

Metropolitan Networks
Estimation of
Traffic Forecast Parameters

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Estimation Of Traffic Forecast Parameters

The planning of a telecommunication network should be based upon a sound traffic forecast. A reliable traffic interest matrix is needed but is, however, difficult to achieve since recorded traffic data may be incomplete, of varying quality and perhaps not relevant in a future situation. The methodology presented here concentrates on the construction of the present traffic interest matrix, and it is hypothetical insofar as it constructs the matrix from assumed traffic characteristics using, as far as possible, the available recorded traffic data. It works step-by-step, correcting the assumed model parameter values between the steps, and it takes conceivable future changes of traffic characteristics into consideration. The scheme has a modular structure, i.e., the models are replaceable.

1. Introduction

A forecasted traffic interest matrix is needed in order to plan a telecommunication network for any future point of time T. An element of the matrix $A_{kl}^{(T)}$ should preferably denote the individual traffic interest from any traffic area k to any traffic area l. A commonly used forecasting procedure is based upon the assumptions about present traffic interests $A_{kl}^{(0)}$, the present subscriber distribution $n_k^{(0)}$, and a reliable forecast of the future subscriber distribution $n_k^{(T)}$. Furthermore, such a forecast should be made for each class of subscribers separately, the total forecast then being the aggregate of the separate ones.

More work has been spent on the study of traffic growth models, than on the study of the present traffic interests $A_k^{()}$. In fact, the preparation of such a matrix presents great difficulties. An existing network usually contains a mixture of different types of analogue equipment, in many cases both crossbar and step-by-step systems. Network losses are often quite high, which would suggest high rates of repeated call attempts. Especially in step-by-step networks, such repeated call attempts cause abnormal holding times and considerable additional inefficient traffic load on the interconnecting routes. There are no or only very limited possibilities for traffic or call dispersion measurements; nor can the recorded route traffics be used for the calculation of traffic interests, since they carry not only inefficient traffic, but also an anonymous mixture of calls of different origins and destinations.

Even if we did have a procedure for deriving the present traffic dispersion from traffic records, such a matrix would not be a relevant basis for a sound forecast, since the future network is supposed to offer improved service and less inefficient traffic compared to the present one, to show a changed traffic profile, and perhaps be subject to changed subscriber behaviour due to changed tariff policy, etc.

Summarizing these obstacles, we find that $A_k^{()}$ is:

- generally impossible or difficult to obtain from traffic records;
- of varying quality; some values will be most uncertain, others will be missing.
- not relevant in a future situation.

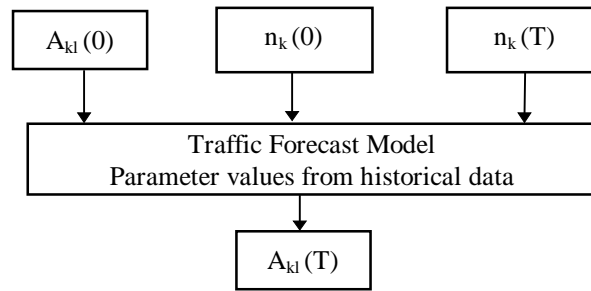


Fig. 1: Traditional forecasting scheme

What we really need is a method that utilizes available recorded data as much as reasonably possible but which is not absolutely dependent on a complete supply of such data. This implies a considerable amount of individual judgement and decision making, i.e., the model must be mixed.

The main idea of the procedure presented here is to define traffic parameter values that can be checked against traffic records in order to ensure, as far as possible, that they do not disagree with the present traffic situation. The parameters must be suitable as a basis for the future traffic interest forecast, which means that it must be possible to update the values according to expected changes in subscriber behaviour and network quality.

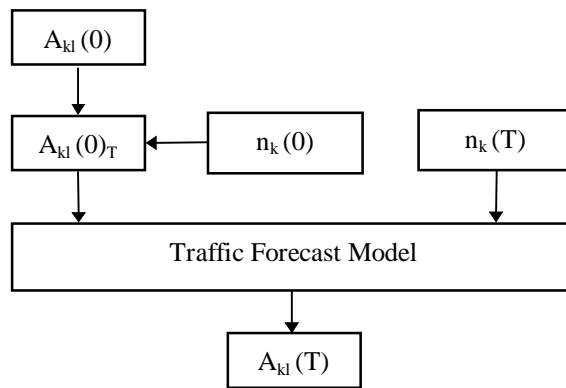


Fig. 2 : Mixed model

2. Basic Parameters

2.1 Definitions

- A = Total traffic
- a = Traffic per subscriber (main line)
- y = Call intensity
- h = Holding time
- K = Dialing time per digit
- B = Congestion level
- R = Routing vector
- d = Dispersion factor
- W = Traffic interest weight
- n = No. of subscriber lines

