FIELD ENGINEERING METHODS FOR ECONOMIC NETWORK PLANNING WITH OR WITHOUT ALTERNATE ROUTING

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1. INTRODUCTION

The economic telephone network planning presupposes the existence of sufficiently exact and handy methods:

1.1 For the *estimation* or the *measuring* of the *traffic quantities*, respectively which form the basis for the design of connecting networks with exchanges as well as for all trunk groups in local and toll networks.

1.2 For the economic *structural design* of switching networks such as link systems, one stage selector arrays and trunk groups, respectively, for prescribed traffic capacity, probability of loss and often also with regard to eventual overload.

1.3 For the dimensioning of telephone networks with alternate routing regarding an economic partition of the traffic streams to high usage routes and to final routes which carry the overflow of high usage routes plus direct final traffic.

This paper gives a survey on the engineering tools to master these problems. The voluminous theoretical background can be found in the cited literature.

2. TRAFFIC MEASUREMENTS AND FORECAST

2.1 *Traffic measurements*, as a base for the dimensioning of trunk groups and connecting arrays, are, as a rule, performed during the busy periods of several working days assuming a stationary offered traffic during these time intervals. They have in each case the character of a statistical sample with a limited accuracy only. Therefore, the "true traffic value" can be situated below or above the measured value within a so-called confidence interval CI. With a certain prescribed statistical confidence significance S (mostly S = 95 per cent) one can simply determine the confidence interval of any traffic measurement. It depends mainly on the number of calls being established on the considered group of selectors, trunks etc. during the measuring interval, e.g. during five busy hours of five measured working days.

Fig. 1 gives for S = 95 per cent and for various desired confidence intervals CI the quantity YQ of Erlang Hours to be measured vs. the average holding time h per call /1,2/.

Proceedings-XX Internat. Meeting, The Institute of Management Sciences

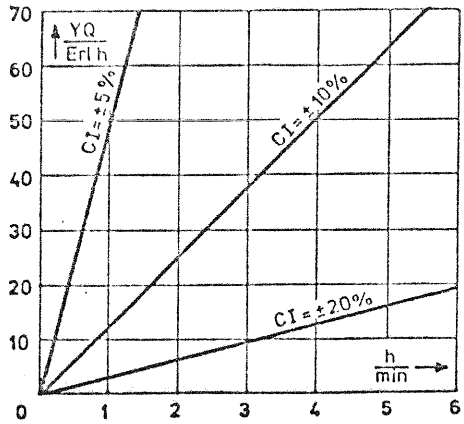


Fig. 1:
The traffic quantity YQ to be measured as a function of mean holding time h and desired confidence interval CI, if S = 95 per cent confidence significance is prescribed.

2.2 Forecasting methods concerning the demand of telephone subscribers are of major importance. This problem has been treated already in many papers. In a comprehensive and precise study /3/ these methods are discussed. Furthermore, two new and improved reliable forecast methods are explained. For reasons of space, the author can only refer to this study.

3. THE PROBABILITY OF LOSS REGARDING ONE-STAGE CONNECTING ARRAYS

3.1 Groups with full accessibility

The probability of loss B, i.e. the share of unsuccessful attempts in front of a trunk group, is given for full accessible groups with n lines and offered traffic A by Erlang's Loss Formula /4/.

$$B = \frac{\frac{A^n}{n!}}{\sum_{j=0}^{n} \frac{A^j}{j!}} \qquad (1)$$

with λ = arrival rate
h = mean holding time

Interarrival time and holding time being negative exponentially distributed. This assumption is rather realistic for telephone traffic, as checked by many measurements e.g. /5,6/.

$A = \lambda \cdot h$ = offered traffic
n = number of trunks in the group

This formula is tabulated in most countries. It presupposes that the number of traffic - generating sources q is so numerous that the arrival rate λ is practically independent of the number x of momentarily busy trunks, i.e. one assumes $q \rightarrow \infty$.
In public telephone networks this assumption is close to reality. Even though the actual number of inlets to any connecting array is finite, one can mostly assume this Poissonian input process (also "PCT 1; Pure Chance Traffic of Type 1").

Within PBX and for other connecting arrays with a comparatively small number of traffic sources ($q \lesssim 15 \cdot n$) one is using Erlang's Bernoulli-Formula /4/ for finite number of sources. For this "Pure Chance Traffic of Type 2 (PCT 2)" one obtains :

$$B = \frac{\binom{q}{n} \cdot \alpha^n}{\sum_{j=0}^{n} \binom{q}{j} \cdot \alpha^j} \cdot \frac{q-n}{q-Y} \quad (2) \qquad \text{and} \qquad Y = \sum_{x=0}^{n} x \cdot p(x) = \sum_{x=0}^{n} x \cdot \frac{\binom{q}{x} \cdot \alpha^x}{\sum_{j=0}^{n} \binom{q}{j} \cdot \alpha^j} \quad (3)$$

with q = number of traffic sources
α = call rate per idle source
n = number of trunks in the group

Interarrival time per idle source and holding time are assumed to be negative exponentially distributed.

