TRAFFIC INTEREST MATRICES—
A FORECASTING SCHEME FOR DEVELOPING NETWORKS

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ABSTRACT

The planning of a telecommunications network should be based upon a sound traffic forecast. A reliable traffic interest matrix is then needed but is however difficult to arrive at since recorded traffic data may be incomplete, of varying quality and perhaps not relevant for the future situation. The methodology presented here concentrates on the construction of the present traffic interest matrix, and it is hypothetical insofar as it builds up the matrix from assumed traffic characteristics but at the same time it utilizes available recorded traffic data as far as possible. It works stepwise, with correction of 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

When planning a telecommunications network for any future point of time T, the forecasted traffic interest matrix is needed. 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 scheme is based upon the assumed knowledge of the 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.

Much work has been spent on the study of traffic growth models, less on the study of the present traffic interests \( A_{kl}(0) \). The preparation of such a matrix offers, however, in practice great difficulties. The existing network contains usually a mixture of different types of analogue equipment, in many cases both crossbar and step-by-step systems. The network losses are often quite high, indicating also 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 limited possibilities for traffic dispersion measurements; neither may the recorded route traffic 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 after all had a method for derivation of the present traffic dispersion from the traffic records, such a matrix would still not be a relevant basis for a sound forecast, since the future network is supposed to offer an improved service and less inefficient traffic compared to the present one, to show a changed traffic profile, and maybe be subject to changed subscriber behaviour due to changed tariff policy, etc.

Summarizing these obstacles, we find that \( A_{kl}(0) \) is,

i) generally impossible or difficult to obtain from traffic records,

ii) of varying quality: some values will be most uncertain, others will be missing,

iii) not relevant for the future situation.

\[ A_{kl}(0) \]
\[ n_k(0) \]
\[ n_k(T) \]

Traffic Forecast Model
Parameter values from historical data

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Fig. 1 Traditional forecasting scheme.

What we really need is a method that utilizes available recorded data as far as reasonably possible but is not being 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 scheme presented here is then 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 the values must be possible to update according to expected changes of subscriber behaviour and network quality.
2. BASIC PARAMETERS

2.1 Definitions

A Total traffic
a Traffic per subscriber line
y Call intensity
h Holding time
D Dialling 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
T Total amount
O Present time
T Future time
* Recorded quantities

2.2 Subscriber Classes

A number of subscriber classes should be defined. A subscriber class should be reasonably homogenous as concerns 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 telecommunications 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 $A_{uv}(O)$, and also the number of subscribers per class b in each area, $n_{bu}(O)$. For planning purposes, however, we need to forecast the future traffic interests between traffic areas $A_{kl}(T)$ rather than $A_{uv}(T)$. Furthermore, we want to make separate forecasts for different subscriber classes and then aggregate those into a total forecast.

This means that we should divide the entire area into traffic areas. Since we have a need to translate forth and back between exchange areas and traffic areas during the forecasting process in regard both to the number of subscribers per class and to the traffic interests, each traffic area should be relatively homogenous from subscriber class point of view.

If this is fulfilled, we can always quite simply calculate

$$n_{bu} = \sum_k n_{ku} \cdot n_{bk}/n_k$$

and

$$n_{bk} = \sum_u n_{ku} \cdot n_{bu}/n_u$$

since

$$n_{bku} = n_{ku} \cdot n_{bk}/n_k$$

and

$$n_{bu} = \sum_k n_{bku}$$

Fig. 2 Mixed model.

Fig. 3 Traffic areas and Exchange areas.

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

- a) Total originating and terminating traffics \( A^*_b(0) \) resp. \( A^*_b(0) \)
- b) Total no. of carried originating and terminating calls \( y^*_b(0) \) resp. \( y^*_b(0) \)

For traffic routes,

- c) Total carried traffics \( A^*_b(0) \)
- d) Total no. of carried calls \( y^*_b(0) \)
- e) Congestion Level \( B^*_b(0) \)

Our matrix for present traffic interests between exchange areas contains for the moment then 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 \( A^*_uv(0) \) and \( A^*_vu(0) \).

Fig. 5 Traffic records related to the traffic matrix. = Known values.

