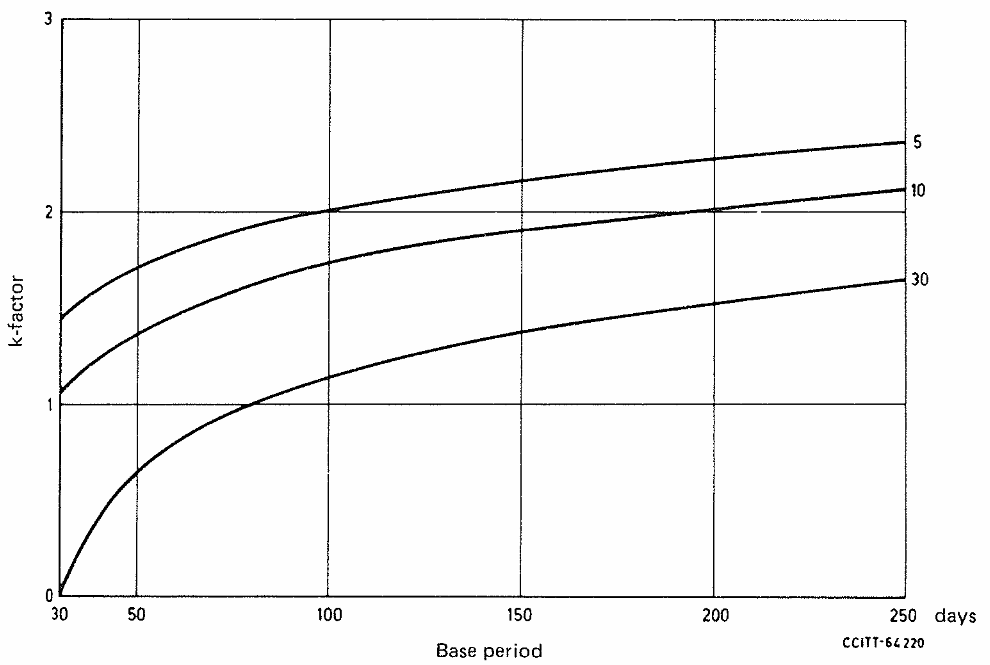

FIGURE 1/E.500

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

5.2.5 *Examples*

The following data illustrate the application of this procedure to the estimation of normal and high load levels from non-continuous measurements on a circuit group over a 1-year period.

After excluding holidays and other known low traffic periods the base period which is available for measurement purposes is determined to be 220 days. The k -factors to be used are therefore (from Figure 1/E.500):

Normal (30-day) load level: $k = 1.6$
High (5-day) load level: $k = 2.3$

Measurements are taken on 50 days within the base period. The daily measured busy-hour traffic values, in Erlangs, are as follows:

21.5	20.5	18.7	15.0	18.4	21.6	18.1	24.2	26.7	22.1
21.8	17.8	17.2	19.8	15.2	20.4	16.7	20.6	23.1	23.5
19.6	18.1	21.3	15.9	15.9	17.8	17.4	20.9	25.9	20.6
20.9	19.2	17.6	12.9	14.2	18.1	16.9	24.2	22.2	26.8
22.5	22.8	19.3	19.1	18.7	19.8	18.0	26.0	22.5	27.5

The sample mean and standard deviation are:

M = 20.11

S = 3.37

The normal and high load level estimates are then calculated from $L = M + k \cdot S$ to give:

Normal load = 25.5 Erlangs

High load = 27.9 Erlangs

5.2.6 *High to normal traffic ratios*

In some circumstances, 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.

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

6 Daily continuous measurements

6.1 *Measurement*

It is recommended that Administrations take traffic measurements continuously over the day throughout the measurement period.

Depending on the application, a busy hour value for dimensioning should be calculated as the peak value of the mean day profile or the average of daily peak values.

6.2 *Time-consistent busy hour (TCBH)-intensity (post-selected)*

For a number of days, carried traffic values for each quarter hour for each day are recorded. The values for the same quarter hour each day are averaged.

The four consecutive quarter-hours in this average day which together give the largest sum of observed values form the TCBH with its TCBH-intensity. This is sometimes referred to as post-selected TCBH.