Tables see /7, 8/.

3.2 Groups with limited accessibility $k < n$

3.2.1 Grading types

In one stage connecting arrays with limited accessibility $k < n$ a grading is performed between g selector groups containing i inlets and k outlets each, and the outgoing group with $n > k$ trunks. A large variety of different grading types is in use.

Three typical grading types are shown in Fig. 2. Each one of these examples has g = 12 selector groups with e.g. 20 inlets each. The accessibility is k = 10 and the number of outgoing trunks is n = 60. The mean interconnection number ("grading ratio") is $H = \frac{g \cdot k}{n} = \frac{12 \cdot 10}{60} = 2$ for all three gradings. As to favourable values of H see /9,10,11/. Generally, the loss B for given offered traffic A decreases (up to $n \approx 100$ and depending on the grading type) if H increases $(2 \lesssim H \lesssim 5)$ /9/. Mostly, economic considerations prescribe $H \gtrsim 2$ and loss tables basing on $H = 2$ are applied.

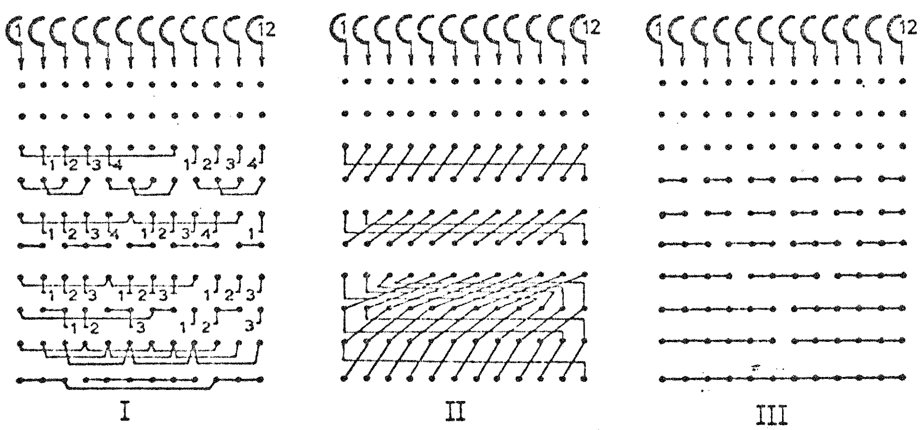


Fig. 2:
Three grading types for sequential hunting from home position:
I. "Perfect" Grading with Skipping
II. Simplified Standard Grading (SSG)
III. O'Dell Grading

3.2.2 Calculation of the probability of loss for offered random traffic

The exact loss calculation of a group with $n > k$ trunks hunted via a grading leads to a linear equation system with 2^n unknowns (for PCT 1) and even to more for PCT 2. The loss of Erlang's "Ideal Gradings" is easily to calculate; these gradings are, however, not applicable in practice.

For "perfect" gradings (e.g. Type I in Fig.2) the most reliable loss tables are based on the Modified Palm Jacobaeus (MPJ-) Formula /12,13,14/.

Simplified grading types e.g. Type II or III in Fig. 2 are sometimes rather economical because of the remarkably reduced manpower which is necessary for their performance or extension, respectively.

The MPJ-Formula can be adapted easily also to the application of more or less simplified gradings (e.g. Type II or III in Fig. 2) /15,16/. Only a reduction ΔA for the admissible offered traffic A is necessary. By a simple formula one gets:

$$A_{admissible} = A_{MPJ} - \Delta A \quad (4) \qquad \text{where} \quad \Delta A = F\left(\frac{n}{k}-1\right)^2 \cdot \frac{k-2}{60+4k} \quad (5)$$

The Fitting Parameter F depends for a standardized minimum interconnection ratio on the grading type only and can be determined by one single series of informing traffic trials for the concerning type. This parameter is e.g. F = 0.3 for SSG's and F = 1.1 for O'Dell-Gradings. The high accuracy of this method can be seen from Fig.3.

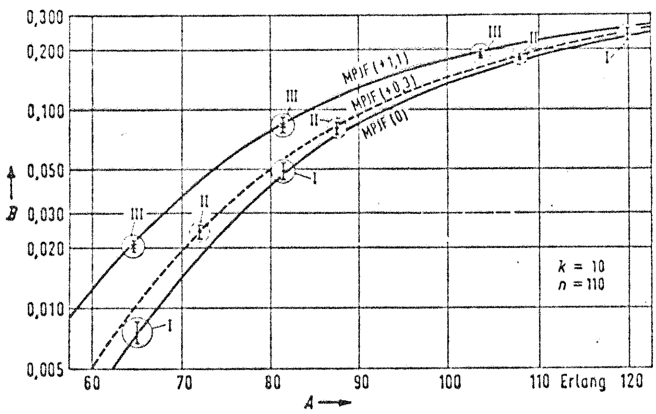


Fig. 3:
Probability of loss B vs. the offered traffic A for the three grading types I, II, III as in Fig.2. The chosen large number of n = 110 trunks is in particular sensitive against any inaccuracy of the adaptation method.