Furthermore, we will see that \( \sum A^*_b(0) \) usually is much greater than \( \sum A^*_b(0) \). 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 by far play the dominating role for the occurrence of this ineffective traffic. Irrespective of the network losses and of the rate of re-attempts, we do not expect that dialling traffic is going to 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:

1) Define \( A^*_b(0) = A^*_b(0) \) as start values in the matrix, and subtract the known \( A^*_uv(0) \)-values from this matrix, thus obtaining the new totals

\[
A^*_b(0)'' = A^*_b(0)' - \sum A^*_uv(0)
\]

\[
A^*_v(0)'' = A^*_v(0)' - \sum A^*_uv(0)
\]

2) Adjust \( A^*_b(0)'' \) into \( A^*_b(0)'' \) so that

\[
\sum A^*_b(0)'' = \sum A^*_v(0)''
\]

That may be done in a simple way, by calculating each originating traffic as

\[
A^*_b(0)''' = A^*_b(0)''' \cdot [\sum A^*_uv(0)'' / \sum A^*_uv(0)'']
\]

or on a somewhat more individualistic basis, e.g.

by first calculating the overall quantity of inefficient traffic per originating call

\[
h_i = \left[ \sum A^*_b(0)''' / \sum y^*_b(0) \right] - y^*_b(0)
\]

or preferably, if \( y^*_uv(0) \) corresponding to the known \( A^*_uv(0) \)-values also are known,

\[
h_i = \left[ \sum A^*_b(0)''' / \sum y^*_b(0) \right] - y^*_uv(0)
\]

and then adjusting each originating traffic as

\[
A^*_b(0)''' = A^*_b(0)''' - y^*_b(0) \cdot h_i
\]

resp.

\[
A^*_v(0)''' = A^*_v(0)''' - \sum_\nu y^*_uv(0) \cdot h_i
\]

3) Now we add back the \( A^*_uv(0) \)-values to the matrix again and accept the new originating traffics as totals:

\[
A^*_b(0) = A^*_b(0)''' + \sum_\nu A^*_uv(0)
\]

\[
A^*_v(0) = A^*_v(0)''' + \sum_u A^*_uv(0)
\]

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, \( A_bL(T) \). It is of course valuable from 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, \( A_b(0) \) resp. \( A_L(T) \), generally is more accurate than the point-to-point forecast, \( A_bL(T) \). The ideal forecast is then the following:

1) Originating and terminating traffics per subscriber class and traffic area are forecasted, \( A_{bk}(T) \) resp. \( A_{bL}(T) \).

2) These are aggregated, giving total originating and terminating traffics per traffic area, \( A_bL(T) \) resp. \( A_{bL}(T) \).

3) Independently of the total traffic forecasts, the point-to-point traffics between sub-
scriber classes are forecasted, \( A_{bkc}(T) \).

iv) These are aggregated, giving the point-to-point traffics for all subscribers, \( A_k(T) \).

v) The originating and terminating traffic forecasts \( A_k(T) \) and \( A_{LT}(T) \) are trusted and thus distributed over the matrix, using the separate point-to-point forecast values \( A_k(T) \) as distribution factors.

We need consequently such traffic forecast parameters as can be checked against available traffic records, be adapted to the future conditions, and in combination with the subscriber distribution data can be used for calculation of the desired traffic quantities. Three such forecast parameters are central for the proposed scheme:

i) \( a_{bk} \) = total originating traffic per subscriber line in subscriber class b. The property of this parameter is that it is relatively universal, i.e. it varies not too much between different places of similar character and stage of development, and it is also rather stable over time.

ii) \( d_{bc} \) = traffic dispersion factor, 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 universality than that of the first one, i.e. it is more locally influenced and it's values change also more with the development of the area.

iii) \( w_{bkcv} \) = traffic interest weight. The parameter corresponds to the tendency that a subscriber of class b and belonging to traffic area k has to call a subscriber of class c due to the fact that the latter belongs to area l. For example, a high class residential subscriber might have a clear tendency to call small shops, provided that these shops are situated in the same area or in the city center, but a diminutive tendency to do the same if they are far away or are situated in a lower class residential district. This parameter is of course of completely local character, and it's 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 \( a_{bk}(O) \), \( d_{bc}(O) \) and \( w_{bkcv}(O) \) for well-defined traffic areas. The following procedure could be applied:

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

\( A^2(O) \) = Route traffics
\( y^2(O) \) = Carried call intensities on the routes
\( B^2(O) \) = Congestion level on the routes
\( A^2(O) \) = Originating exchange traffics
\( y^2(O) \) = Originating carried call intensities
\( A^2(O) \) = Terminating exchange traffics
\( y^2(O) \) = Terminating carried call intensities
\( A^{UV}(O) \) = Exchange-to-exchange traffics
\( y^{UV}(O) \) = Exchange-to-exchange carried call intensities
\( R^{UV}(O) \) = 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:

\( n_{bk}(O) \) = No. of subscribers of class b in area k
\( n_{ku}(O) \) = No. of subscribers in traffic area k that are connected to exchange area u

Because of the homogeneity principle applied to the choice of traffic areas, \( n_{ku}(O) \) can be derived from these relation matrices.

c) In section 2.4 was shown how the recorded data could be used for a partial preparation of the traffic matrix \( A_k(O) \) 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 exemplified by some examples:

i) 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, say 100 erl. If we consider the possible deviation from the true mean value being at most 5%, then \( A_{UV}(O)_{min} = 95 \) erl., \( A_{UV}(O)_{max} = 105 \) erl.

ii) Take now the case when alternative routing is employed. Say 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 to about 5% e.g. by using a traffic route tester, then we may calculate the total traffic arriving to the terminating exchange as 80\( [1-0.05]/[1-0.20] = 95 \) 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 that there is a possible deviation of 60% or 9 erl. Therefore, we may put \( A_{UV}(O)_{min} = 86 \) erl., and \( A_{UV}(O)_{max} = 104 \) erl.

iii) Cases where a great part or the whole traffic is routed via the tandem network may give rise to such uncertainty of estimated point-to-point traffics that the value of such estimate is doubtful.

d) Now we determine the originating traffic per subscriber line in each subscriber class, \( a_{bk}(O) \), in the following way:

\[ \sum_b n_{bk}(O) \cdot a_{bk}(O) = A^*_k(O) \]

where \( U = \) no. of exchange areas.

If there are in all S subscriber classes, we will get \( U \) sets of solutions.

Since the assumption that the originating traffic per subscriber belonging to a particular class is constant irrespective of the exchange area of course can not be absolutely true, and the "known" data \( n_{bk}(O) \) and \( A^*_k(O) \) furthermore are more or less uncertain, some of the sets will look a bit strange, as they will comprise also extreme values, e.g. negative values and very high values as well. Fortunately, extremely low and extremely high values generally belong to the same sets. What we do is to remove those sets from the lot. From the remaining acceptable sets we calculate the most likely values of \( a_{bk}(O) \). There are seve-
eral possibilities to do that. The simplest way is to consider each class b separately and estimate \( a_{b,c}(0) \) 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 also a confidence interval for each \( a_{b,c}(0) \) -value.

Again, there are several possibilities. A statistically calculated 95% confidence interval could be used, but also a fixed percentage around the chosen value, or maybe the whole range of values from the different sets.

e) We will need the terminating traffic per subscriber line in each class \( a_{b,c}(0) \) 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

\[
\sum c n_{bc}(0) \cdot a_{c}(0) = A_{bc}(0)
\]

\[ v = 1,2,\ldots U \]

Again, sets containing extreme values are rejected, and representative \( a_{c}(0) \) -values and confidence intervals are calculated from the remaining ones.

f) Now we come to the delicate problem of determining the traffic dispersion factors \( d_{bc}(0) \). 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. We will understand the idea by imagining that Fig. 7 is a picture shown on a visual data screen.