In the case where a stable traffic profile exists, the TCBH-intensity is used as a base method for dimensioning; if measurement methods yielding systematically lower or higher intensity values than the TCB-method are used, adjustments to the calculations are needed.

6.3 *Average of the daily peak hours traffic, defined on quarter hour or on full hour basis*

To find the average of daily peak quarterly defined hour (ADPQH) intensity, the traffic intensity is measured continuously over a day in quarter-hour periods. The intensity values are processed daily to find out the four consecutive quarter hours with the highest intensity value sum. Only this daily peak hour traffic intensity value is registered. The average is taken over a number of working days peak intensities. The timing of peak intensity normally varies from day to day.

To find the average of daily peak full hour (ADPFH) intensity, the traffic intensity is measured continuously over a day in full-hour periods. Only the highest of these intensity values is registered. The average is taken over a number of days peak intensities.

The comparative measurements have shown that the traffic intensity values measured by the ADPF-method, are very consistent with the values measured by the TCBH-method, whereas the ADPQH-method yields slightly (a few percent) higher values. (See Annex A.) ADPH has an advantage over TCBH when traffic profiles are unstable.

6.4 *Alternate routing networks*

When alternate routing is used, the dimensioning methods in Recommendation E.522 should be applied (multi-hour dimensioning technique). In general this requires the continuous measurement of a 24-hour profile for each traffic quantity in the alternative routing cluster.

In Annex A the differences in results between busy hours defined for individual circuit groups and for clusters indicate the advantage of continuous measurements and multi-hour dimensioning for alternative routing networks.

In circumstances where the traffic profiles are stable and similar in the whole cluster, the multi-hour dimensioning may be applied on a few selected hours of significance to the entire cluster. The stability of traffic profiles must be confirmed.

7 Daily non-continuous measurements

7.1 *Measurement*

Some Administrations may find it necessary or economically attractive to restrict measurements to a few hours or only one hour per day. Such measurements will always be less accurate than continuous measurements. The resulting busy hour values will always be less than or equal to TCBH.

The time of fixed daily measurements should be confirmed several times a year by measurement of the full daily traffic profile for every circuit group. The measurement can cover several periods daily, as well.

7.2 *Fixed daily measurement period (FDMP)*

With this method measurements are taken within a fixed period (e.g. of 3 hours) each day. This period should correspond to the highest part of the traffic profile, which is expected to include the TCBH. Measurement values are accumulated separately for each quarter-hour, and the busiest hour is determined at the end of the measurement period, as for the TCBH. This method will normally give results which are about 95% of the TCBH traffic level, when the time of fixed daily measurement is defined for every single circuit group, although major changes in the traffic profile could lead to larger errors.

In alternate routing networks with traffic profiles that are similar and stable in the whole cluster, FDMP may be used to produce measurements for multi-hour dimensioning applied on a few selected hours of significance. The stability of traffic profiles should be confirmed several times a year.

7.3 *Fixed daily measurement hour (FDMH)*

If the fixed daily measurement period is reduced to 1 hour, then it is only necessary to accumulate a single measured value from each day. This is the simplest measurement method, and it will normally give results which are about 90% of the TCBH traffic value, when the time of the fixed daily measurement is defined for single circuit groups individually. However, the variations around the average are large.

8 Flow chart for the application of the different calculation methods

The decisions represented in Figure 2/E.500 compare measurement and analysis costs to variations in the results for a single circuit group or cluster. The costs are particular to each Administration.

The preceding sections of this Recommendation indicate the amount of measurement variance that can occur in typical situations which can result in overprovisioning or a risk of poor grade of service.

In cluster engineering for alternative routing networks, measurements outside the busy hour are normally needed if the traffic profile is unstable. In situations of stable traffic load the significant traffic hours can be predicted accurately, allowing use of a FDMP method.