This MPJ-Formula is for instance part of the dimensioning outlines of telephone administrations in the FRG, GDR and other countries and is tabulated for SSG e.g. /8,20/. For other grading types it can quickly be tabulated.

For "finite" number of traffic sources one can apply two different approximate formulae, both yielding results close to the actual loss of "perfect" gradings (Type I in Fig. 2).

a) the Bernoulli Interconnection Formula (BIF) /17/
b) the Bernoulli Quotient Formula (BQF) /18/

Both formulae lead, however, to big and unhandy table volumes, because all practically arising source to trunk ratios q/n lead to another loss table for any value k of accessibility.

This disadvantage can be avoided by an elegant transformation from available PCT 1 loss tables by the aid of the FST-Method i.e. Finite Source Transformation /19/; e.g. the corresponding loss tables for PCT 1 /20,8/ are being used for Simplified Standard Gradings according to Type II of Fig.2. There, one can draw from a tabulated triple $\{A_{PCT1}, B, n\}$ the increase ΔA of the offered traffic which is admissible for an actual source to trunk ratio $q/n < \infty$:

$$\Delta A = 0.3 \cdot \frac{n - 0.77 \cdot A_{PCT1}(1-B)}{\frac{q}{n}+1} \qquad (6)$$

Thus, for $q/n < \infty$

$$A = A_{PCT1} + \Delta A \qquad (7)$$

Figures 4 and 5 show the accuracy and furthermore the influence of decreasing q/n on the loss.

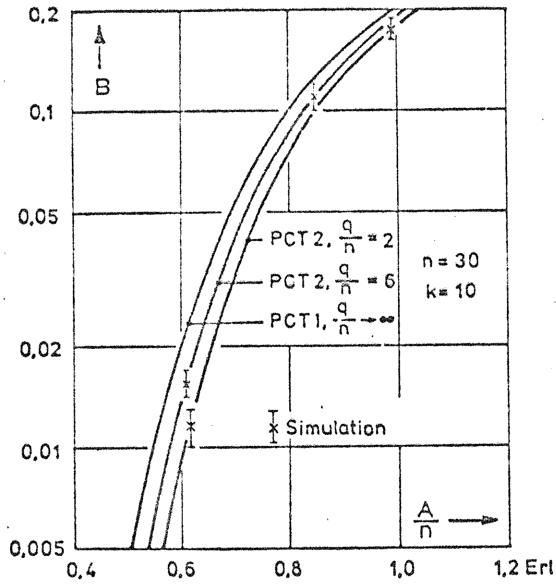


Fig.4:
Probability of loss B vs. the offered traffic per trunk A/n for n=30, k = 10 and varying source to trunk ratio q/n. (Simulation with 95 per cent confidence interval.)

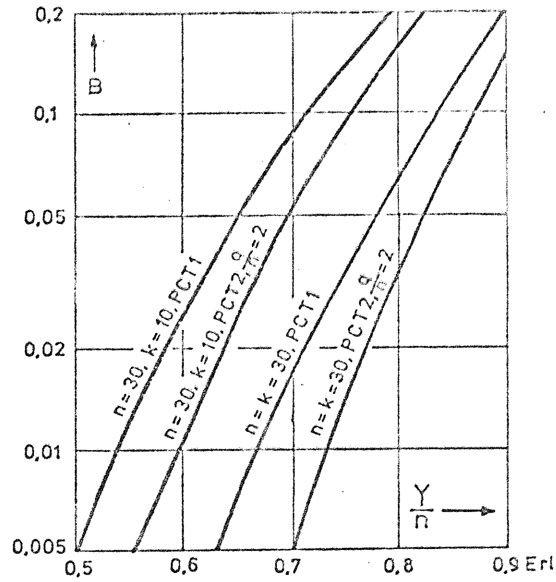


Fig.5:
Probability of loss B vs. carried traffic per trunk Y/n for full access (k=n=30) and for limited access (k=10,n=30) with PCT 1 and PCT 2 (q/n=2) resp.

4. LINK SYSTEMS (MULTI STAGE CONNECTING ARRAYS WITH CONJUGATED SELECTION)

4.1 General Remarks

Many local or toll exchanges respectively, have link systems as connecting arrays. A large variety of structures is in use, as to the number S of stages (mostly 2 ÷ 8), furthermore as to the structures in detail. Fig.6 shows four main features of link systems.