Subscripts:

- b,c = Subscriber class no.
- k,l = Traffic area no.
- u,v = Exchange area no.
- r = Route no.
- o = Originating
- t = Terminating
- = Total amount

- 0 = Present time
- T = Future time
- * = Recorded quantities
- (prime) means "intermediate (temporary) value"

2.2 Subscriber classes

A number of subscriber classes should be defined. A subscriber class should be reasonably homogeneous as regards traffic level and subscriber behaviour. It must, of course, also be possible to estimate the present and future distribution of the number of subscribers per class. Examples of subscriber classes are:

- a) Residentials, high and middle class
- b) Residentials, lower class
- c) Single business lines of various kinds
- d) Lines to small PBXes
- e) Lines to larger PBXes
- f) Coin boxes
- g) Data users, switched lines
- h) Data users, leased lines

2.3 Traffic areas and Exchange areas

An area where a telecommunication network exists is divided into a number of exchange areas. Traffic records are related to these exchange areas. In favourable cases, we may know some present traffic interests between exchange areas $A_{iw}^{(0)}$, as well as the number of subscribers per class b in each area, $n_{bu}^{(0)}$. For planning purposes, however, we need to forecast the future traffic interests between traffic areas $A_k^{(T)}$ rather than $A_{iw}^{(T)}$. Furthermore, we want to make separate forecasts for different subscriber classes and then aggregate those into a total forecast.

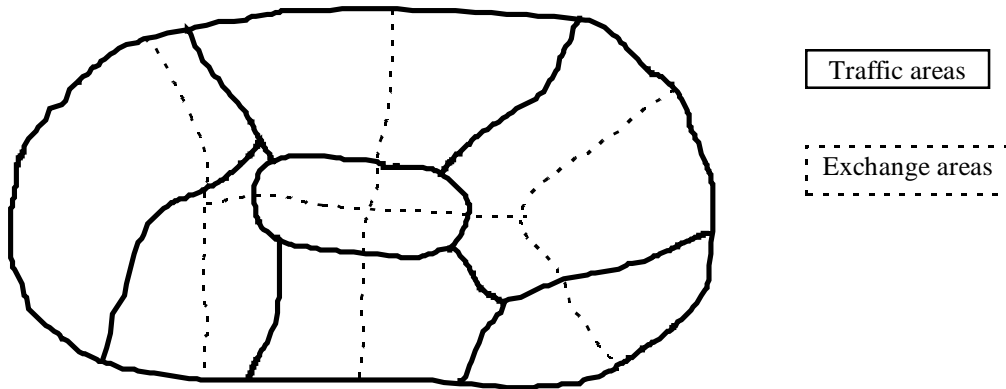


Fig. 3: : Traffic areas and Exchange areas

This means that we should divide the entire area into traffic areas. Since we need to translate back and forth between exchange areas and traffic areas during the forecasting process both for number of sub-scribers per class and for traffic interests, each traffic area should be relatively homogeneous from the subscriber class point of view.

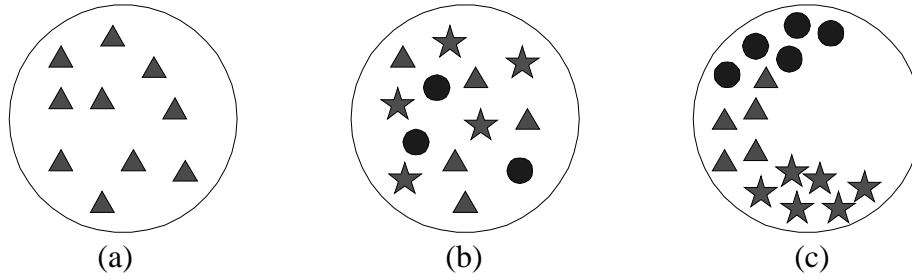


Fig. 4 Traffic areas

- (a) One subscriber class: suitable traffic area
 (b) Several classes, but well mixed: suitable traffic area
 (c) Unsuitable traffic area

Under such circumstances, we can always calculate quite simply:

$$n_{bu} = \sum_k \frac{n_{ku} \cdot n_{bk}}{n_k} \quad \text{and} \quad n_{bk} = \sum_u \frac{n_{ku} \cdot n_{bu}}{n_u}$$

since

$$n_{bku} = \sum_k \frac{n_{bu} \cdot n_{bk}}{n_k} \quad \text{and} \quad n_{bu} = \sum_k n_{bku}$$

where n_{bu} = no. of subscribers of class b in exchange area u;
 n_{bk} = no. of subscribers of class b in traffic area k; etc.