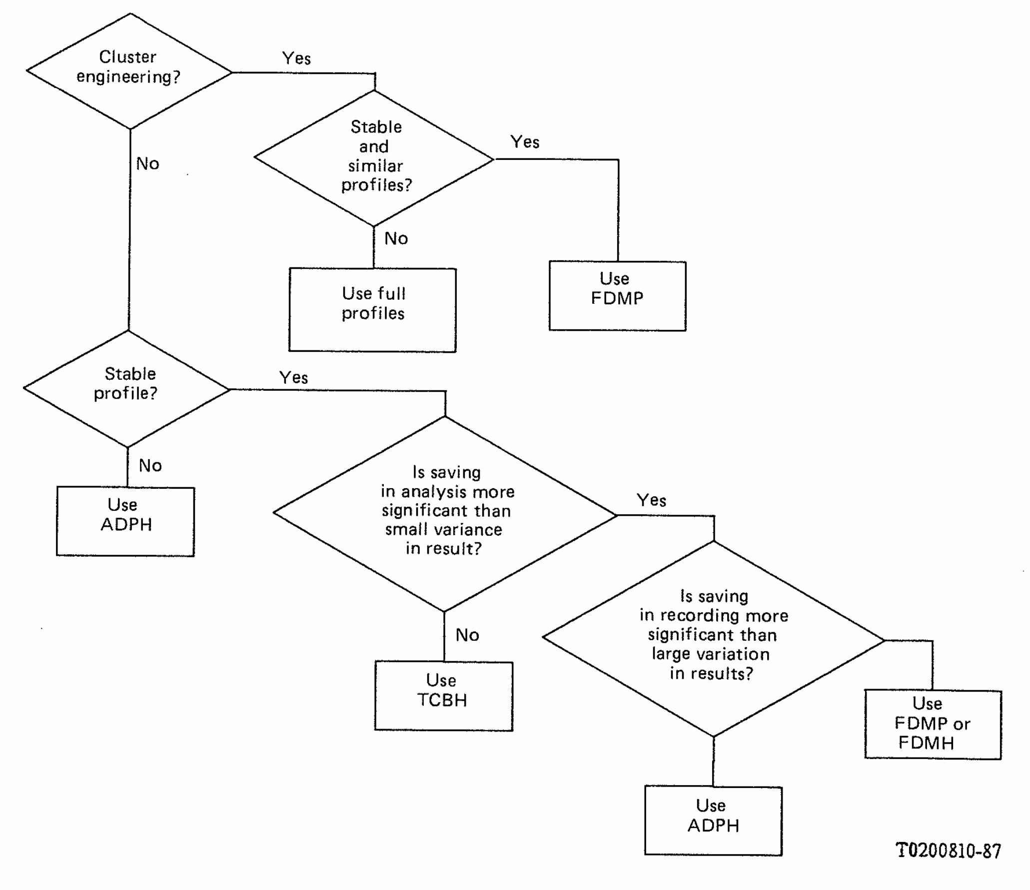

FIGURE 2/E.500
Flow chart for choosing the measurement method

ANNEX A
(to Recommendation E.500)

Example of influence of different busy hour definitions on measured traffic intensity

A.1 *Introduction*

The influence of different busy hour definitions on measured traffic intensity has been investigated by means of measurements on real traffic outgoing from an international exchange.

Three clusters with a total of 15 circuit groups have been studied. One of the clusters (Cluster 1) carries traffic between different time zones.

Traffic per quarter of an hour was measured during the whole day in 5 two-week periods (10 consecutive working days). The total elapsed time covered 9 months.

From the results of the first two-week period of daily continuous measurements the times of FDMH and FDMP have been determined:

– for each circuit group individually (ind),
– per cluster (clu), and
– for all three clusters commonly (com).

The time of FDMH is equal to the time of TCBH in the first two-week period. FDMP includes FDMH and the hour before and the hour after.

A.2 *Results of measurements*

The results of the measurements undertaken are summarized in Figures A-1/E.500 to A-5/E.500.

Figure A-1/E.500 shows how the starting time of TCBH varies between the five measurement periods:

– for each cluster, and
– for individual circuit groups in each cluster.