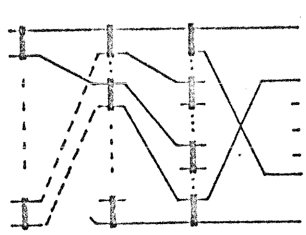


Fig. 6A:
Fan Out System mostly used for small group selection arrays, limited accessibility

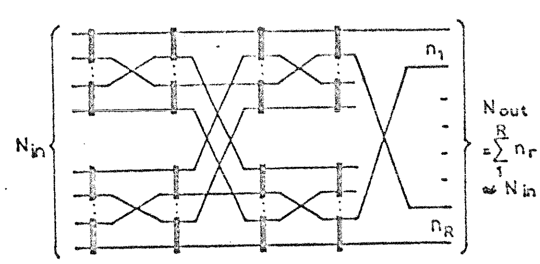


Fig. 6B:
Meshed System for group selection, mostly designed for full or almost full access

The following notations are used:

i_j = inlets per multiple in stage j
k_j = outlets per multiple in stage j (j=1,...,S)
g_j = number of multiples in stage j
S = number of stages

R = number of trunk groups

k_{Sr} = outlets per multiple to group r (r=1,...,R)

n_r = number of trunks per group r

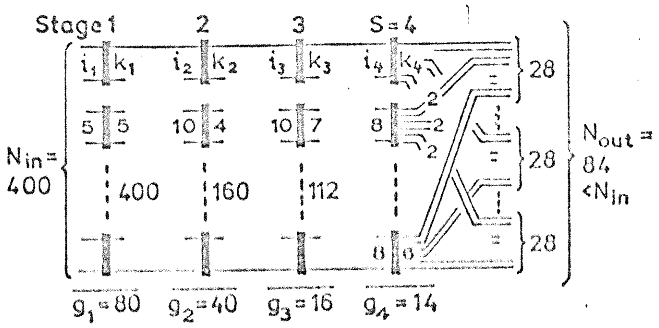


Fig. 6C:
Subscriber link system for the concentration or expansion resp., from 400 subscribers to 3 groups with 28 trunks each

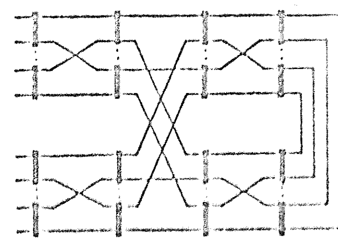


Fig. 6D:
One sided link system

The main advantage of link systems lies in the remarkable saving of crosspoints compared with equivalent one stage connecting arrays (saving factor about 2 up to 5).

Reliable approximate calculations of loss as well as definite optimum rules for the design are not yet known for one sided structures as in Fig. 6 D. The dimensioning is performed by means of artificial traffic simulation.

Regarding, however, structures as in Fig.6 A,B,C intensive investigations have been performed during the last years /among others 21÷26/. The following shortened outlines show some important rules of design.

4.2 Outlines for the design of group selection link systems

4.2.1 Basic structural features of link systems for group selection

	Type of Link System	LW_{in}	LW_{out}	Feature of Link System
A	Wide	>1	>1	N_{in} — P — N_{out}
B	Wide	>1	=1	N_{in} — P — N_{out}
C	Narrow	=1	=1	N_{in} — P — N_{out}
D	Narrow	=1	>1	N_{in} — P — N_{out}
	$N_{in}=g_1 \cdot i_1$; $N_{out}=g_S \cdot k_S$; $P=g_1 \cdot k_1 = \ldots = g_{S-1} k_{S-1}$			

Linkwidth $LW_{in} = P/N_{in}$, $LW_{out} = P/N_{out}$

P = number of links between two stages

S = number of stages

Fig. 7: Four basic features

With regard to the traffic capacity for given number of crosspoints and grade of service one can judge the four features as follows /26/ :

Fig. 7A: Very good, yields minimum overload sensibility for fixed amount of crosspoints and prescribed traffic.

Fig. 7B: Reasonably good, if the property $LW_{in} \gtrsim 1.2$ is realizable by means of a well concentrated incoming traffic from preceding selector stages.

Fig. 7C: and 7D By no means recommendable. As soon as the total number P of links between two subsequent stages is only equal to N_{in}, the normal statistical variations of calls being momentarily established within the link system can lead to momentary high blocking and loss probabilities which increase the expectation value of loss remarkably. Crosspoint equivalent more favourable features like Fig.7A,B can be designed in any case.

4.2.2 The design of so-called Optimum Link Systems which require a minimum number of crosspoints for prescribed traffic capacity has been treated in detail in /24/. For group selection link systems this method has been still improved /26/ and will be described in a short way. The basic formulae lead to structures with a minimum number of crosspoints per Erlang and are given by the following equations:

$$T = \prod_{j=1}^{S-1} (k_j - Y_j) k_S \qquad (8)$$

where $Y_j = Y_{tot}/g_j$ is the carried traffic per multiple in stage j.