To our guidance, our earlier determined \( a_{b,c}(0) \) -values are shown to the left. The matrix on the top right should be filled up by us, from experience and through local knowledge, and by reasoning, row by row. At the extreme 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

\[
a_{bc}(0) = \left[ \sum n_{bc}(0) \cdot a_{b,c}(0) \cdot d_{bc}(0) \right] / n_{c}(0),
\]

appearing immediately below the \( d_{bc}(0) \) -matrix. Next step is to compare these resulting \( a_{bc}(0) \) -values with the check values \( a_{c}(0) \) displayed further below, and to decide whether the observed differences can be accepted or not. If not, the \( d_{bc}(0) \) -matrix is revised, which is quite simple because e.g. high \( a_{bc}(0) \) -values relate to high \( d_{bc}(0) \) -factors, etc.

g) The traffic distribution weight \( W_{bkcl} \) is defined as a measure of the tendency that a subscriber of class b and belonging to traffic area k has to call a subscriber of class c, due to the fact that that subscriber belongs to traffic area l. Therefore, each pair of \( b, c \) -values can be treated separately in the process of setting the \( W_{bkcl}(0) \) -values. Furthermore, a very limited set of round values can 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, e.g. 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 now having been determined, we can calculate

\[
A_{bkcl}(0) = \left[ a_{b,c}(0) \cdot d_{bc}(0) \cdot n_{bk} \right] \cdot \left[ n_{cl}(0) \cdot W_{bkcl}(0) / \sum n_{cl}(0) \cdot W_{bkcl}(0) \right]
\]

\[
\begin{array}{ccc|c}
1 & i) & \cdots & \cdots & c \\
& ii) & \cdots & \cdots & \Sigma \\
\hline
b & \cdots & d_{bc}(0) & \cdots & 1 \\
\end{array}
\]

...these values are set...

\[
\begin{array}{ccc|c}
\hline
\text{upper limit} & a_{b}(0) & \cdots & \text{lower limit} \\
\end{array}
\]

...giving this result...

\[
\begin{array}{ccc|c}
\hline
\text{upper limit} & a_{c}(0) & \cdots & \text{lower limit} \\
\end{array}
\]

...which is checked against these values!

Fig. 7 Setting and checking of traffic distribution factors.
The values \( A_{\text{uv}}(0) \) can be checked against the known \( A_{\text{uv}}^* (0) \)-values (if any). But the recorded route traffics \( A_{\text{uv}}^* (0) \) should also be utilized for checking!

\[
A_{\text{kl}}(0) = \sum_{b} \sum_{c} A_{bkcl}(0)
\]

and

\[
A_{\text{uv}}(0) = \sum_{k} \sum_{l} A_{kl}(0) \cdot [n_{ku}(0) - n_{lv}(0)] / [n_k(0) - n_l(0)]
\]

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

The general calculation procedure may be as follows:

i) Estimate \( h_t(0) = \{ \Sigma A_{\text{vu}}^*(0) \} / \{ \Sigma Y_{\text{vu}}(0) \} \) 

ii) Estimate \( Y_{\text{uv}}(0) = A_{\text{uv}}(0) / h_t(0) \) 

iii) Estimate the contribution of traffic on route \( r \) from traffic case \( uv \) as

\[
A_{r \text{uv}}(0) = f[A_{\text{uv}}(0), R_{\text{uv}}(0), B_{\text{uv}}(0)]
\]

where \( A_{\text{uv}}(0) \) is calculated earlier 

\( R_{\text{uv}}(0) \) is the routing vector, telling us which routes are used, and in what order 

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

iv) The \( A_{r \text{uv}}(0) \)-values can now be aggregated into total route traffics:

\[
A_r(0) = \sum_u \sum_v A_{r \text{uv}}(0)
\]

j) It is now time to check our hypothetical values \( A_{r \text{uv}}(0) \) and \( A_r(0) \) against the traffic records \( A_{r \text{uv}}^*(0) \) resp. \( A_r^*(0) \). Too large differences indicate that, primarily, our \( W_{\text{bkcl}}(0) \)-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 worst one, 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

\[
\left| \frac{A_{r \text{uv}}(0) - A_{r \text{uv}}^*(0)}{A_{r \text{uv}}^*(0)} \right| \cdot 100 / 100^2 / A_r^*(0)
\]

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 analogously. One way of calculating the confidence intervals for exchange-to-exchange traffics was described in section b) above.