The following observations on the starting time of TCBH can be made:

– the starting time of TCBH is the same in not more than 2 periods. This refers to both circuit groups and clusters;
– 5 circuit groups and 1 cluster have different TCBH in all periods;
– 8 circuit groups and 2 clusters have TCBH within the same part of the day (morning or evening) in all periods;
– TCBH common to all clusters is in the evening in all periods. Only 2 periods have the same common TCBH.

In Figures A-2/E.500 to A-5/E.500 traffic intensities according to different busy hour definitions have been compared. Traffic intensity according to the TCBH definition has been used as reference value (corresponding to 100% in the figures).

Figure A-2/E.500 shows the results of comparisons on a cluster level, and Figures A-3/E.500 to A-5/E.500 on a circuit group level.

Means and variations of traffic intensities are given as:

– an average of all five periods (ADPQH and ADPFH), and
– an average of measurement periods 2, 3, 4 and 5 compared with period 1 (FDMH and FDMP).

A.3 *Results on cluster level (Figure A-2/E.500)*

ADPQH	intensities over 100%, mean = 102%.
ADPFH	intensities around 100%, mean = 100%.
FDMP_{clu}	intensities from 95 to 100%, mean = 99%.
FDMH_{clu}	intensities from 90 to 98%, mean = 94%.
FDMP_{com}	intensities from 42 to 100%, mean = 89%.
FDMH_{com}	intensities from 35 to 93%, mean = 83%.

A.4 *Results on circuit group level (Figures A-3/E.500 to A-5/E.500)*

ADPQH	intensities over 100%, mean = 104%.
ADPFH	intensities around 100%, mean = 100%.
$FDMP_{ind}$	intensities from 88 to 100%, mean = 99%.
$FDMH_{ind}$	intensities from 80 to 100%, mean = 93%.
$FDMP_{clu}$	intensities from 51 to 100%, mean = 98%.
$FDMH_{clu}$	intensities from 45 to 99%, mean = 91%.
$FDMP_{com}$	intensities from 24 to 100%, mean = 89%.
$FDMH_{com}$	intensities from 14 to 99%, mean = 81%.