The T r a n s p a r e n c y T according to eq. (8) means that average number of idle paths (each consisting of (S-1) links in series) which lead from an arbitrary free inlet of the first stage to the total of N_{out} outlets behind the last stage S. Meshed link systems have, for normally carried traffic, often $T > N_{out}$. In addition to T one prescribes for the design the total traffic Y_{tot} to be carried, the total number N_{in} of inlets to the first stage and therewith the carried traffic per inlet of the first stage

$$a_1 = Y_{tot} / N_{in} \qquad (9)$$

If one prescribes $T \gtrsim N_{out}$, one obtains practically full access to any outgoing group if the following rules of design are observed and if PG-Mode Hunting is applied. PG-mode means "hunting all accessible outlets of the desired group from the considered first stage inlet being occupied" (Point to Group Selection).

For prescribed transparency $T < N_{out}$ one gets a lower bound of the effective accessibility to the considered group by $k_{min} = T \cdot \frac{k_{s,r}}{k_s}$.

The most crosspoint saving structure is obtained with

$$S_{opt} = \ln \frac{T}{4a_1} \text{ stages} \qquad (10)$$

Fig.8 shows that S_{opt} has a very flat minimum. The s m a l l e s t S which is still reasonably close to the minimum of crosspoints per Erlang (CPE, eq. (11 D)) should be chosen because it guarantees at the same time the smallest loss increase in case of overload.

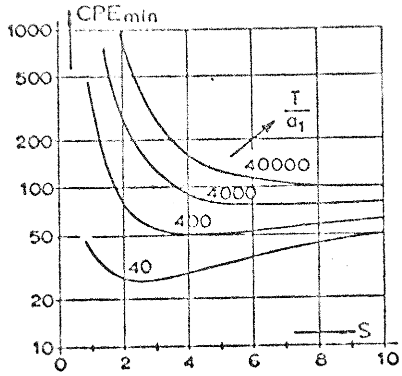


Fig. 8:
Minimum number of crosspoints per Erlang CPE_{min} vs. number of stages

The number i_j and k_j per multiple in all stages 1,2,..S are calculated from eq. (11):

$$k_j = 2 \cdot \sqrt[S]{\frac{T}{4a_1}} \; , \; j = 2,3,..(S-1) \qquad (11A)$$

$$i_j = k_j \; , \; j = 1,2,3,..(S-1) \qquad (11B)$$

$$i_s = k_1 \qquad (11C)$$

$$\text{Crosspoints per Erlang CPE} = 2 \cdot S \cdot k_j \qquad (11D)$$

$$k_1 = i_1 \cdot 2 \cdot a_1, \text{ however in any case at least} \qquad (11E)$$

$$k_1 = (1.2 \ldots 1.3)\, i_1$$

to guarantee a wide structure as in Fig. 7 A,B. This mode of action is equivalent to the assumption of a virtual carried traffic per inlet $a_1^* \gtrsim 0.6 \ldots 0.65$ as long as the actual value is $a_1 < 0.6 \ldots 0.65$.

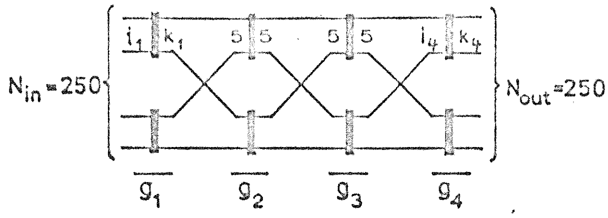
The prescribed number N_{in} of inlets remains unchanged by the eventual use of an increased a_1^* according to eq. (11 E)..

The results for the number of outlets and inlets have of course to be rounded up or down to obtain integer values as well as suitable structures. This does not influence very much the total crosspoint requirement $C = CPE \cdot Y_{tot}$. One has to check whether the desired value T remains about fulfilled with the final, rounded parameters.

4.2.3 Example:

Be prescribed Y_{tot}=125 Erlang, N_{in}=250 inlets; therefore a_1=0.5 Erl.; and N_{out} = 5 x 50 = 250 outlets. We desire $T \approx N_{out}$ = 250. With T/a_1 we find from Fig.8 or from eq. (10) that S = 4 stages will be favourable. Then, we go into eq. (12) with an increased virtual a_1^* = 0.7 and with $\frac{T}{a_1}$ = 357.

Rounding down one gets system L43, rounding up one finds another suitable structure L41. Both link systems are favourable wide structures. They can be seen in Fig.9 together with a further link system L48 which neglects the rule $k_1 > i_1$.