\[
A_{r \text{uv}}(0) = Y_{\text{uv}}(0) \cdot [D \cdot B_2 / [1 - B_3] - [1 - B_3] \cdot [1 - B_4]] + 2 \cdot D \cdot B_3 / [1 - B_3] - [1 - B_4] + 3 \cdot D \cdot B_4 / [1 - B_4] + 3 \cdot D \cdot h_t(0)]
\]

where

\( D \) = Dialling time per digit 

\( h_t(0) \) = Remaining holding time for calls that reach the terminating exchanges 

\( Y_{\text{uv}}(0) \) = No. of calls from exchange \( u \) that reach exchange \( v \)

\[
\begin{array}{cccc}
| b | c | k | l |
\hline
1 & 2 & 3 & 4 \\
1 & 3 & 3 & 3 \\
2 & 3 & 3 & 3 \\
3 & 3 & 3 & 3 \\
4 & 3 & 3 & 3 \\
\end{array}
\]

We change some of the values....

Fig. 8 Setting of \( W_{\text{bkcl}}(0) \)-values.

i) Calculation of hypothetical route traffic values: Suppose that totally \( y \) call attempts are made in exchange \( u \) in order that some traffic shall reach 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 and 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 \( B_4 \), resp. It can then be shown, that about \( y \cdot [1 - B_3] \cdot [1 - B_3] \cdot [1 - B_4] \) calls are carried by route 1 but rejected by route 2. What happened on route 1 was that next digit was dialled, and after that the call was lost. To go one step further: \( y \cdot [1 - B_3] \cdot [1 - B_3] \cdot [1 - B_3] \cdot [1 - B_4] \) 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 may calculate, approximately, the contribution from traffic case \( uv \) to the carried traffic on route \( r \) as

\[
A_{r \text{uv}}(0) = Y_{\text{uv}}(0) \cdot [D \cdot B_2 / [1 - B_3] - [1 - B_3] \cdot [1 - B_4]] + 2 \cdot D \cdot B_3 / [1 - B_3] - [1 - B_4] + 3 \cdot D \cdot B_4 / [1 - B_4] + 3 \cdot D \cdot h_t(0)]
\]

where

\( D \) = Dialling time per digit 

\( h_t(0) \) = Remaining holding time for calls that reach the terminating exchanges 

\( Y_{\text{uv}}(0) \) = No. of calls from exchange \( u \) that reach exchange \( v \)

\[
\begin{array}{cccc}
| b | c | k | l |
\hline
1 & 2 & 3 & 4 \\
1 & 3 & 3 & 3 \\
2 & 3 & 3 & 3 \\
3 & 3 & 3 & 3 \\
4 & 3 & 3 & 3 \\
\end{array}
\]

We change some of the values....

Fig. 8 Setting of \( W_{\text{bkcl}}(0) \)-values.
3.2 Calculations for the Future Point of Time

The main task of this paper is to illustrate a way of finding the present values of some traffic parameters that are important for the future traffic forecast. Therefore, only some brief comments will be made as to how these parameters should be updated in order to be relevant for that future situation.

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

First example:
1) Adjust the $A_{uv}(O)$ -values individually, for expected changes of the traffic profiles.
2) Calculate new $A_{uv}(O)$ -values.
3) Calculate new sets of $a_{b}(O)$, corresponding to the sets that were accepted before.
4) Calculate the new $a_{b}(O)$ -values, but do not change $d_{bc}(O)$ or $W_{bkcl}$.

Second example:
1) Revise the $a_{b}(O)$ -values directly.
After that, $a_{b}(O)$, $d_{bc}(O)$ and $W_{bkcl}(O)$ should be updated to the expected future conditions of development and subscriber characteristics, $a_{b}(T)$, $d_{bc}(T)$ resp. $W_{bkcl}(T)$. Combining them with the subscriber forecast $m_{bk}(T)$, the future traffic interest matrices are calculated.

4. CONCLUSIONS

The forecasting scheme 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 is 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 through decisions made by the forecaster.
5) The calculations are based upon simple and replaceable algorithms, suitable for computer applications. Personal computers may very well be used.
6) The scheme works stepwise. Judgement and decision-making are essential elements of each step. The scheme is thus best suited for interactive use.
7) The sensitivity of the forecast due to variations of the basic parameter values is therefore easily investigated.
8) The forecast is likewise easily updated when more traffic data are being collected.