2.4 Traffic records

At least parts of the following traffic records are usually available:

For exchanges:

- Total originating and terminating traffics $A_0^{*(0)}$ and $A_t^{*(0)}$ respectively.
- Total no. of carried originating and terminating calls $y_0^{*(0)}$ and $y_t^{*(0)}$ respectively.

For traffic routes:

- Total carried traffics $A_r^{*(0)}$
- Total no. of carried calls $y_r^{*(0)}$
- Congestion level $B_r^{*(0)}$

Our matrix for present traffic interests between exchange areas contains, for the moment, only the total originating and terminating traffics, except for traffic cases when register control and end-to-end signalling is employed, where we may have records or estimates of the corresponding traffics between exchange areas $A_{uv}^{*(0)}$.

\Rightarrow					Σ
	?		$A_{uv}^{*(0)}$?	
	?	?	?	?	
	?	?		?	$A_0^{*(0)}_u$
	?	?		?	
Σ			$A_t^{*(0)}_v$?

Fig. 5: Traffic records related to the traffic matrix

= known values

Furthermore, we will see that $\sum A_0^{*(0)}$ is usually much greater than $\sum A_t^{*(0)}$. The difference is mainly due to dialling traffic for calls that fail before reaching the terminating exchange, and it is the step by-step calls that are, above all, responsible for causing this ineffective traffic. Despite network losses and the rate of re-attempts, we do not expect that dialling traffic will load the future interconnecting network. This traffic should therefore be removed from the observed originating traffic values.

What we can do so far is the following:

- (i) Define $A_u^{*(0)'} = A_0^{*(0)}$ and $A_v^{*(0)'} = A_t^{*(0)}$

as start values in the matrix, and subtract the known $A_v^{*(0)}$ values from this matrix, thus obtaining the new totals

$$A_u^{*(0)''} = A_u^{*(0)'} - \sum_v A_{uv}^{*(0)} \qquad A_v^{*(0)''} = A_v^{*(0)'} - \sum_u A_{uv}^{*(0)}$$

- (ii) Adjust $A_u^{*(0)''}$ to $A_u^{*(0)'''}$ so that

$$\sum A_u^{*(0)'''} = \sum A_v^{*(0)''}$$

That can be done in a simple way by calculating each originating traffic as:

$$A_u^{*(0)'''} = A_u^{*(0)''} \cdot \frac{\sum A_v^{*(0)''}}{\sum A_u^{*(0)''}}$$

or, on a somewhat more individualistic basis, e.g., by first calculating the overall quantity of inefficient traffic per originating call

$$h_i = \frac{\sum A_0^{*(0)} - \sum A_t^{*(0)}}{\sum y_o^{*(0)}}$$

or preferably if $y_{uv}^{*(0)}$ which corresponds to the known $A_{uv}^{*(0)}$ values are also known,

$$h_i = \frac{\sum A_0^{*(0)} - \sum A_t^{*(0)}}{\sum y_o^{*(0)} - \sum y_{uv}^{*(0)}}$$

and then adjusting each originating traffic as:

$$A_u^{*(0)'''} = A_u^{*(0)''} - y_o^{*(0)} \cdot h_i \quad \text{and} \quad A_u^{*(0)'''} = A_u^{*(0)''} - \left[y_o^{*(0)} \cdot h_i - \sum_v y_{uv}^{*(0)} \right] \cdot h_i$$

respectively.

(iii) Now we add back the $A_{uv}^{*(0)}$ values to the matrix and accept the new originating traffics as totals:

$$A_u^{*(0)} = A_u^{*(0)'''} + \sum_v A_{uv}^{*(0)} \qquad A_v^{*(0)} = A_v^{*(0)''} + \sum_u A_{uv}^{*(0)}$$

↗					Σ
	?		$A_{uv}^{*(0)}$?	
	?	?	?	?	
	?	?		?	$A_{ir}^{*(0)}$
	?	?		?	
Σ			$A_{.v}^{*(0)}$		$A_{..}^{*(0)}$

Fig. 6: adjusted and restored matrix of inter-exchange traffics

= known values

2.5 Forecast parameters

Our aim is to forecast the future traffic interests between traffic areas, $A_{kl}^{(T)}$. It is, of course, valuable from the planning point of view to have the possibility of separate forecasts for different kinds of traffic, e.g., data traffic on leased lines, business-to-business traffic, etc. But besides that, the final forecast is much more reliable if it is the aggregate of separate ones. Another point is that a forecast of total originating and terminating traffics, $A_k^{(T)}$ and $A_l^{(T)}$ respectively, generally is more accurate than the point-to-point forecast, $A_{kl}^{(T)}$. The ideal forecast is then the following:

- Originating and terminating traffics per subscriber class and traffic area are forecasted, $A_{bk}^{(T)}$ and $A_{b,l}^{(T)}$ respectively.
- These are aggregated, giving total originating and terminating traffics per traffic area, $A_k^{(T)}$ and $A_l^{(T)}$ respectively.
- Independently of the total traffic forecasts, the point-to-point traffics between subscriber classes are forecasted, $A_{bckl}^{(T)}$.
- These are aggregated, giving the point-to-point traffics for all subscribers, $A_{kl}^{(T)}$.
- The originating and terminating traffic forecasts $A_k^{(T)}$ and $A_l^{(T)}$ respectively are accepted and thus distributed over the matrix, using the separate point-to-point forecast values $A_{kl}^{(T)}$ as distribution factors.

Consequently, we need traffic forecast parameters that can be checked against available traffic records, be adapted to future conditions, and can be used for the calculation of the desired traffic quantities, in combination with subscriber distribution data. Three such forecast parameters are central for the proposed procedure.

- a_b = total originating traffic per subscriber line in subscriber class b . The property of this parameter is that it is relatively universal, i.e., there is little variation between different places of similar character and stage of development, and it is also fairly stable over time.
- d_{bc} = traffic dispersion factor. It shows how the originating traffic per subscriber of class b is spread over all classes. $\sum d_{bc} = 1$. The property of the parameter is a little less universal than the first one, i.e., it is more locally influenced and its values also change more with the development of the area.
- W_{bckl} = traffic interest weight. The parameter corresponds to the tendency of a subscriber in class b , in traffic area k to call a subscriber in class c because the latter is in area l . For example, a high class residential subscriber might show a clear tendency to call small shops provided that these shops are situated in the same area or in the city centre, but less tendency to call shops located further away or situated in a lower class residential district.

This parameter is, of course, entirely of local character, and its values may also change considerably with the development of the area. Fortunately, the individual weights can be taken as very round figures without causing serious errors in the aggregated traffic quantities.

3. Forecasting Procedure

3.1 Calculations for the present point of time

The goal is to find realistic present values of the forecast parameters $a_b^{(0)}$, $d_{bc}^{(0)}$, and $W_{bc}^{(0)}$ for well defined traffic areas. The following procedure could be applied:

- a) We collect the parts of the following data that are available:

$A_r^{*(0)}$ = Route traffics

$Y_r^{*(0)}$ = Carried call intensities on the routes

$B_r^{*(0)}$ = Congestion level on the routes

$A_0^{*(0)}$ = Originating exchange traffics

$A_t^{*(0)}$ = Terminating exchange traffics

$Y_0^{*(0)}$ = Originating carried call intensities

$Y_t^{*(0)}$ = Terminating carried call intensities

$A_{uv}^{*(0)}$ = Exchange-to-exchange traffics

$Y_{uv}^{*(0)}$ = Exchange-to-exchange call intensities

$R_{uv}^{*(0)}$ = Routing vector for step-by-step traffic

b) We define subscriber classes and traffic areas, which implies that the following relation matrices should be prepared:

$$n^{(0)} = \text{No. of class b subscribers in area k}$$

$$n_u^{(0)} = \text{No. of subscribers in traffic area k who are connected to exchange area u.}$$

Because of the homogeneity principle applied to the choice of traffic areas, $n_{bu}^{(0)}$ can be derived from these relation matrices.

c) Section 2.4 showed how recorded data could be used for a partial preparation of the traffic matrix $A_{uv}^{*(0)}$ after the removal of estimated inefficient traffic. Since the point-to-point traffics in the matrix will be used as check values during the calculation of forecast parameter values, some kind of confidence intervals should be attached to them. The size of a confidence interval depends, of course, on how the particular exchange-to-exchange traffic value was derived. This is best illustrated in the following examples:

- Let us say that the traffic from one exchange to another is carried on a direct low-loss route where it is properly recorded. The meter shows 100 erl. If we consider the possible deviation from the true mean value at 5% at most, then $A_{uvmin}^{*(0)} = 95 \text{ erl}$, $A_{uvmax}^{*(0)} = 105 \text{ erl}$.
- Now take the case when alternative routing is employed. Assume that we have recorded the carried traffic on the direct high-usage route = 80 erl. and the congestion level on the same route = 20%. If we suppose that we have estimated the point-to-point congestion at about 5%, e.g., by using a traffic route tester, then we can calculate the total traffic arriving at the terminating exchange as $80 [1-0.05] / [1-0.20] = 95 \text{ erl.}$, i.e., 80 erl. goes via the high-usage route and 15 erl. via the tandem network. But the 15 erl. figure is highly uncertain. Say there is a possible deviation of 60% or 9 erl. Therefore we can put $A_{uvmin}^{*(0)} = 86 \text{ erl.}$, and $A_{uvmax}^{*(0)} = 104 \text{ erl.}$
- Cases where a great part or all the traffic is routed via the tandem network may give rise to such uncertainty in the estimated point-to-point traffics that the value of such estimates is doubtful.

d) Now we determine the originating traffic per subscriber line in each subscriber class, $a_b^{(0)}$, in the following way: Solve the equation system:

$$\sum_b n_{bu}^{(0)} \cdot a_b^{(0)} = A_u^{*(0)} \quad u = 1, 2, \dots, U$$

where U = no. of exchange areas.

If the total number of subscriber classes equals S, then we will get $\binom{U}{S}$ sets of solutions.

The assumption that the originating traffic per subscriber in a particular class is constant irrespective of the exchange area, cannot be absolutely true, of course, and since the "known" data $n_{bu}^{(0)}$ and $A_u^{*(0)}$, furthermore, are more or less uncertain, some of the sets will look a bit strange as they will also have extreme values, e.g., negative values and very high values. Fortunately, extremely low and extremely high values generally belong to the same sets. What we do is remove those sets from the lot. From the remaining acceptable sets, we calculate the most likely values of $a_b^{(0)}$. There are several ways to do that. The simplest is to consider each class b separately and estimate $a_b^{(0)}$ as the median of all accepted values. Another way is to apply the method of least squares to each class individually, or to consider all classes simultaneously. The flexibility of the so composed set may be increased by determining a confidence interval for each $a_b^{(0)}$ value. Again, there are several possibilities. A statistically calculated 95% confidence interval could be used, or a fixed percentage around the chosen value, or, perhaps, the whole range of values from the different sets.

e) We will need the terminating traffic per subscriber line in each class $a_c^{(0)}$ as a check value when we determine the traffic dispersion factors, so we repeat the procedure as per d) above, but now solving the equation system

$$\sum_c n_c^{(0)} \cdot a_c^{(0)} = A^{*(0)} \quad v = 1, 2, \dots, U$$

Again, sets containing extreme values are rejected, and representative $a_c^{(0)}$ values and confidence intervals are calculated from those remaining.

f) Now we come to the delicate problem of determining the traffic dispersion factors $d_b^{(0)}$. The definition of d_{bc} is: the proportion of the originating traffic per subscriber line of class b that terminates among class c subscribers. Consequently, $\sum d_{bc} = 1$, and in the $d_{bc}^{(0)}$ matrix, we set the values row by row. To understand the idea, we imagine that Fig.7 is a picture shown on a visual data screen.

To guide us, our earlier determined $a_b^{(0)}$ values are shown on the left of figure 7. We should fill in the matrix on the top right, row by row, based on our experience and reasoning, and using local information. At the very bottom, the earlier determined $a_c^{(0)}$ values with their confidence intervals are displayed.

When we have set all $d_{bc}^{(0)}$ values, our computer calculates the resulting values:

$$a'_c{}^{(0)} = \frac{\sum_b n_b^{(0)} \cdot a_b^{(0)} \cdot d_{bc}^{(0)}}{n_c^{(0)}}$$

appearing immediately below the $d_{bc}^{(0)}$ matrix.