System	$g_1=g_4$	$g_2=g_3$	$i_1=k_4$	$k_1=i_4$	C	T (0.5)
L41	50	80	5	8	8000	325
L43	50	70	5	7	7000	233
L48	25	50	10	10	7500	312

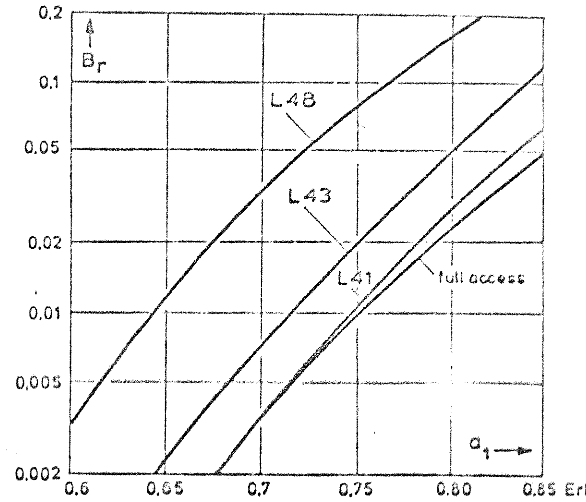


Fig. 9: Structure of the link systems and probability of loss B_r vs. carried traffic a_1 per inlet

4.3 Link systems with traffic concentration or expansion respectively according to Fig. 6C

With regard to the lack of space the author has to refer to the design outlines as described in /24, Chapter 7.3/.

A variety of structures exists with regard to the partition of internal, external incoming and external outgoing traffic to common or separate trunk groups respectively. This problem and the corresponding methods for the calculation of loss have been published in /25/.

4.4 Calculation of the probability of loss

For group selection systems, as dealt with in Section 4.2, one finds a very reliable approximate method (which can also be evaluated manually) in /26/. Corresponding methods for concentration link systems with or without internal traffic can be found in /25/.Fig.10 shows examples.

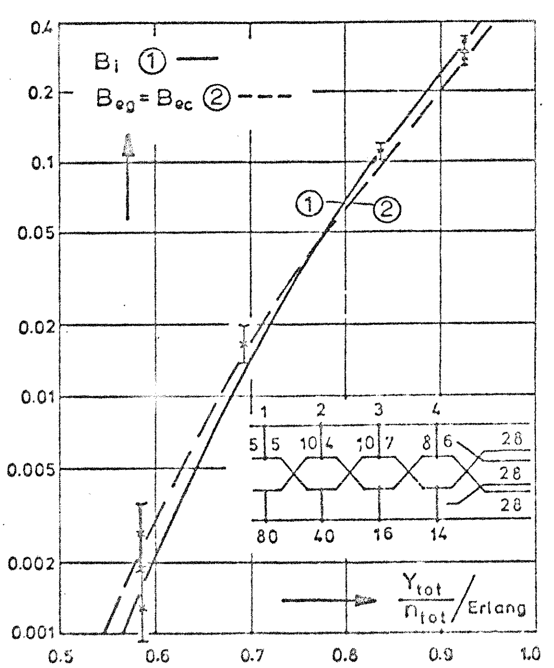


Fig.10:

① Probability of loss B_i of the internal traffic.

② Probability of loss B_{eg} and B_{ec} of the outgoing and incoming external traffic resp.,

as a function of the carried traffic per outlet Y_{tot}/n_{tot}.

Parameter: Ratio internal to total traffic: 2/3.

(The trunk groups No.1 and No.2 carry the outgoing and incoming part of the internal traffic resp.; the trunk group No.3 carries the outgoing and incoming external traffic.)

5. DIMENSIONING TELEPHONE NETWORKS WITH ALTERNATE ROUTING

5.1 General remarks

Two main problems must be mastered:

- Finding a handy dimensioning method valid for full as well as for limited accessibility which regards the peakedness of traffics overflowing from high usage groups to subsequently hunted groups.
- The economic partition of the offered traffics to high usage trunk groups and to the final group.

5.2 The variance V and ratio V/R of overflowing "peaked rest traffic"

The description of a peaked overflowing traffic by its first two moments only, i.e. mean R and variance V allows already a highly accurate dimensioning of all subsequently hunted secondary groups etc. This "two-moment-description" of overflow traffic has been studied and suggested for groups with full access for the first time by Wilkinson and Riordan in 1955 /27,28/. This method is well known as ERT-Method and has been extended to connecting arrays with limited accessibility (gradings or link systems) by the RDA-Method /29,30/.

The variance V_1 of "rest traffic" $R_1 = A_1 \cdot B_1$ which overflows behind a first hunted group (n_1 trunks, accessibility k_1) is given by

$$V_1 = R_1 (1 + pR_1 \cdot \frac{k_1}{n_1}) \; , \; \frac{V_1}{R_1} = (1 + pR_1 \cdot \frac{k_1}{n_1}) \qquad (12)$$

with $p = \frac{1}{B_1(n_1 + 1 - A_1(1 - B_1))} - 1$ for full access of the primary group (13)

$p = \frac{1}{B_1(k_1 + 1 - A_o(1 - B_1))} - 1$ for limited access $k_1 < n_1$ of the primary group (14)

where A_o = offered traffic to a trunk group with full accessibility $k_1 = n_1$ and $B_1 = \frac{R_1}{A_1}$.

The parameter p can be drawn as a function $p(B_1, k_1)$ directly from graphs /13/.

5.3 Basic idea regarding the dimensioning of groups with offered overflow traffic

The basic idea how to dimension Secondary Groups to which peaked overflowing traffic is offered is drawn in Fig.11 for a simple array with two primary groups and one secondary (final) group.