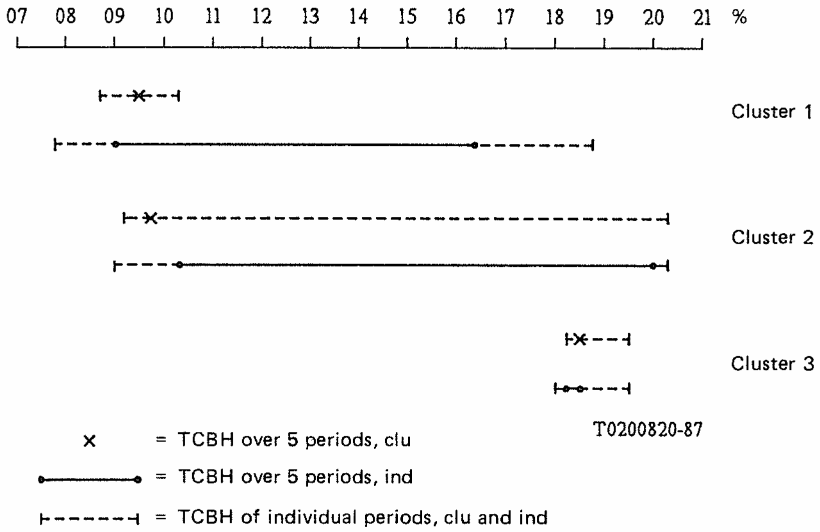

FIGURE A-1/E.500

Variations in time of TCBH

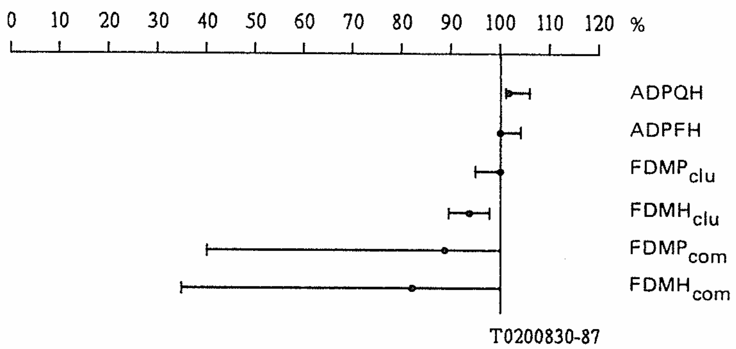

FIGURE A-2/E.500

Comparisons on cluster level

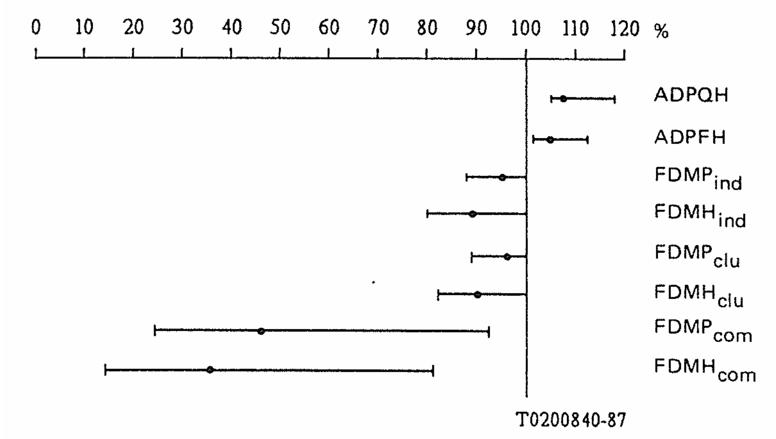

FIGURE A-3/E.500

Comparison on circuit group level
(Cluster 1)

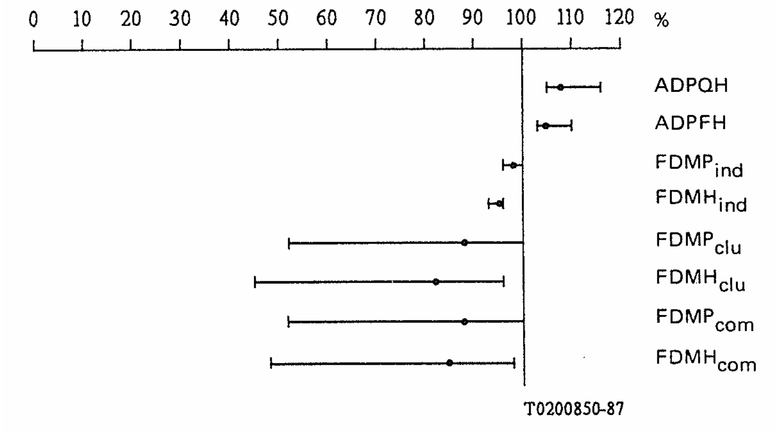

FIGURE A-4/E.500

Comparison on circuit group level
(Cluster 2)

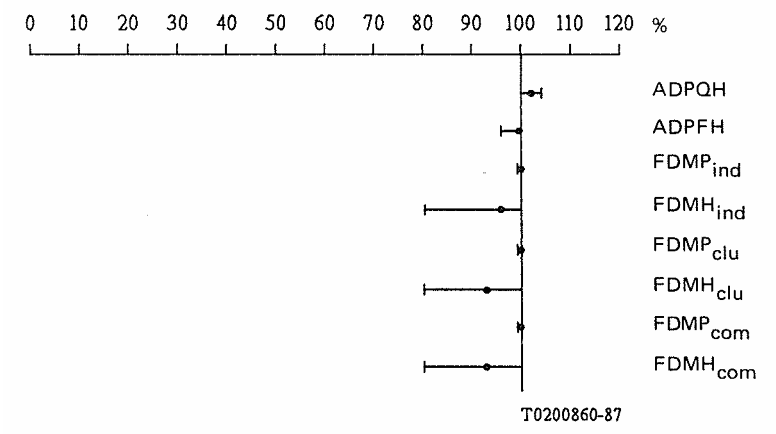

FIGURE A-5/E.500

Comparison on circuit group level
(Cluster 3)

References

[1] PARVIALA (A.): The stability of telephone traffic intensity profiles and its influence on measurement schedules and dimensioning (with Appendix). 11th International Teletraffic Congress, Kyoto 1985.

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

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