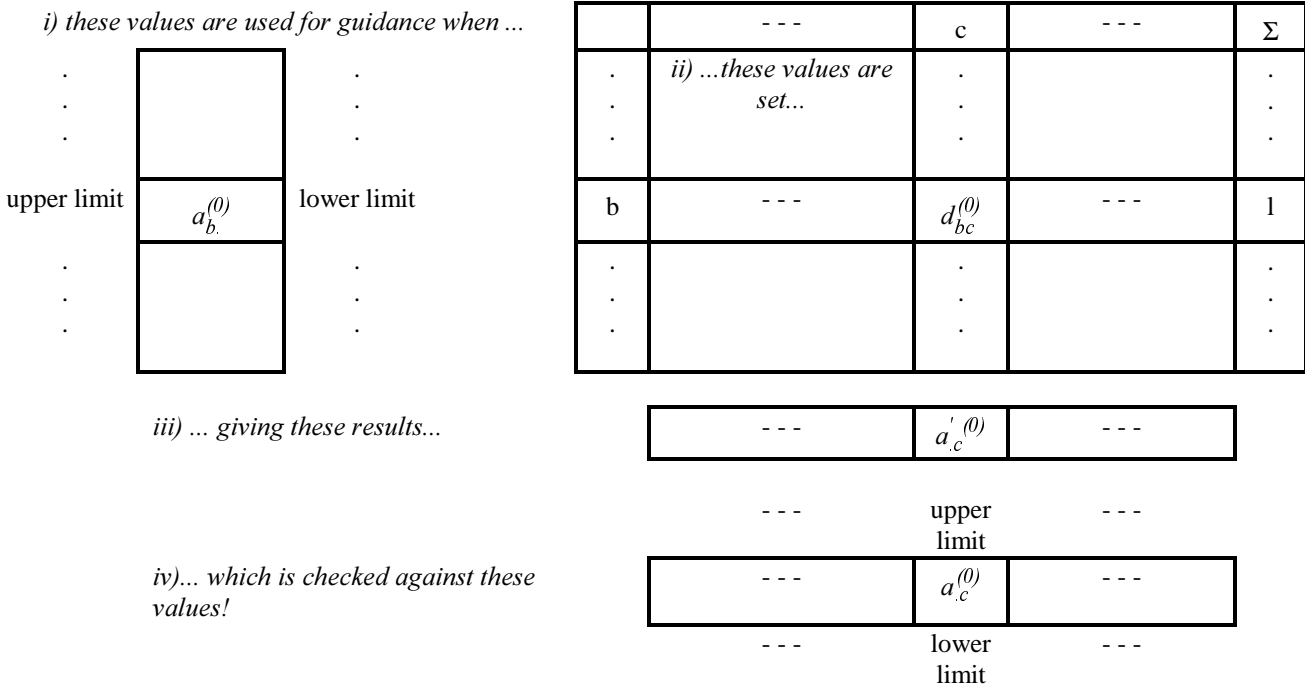


Fig. 7 : Setting and checking of traffic distribution factors

The next step is to compare these resulting $a'_c{}^{(0)}$ values with the check values $a_c^{(0)}$ displayed further below, and then decide whether the observed differences can be accepted or not. If not, the $d_{bc}^{(0)}$ matrix is revised, which is quite simple because, for example, high $a'_c{}^{(0)}$ values relate to high $d_{bc}^{(0)}$ factors, etc.

g) The traffic distribution weight W_{bckl} is defined as a measure of the tendency of a class b subscriber in traffic area k to call a class c subscriber because that subscriber is in traffic area l. Therefore, each pair of b,c values can be treated separately in the process of setting the $W_{bckl}^{(0)}$ values. Furthermore, a very limited set of round values may be

used, e.g., three values 1,2 or 3. In that case, 1="low", 2="normal", and 3="high". There may, of course, be reason to use a finer scale, viz., five values 1,2,3,4, or 5. In that case, 1="very low", 2="low", 3="normal", 4="high", and 5="very high".

Again, let us imagine that we are looking at the data display. If we set a pair of b,c values, a matrix filled with 3:s appears. The 3:s are default values, which will be used if we do not set other values.

h) All basic traffic parameters having now been determined, we can calculate:

$$A_{bckl}^{(0)} = \frac{a_b^{(0)} \cdot d_{bc}^{(0)} \cdot n_{bk}^{(0)} \cdot n_{cl}^{(0)} \cdot W_{bckl}^{(0)}}{\sum_l n_{cl}^{(0)} \cdot W_{bckl}^{(0)}}$$

$$A_{kl}^{(0)} = \sum_b \sum_c A_{bckl}^{(0)}$$

and

$$A_{uv}^{(0)} = \sum_k \sum_l A_{kl}^{(0)} \cdot \frac{n_{ku}^{(0)} \cdot n_{lv}^{(0)}}{n_k^{(0)} \cdot n_l^{(0)}}$$

The values $A_{uv}^{(0)}$ can be checked against the known $A_{uv}^{*(0)}$ values (if any). But the recorded route traffics $A_r^{*(0)}$ should also be utilized for checking!