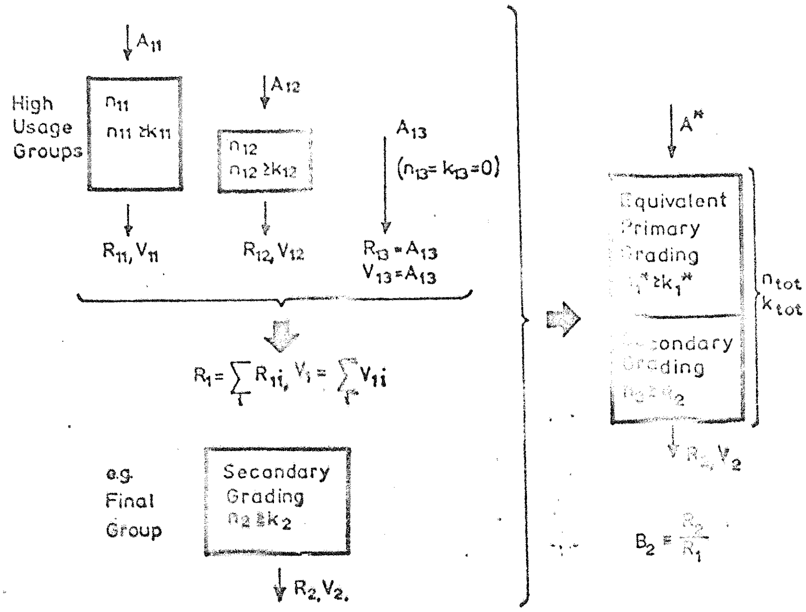


Fig. 11: The basic idea of the ERT and the RDA method to calculate the loss of groups with offered overflow traffic

Various first hunted high usage groups offer their overflowing traffics $(R_{11}, V_{11}), (R_{12}, V_{12})$,..to the final group (n_2, k_2) or eventually to a further high usage group in between. From tables one can draw the overflowing traffics R_{1i} and its variances V_{1i} as a function of the offered primary traffics A_{1i} and the structures n_{1i}, k_{1i} of the primary groups. The sum of overflowing traffic offered to the subsequently hunted group is, then, characterized by (see example above)

$$R_1 = \sum_i R_{1i} \qquad V_1 = \sum_i V_{1i} \tag{15}$$

Now, a (fictitious !) substitute primary group (SPG) can be determined. An Equivalent Random Traffic A^* is offered to this SPG causing the same sum of overflowing traffic (R_1, V_1). This SPG being suitably designed with regard to its parameters k^* and n^* is now considered as the first hunted part of one common connecting array consisting of the (fictitious) SPG a n d the following secondary trunk group; e.g. the final group in Fig.11. Therewith one can calculate the loss of the secondary group as $B_2 = \frac{R_2}{R_1}$.

5.4 Simplification

In spite of the simple basic idea, this method is however still too time consuming for telephone administrations with many hundred toll exchanges. Investigations of the telephone administration of the FRG have shown that for reasons of simplicity, one can assume a uniform ratio V/R for the sum of the overflowing traffics which is offered to a subsequently hunted group in all toll dialling centers. E.g. a ratio V/R = 1.6 is applicable according to measurements in the FRG network.

It is, however, on no account allowed to neglect the variance of offered overflow traffic. As it can be seen in Fig. 12 the increase of loss, as a consequence of the peakedness of offered overflow, cannot be tolerated.

For other networks another ratio V/R or some more tables with different ratios might be applied. But in any case, tables implying already a certain ratio V/R save any individual variance calculation and facilitate the dimensioning of groups with offered overflow enormously.

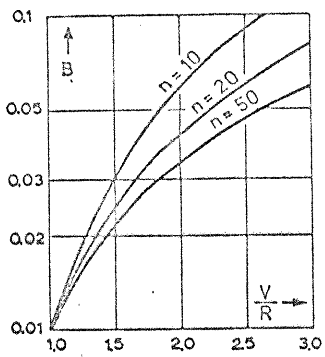


Fig. 12:
The influence of increasing V/R on the loss of full accessible groups with 10,20 and 50 trunks

5.5 Economy

The next problem to be regarded is the e c o n o m i c partition of the offered random traffics to high usage groups and the final group /31÷33/.

This partition depends on the traffic carried per last hunted trunks in the first and the following groups respectively. Furthermore it depends on the cost ratio between a trunk in the final group and in the preceding groups. The differentiation of a cost equation including these parameters yields to simple dimensioning tables. The most economic number of trunks in the first hunted high usage group can be read off as a function of the offered traffic, cost ratio and accessibility parameters. The necessary (mostly standardized) cost ratios with regard to certain trunk types in the various groups have to be tabulated by the telephone administrations

5.6 Practical Engineering

The whole dimensioning of selector and trunk groups in toll dialling centers with alternate routing is now reduced to a minimum. Only the following tables are necessary:

Fig.13 shows a table for the "normal" dimensioning of a group with offered random traffic.

Fig. 14 shows a table which is calculated for a certain accessibility k_1 of the considered high usage group, (right hand side on the top, k_1=10).

Furthermore three headlines on the left indicate three scopes of the accessibility k_{fin} which have to be regarded in the final group to which the overflow of the considered high usage group is offered. This table is considering implicitly also the economic marginal load per trunk in the final group. The corresponding table headlines containing the so-called cost factor P are, for that reason, shifted against each other. (P = cost per final trunk/cost per high usage trunk ≥ 1).

Fig.15 shows a dimensioning table which implies a constant variance to mean ratio, here V/R =1.6 . For B = 1 per cent, as in Fig.15, it is used for the dimensioning of final groups. The same type of table, however, for B = 20 per cent, is applied for intermediate high usage groups being hunted behind a first hunted group, however, before the last hunted final group. In those cases one can furthermore regard the costs per trunk in such a group by means of a table and take it into consideration for a "corrected" cost factor in the table of Fig. 14.

The uniform overflow probability B=20 per cent, applied to all high usage trunks between the first one and the final group, avoids complicated iterations. Many test calculations have proved that, even in such cases, one achieves network costs very close to the theoretical minimum if one is using this simply tabulated method.

Table for the Determination of the Number of Trunks n from the Offered Random Traffic A

B=1%

n \ k	4 . . 15 . . . [k] . . . n	n
1	. . . .	1
.	. ↓ .	.
[n]	← [A] .	.
.	. .	.
48	. . 30.8 . . . . 36.1	48
49	. . 31.5 . . . . 37.0	49
50	. . 32.3 . . . . 37.9	50

Fig.13: Table for the determination of the number of trunks n as a function of the offered random traffic A, the accessibility k and the probability of loss B

Table for the Dimensioning of High Usage Groups of First Order

k of the final group	Cost Ratio P					$k_1=10$
≤ 15	..	..	1.6	1.8	2.0	..
→ [k_{fin}]	→		[P]	2.2	2.5	..
>25	1.1	..	↓	2.5	3.0	..
	n R			n R	n R	
A = 1	..	..	↓	..	..	..
..	..	..	↓	..	..	..
[A]	→		[n R]	38 2.75	40 2.15	..
31	..	..	38 3.25	40 2.59	41 2.29	..
32	..	..	39 3.42	41 2.75	43 2.16	..
33	..	..	41 3.23	42 2.90	44 2.31	..
34	..	..	42 3.40	43 3.06	45 2.45	..
..	..	..		..	..	..

Fig.14: Table for the determination of the number of trunks n and the overflowing traffic R for high usage groups of first order as a function of the offered random traffic A, the cost ratio P and the accessibility k of the high usage group of first order and of the final group

Table for the Dimensioning of High Usage Groups of 2nd, 3rd Order etc. and for the Final Group

B = 1 %
V/R = 1.6

n \ k	6 . . 15 . . . [k] . . . n	n
1	. . . .	1
.	. ↓ .	.
[n]	← [R] .	.
.	. .	.
48	. . 27.6 . . . . . 32.8	48
49	. . 28.3 . . . . . 33.6	49
50	. . 28.9 . . . . . 34.5	50

Fig.15: Table for the determination of the number of trunks n for high usage groups of 2nd, 3rd order etc. and for the final group as a function of the offered overflow traffic R, the accessibility k and the probability B of loss or overflow resp. (according to the RDA-method)

5.7 Example

Regarding a system according to Fig. 11 with $k_2=k_{fin}=15$ and the following values for A_{1i}, k_{1i} and P_{1i} one obtains the number of trunks N_{1i}, the individual traffic rests R_{1i} and the total traffic rest R_1 by means of this table (Fig. 14) as follows:

Be given A_{11} = 34 Erl $\quad A_{12}$ = 31 Erl $\quad A_{13}$ = 23 Erl

k_{11} = 10 $\quad k_{12}$ = 10

P_{11} = 1.6 $\quad P_{12}$ = 2.0

Results $n_{11} = 42$ $n_{12} = 41$

$R_{11} = 3.40$ Erl $R_{12} = 2.29$ Erl $R_{13} = 23.00$ Erl

$R_1 = R_{11} + R_{12} + R_{13} = 28.69$ Erl

Therewith, one obtains from Fig.15 for B=1 per cent the number of trunks $n_2 = 50$.

6. Conclusion

The aim of this paper is to demonstrate that the results of teletraffic theoretical research allow, at the time being, the dimensioning of one stage as well as multi stage connecting arrays by means of handy engineering methods. Furthermore, the problem of economic telephone network planning has been solved by means of tables only and leads , as it had been examined in many cases, to network costs which differ from the theoretical minimum costs only in a range of less than $\pm$ 5 per cent.

7. Acknowlegement

The author wishes to express his thanks to the Federal German Research Society (DFG) which has sponsored a large number of concerning investigations at the University of Stuttgart.

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