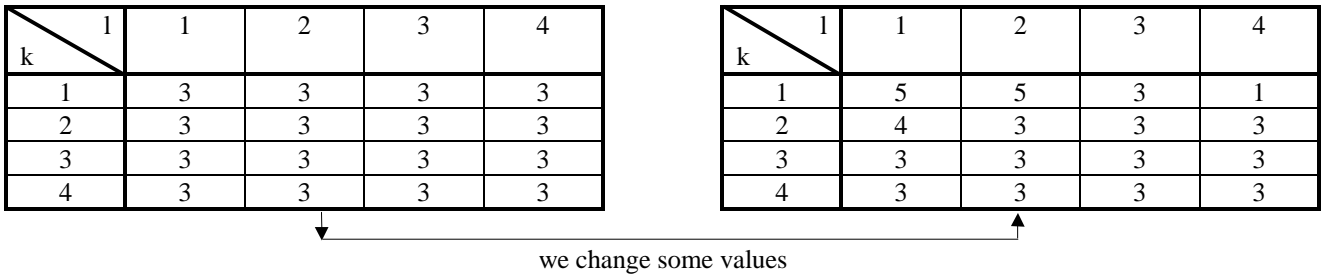


Fig. 8 : Setting of $W_{bckl}^{(0)}$ - values

i) Calculation of hypothetical route traffic values: suppose that in all y call attempts are made in exchange u in order that some traffic reaches exchange v. Suppose also that the calls are set up in a step-by-step part of the network, via routes nos.1,2,3,4,5 in that order, where route no.1 is the outgoing route from exchange u, and route no.4 is the incoming route to exchange v. The congestion levels are B_1 , B_2 , B_3 , and B_4 respectively. It can then be shown that about $y(1 - B_1) (B_2)$ calls are carried by route 1 but rejected by route 2. What happened on route 1 was that the next digit was dialled and after that the call was lost. To go one step further: $y(1 - B_1) (B_2) (B_3)$ calls are carried by route 1, and accepted by route 2, but rejected from route 3. For these calls, 2 digits were dialled after the acceptance on route 1.

By proceeding with the same kind of reasoning and neglecting some disturbing factors like strange subscriber behaviour, etc., but starting from the terminating exchange instead, we can calculate, approximately, the contribution from traffic case uv to the carried traffic on route r as:

$$A_{ruv}^{(0)} = y_{uv}^{(0)} \cdot \left[\frac{K \cdot B_2}{(1 - B_2)(1 - B_3)(1 - B_4)} + \frac{2 \cdot K \cdot B_3}{(1 - B_3)(1 - B_4)} + \frac{3 \cdot K \cdot B_4}{1 - B_4} + 3 \cdot K + h_t^{(0)} \right]$$

where

K = Dialling time per digit

$h_t^{(0)}$ = Remaining holding time for calls that reach the terminating exchanges

$h_{uv}^{(0)}$ = No. of calls from exchange u that reach exchange v.

The general calculation procedure may be as follows:

- Estimate $h_t^{(0)} = \frac{A_t^{*(0)}}{y_t^{*(0)}}$
- Estimate $y^{(0)} = \frac{A^{(0)}}{h_t^{(0)}}$
- Estimate the contribution of traffic on route r from traffic case uv as: $A_{ruv}^{(0)} = f[A_{uv}^{(0)}, R_{uv}^{(0)}, B_{uv}^{(0)}]$

where

$A^{(0)}$ was calculated earlier

$R_{uv}^{(0)}$ is the routing vector which tells us which routes are used, and in what order

$B_{uv}^{(0)}$ are the congestion levels for the routes defined in the routing vector. Should the individual congestion values not be known, one solution is to use an estimated common average value instead.

- The $A_{ruv}^{(0)}$ values can now be aggregated into total route traffics:

$$A_r^{(0)} = \sum_u \sum_v A_{ruv}^{(0)}$$

j) It is now time to check our hypothetical values $A_{uv}^{(0)}$ and $A_r^{(0)}$ against the traffic records $A_{uv}^{*(0)}$ and $A_r^{*(0)}$ respectively. Differences that are too large mainly indicate that our $W_{bckl}^{(0)}$ values should be revised. However, smaller deviations can be neglected since the whole business up to this point has been quite a tricky one.

We conveniently let our computer prepare two lists to be shown on the data display; one list displays bad route traffic cases, and the other one shows the bad exchange-to-exchange traffic cases. The computer should pick the worst case first, then the next to worse, etc.

Now, large absolute deviations are more serious than small ones, but on the other hand, large relative deviations are also more serious than small ones. Therefore we must make a compromise between these two principles. Furthermore, we should also make an allowance for certain reasonable variations around the recorded value, say p% for route traffics. As an example, the expression:

$$\frac{\left[\left| A_r^{*(0)} - A_r^{(0)} \right| - A_r^{*(0)} \cdot \frac{P}{100} \right]^2}{A_r^{*(0)}}$$

could be used to find the worst case for the route traffic list. Fig.9 shows how this list could be designed. The exchange-to-exchange traffic list is prepared in a similar fashion. One way to calculate the confidence intervals for exchange-to-exchange traffics was described in section b) above.

$u = .., v = .., A_r^{*(0)} = .., A_r^{(0)} = ..$					
b	c	k	l	W_{bckl}	Contribution to $A_r^{(0)}$

Fig. 9 : List for route traffic check

k) So far, we have estimated $a_b^{(0)}$ as values common to all exchange areas. This assumption seems to be the only logical one since exchange areas are neither homogeneous from the socio-economic nor from the subscriber category point of view. What we actually need for planning, however, are forecast parameters related to traffic areas, and such areas will be chosen so as to be homogeneous. This means that it will usually be possible to identify the specific socio-economic character of each particular area.

This again raises the possibility of defining different a_b values for different areas, k, viz. $a_{b,k}$, which will greatly refine and improve our forecasts.

The estimation procedure will be as follows:

1. keep $W_b^{(0)}$ (no change);
2. keep $d_{bc}^{(0)}$ (no change);
3. set $a_{b,k}^{(0)}$ using the earlier obtained $a_b^{(0)}$ values for guidance;
4. Calculate hypothetical point-to-point traffics $A'_{uv}^{(0)}$ as:

$$A'_{uv}^{(0)} = \sum_k \sum_l A'_{kl}^{(0)} \cdot \frac{n_{ku}^{(0)} \cdot n_{lv}^{(0)}}{n_k^{(0)} \cdot n_l^{(0)}}$$

where

$$A'_{kl}^{(0)} = \sum_b \sum_c A'_{bckl}^{(0)}$$

and

$$A'_{bckl}^{(0)} = a_b^{(0)} \cdot d_{bc}^{(0)} \cdot n_{bk}^{(0)} \cdot \frac{n_{cl}^{(0)} \cdot W_{bckl}^{(0)}}{\sum_l n_{cl}^{(0)} \cdot W_{bckl}^{(0)}}$$

5. Checking the hypothetical values $A'_{uv}^{(0)}$ against the already approved $A_{uv}^{(0)}$ values (see para 3.1.j), adjust $A_{b,k}^{(0)}$ until a reasonable agreement is obtained.

6. If the result is unsatisfactory, $W_{b k}^{(0)}$ and/or $d_b^{(0)}$ values can be revised.

3.2 Calculations for the future point of time

The main object of this paper has been to present a procedure to find the present values of some traffic parameters that are important for a future traffic forecast. Therefore only brief comments will be made on how these parameters should be updated such that they continue to be relevant in a future situation.

The traffic profile for the hours of the day is often quite deformed in older networks. For example, the traffic ratio of the present busy hour to all hours might be, say, 1/12, while if the network were working at a good quality of service level, the value of the same ratio would be, say, 1/8. This indicates that the traffic parameters need to be revised. Depending on how much we know, or can reasonably guess, about the present conditions, this revision could be done in several ways. Two examples:

First example:

1. Adjust the $A_{w'}^{(0)}$ values individually for expected changes in the traffic profiles.
2. Calculate new $A_u^{(0)}$ values.
3. Calculate new sets of $a_b^{(0)}$, corresponding to the sets that were accepted previously.
4. Calculate the new $a_b^{(0)}$ values but do not change $d_b^{(0)}$ or $W_{b k}^{(0)}$!

Second example:

Revise the $a_b^{(0)}$ values directly. Then $a_b^{(0)}$, $d_b^{(0)}$ and $W_{b k}^{(0)}$ should be updated to reflect the expected future conditions of development and subscriber characteristics, $a_b^{(T)}$, $d_b^{(T)}$ and $W_b^{(T)}$ respectively. Combining them with the subscriber forecast $n_b^{(T)}$, results in the calculation of the future traffic interest matrices.

4. Conclusions

The forecasting procedure presented here has the following properties:

1. Recorded data are used as far as reasonably possible for the calculation of forecast parameter values.
2. The forecaster's experience and local knowledge are used for setting hypothetical values of the remaining forecast parameters.
3. The hypothetical values are utilized to calculate quantities that can be checked against recorded data.
4. Where serious deviations are obtained, the forecast parameter values are revised by decisions made by the forecaster.
5. The calculations are based upon simple and replaceable algorithms, suitable for computer applications. Personal computers can very well be used.
6. It is a step-by-step procedure where judgement and decision-making are essential elements for each step. The procedure is thus best suited to interactive use.
7. The sensitivity of the forecast, based on variations of the basic parameter values, is therefore easily investigated.
8. The forecast is, likewise, easily updated when more traffic data has been collected.