IMPROVED UTILISATION OF THE TELEPHONE NETWORK THROUGH INTRODUCTION OF DIFFERENTIATED RATES

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ABSTRACT

During the seventies several countries have introduced differentiated rates to improve the utilization of the telephone network. The Norwegian Telecommunications Administration has introduced two main tariff changes concerning periodic pulse metering (PPM) for local calls and reduced rates for long distance calls during periods of low traffic density.

It is desirable to construct a model which describes the interaction between traffic and tariffs. In the present situation, however, several factors cause uncertainty. In this paper different factors influencing the long distance telephone traffic are studied in order to establish appropriate rates.

Prior to the introduction of the new tariff structure, extensive traffic measurements have been carried out. Results from these were compared to measurements taken after the introduction. Measurements were made on 115 trunk groups in service throughout Norway. The recording periods are parts of December 1977, March 1978 and December 1978. In addition more detailed measurements have been carried out in some exchanges.

In evaluating the effect of tariff change, it is not sufficient to analyse the traffic measurements only. It is also necessary to determine the percentage of the subscribers reacting to the change in tariffs.

The Norwegian Telecommunications Administration has in several stages informed the subscribers about the new tariff change for long distance calls. During April 1978 and December 1978 sample surveys consisting of 1500-1600 households distributed over the whole country, has been carried out showing that a significant part of the subscribers had not noticed the tariff changes.

1 DIFFERENTIATION OF THE TARIFFS FOR LONG-DISTANCE CALLS

1.1 Pilot survey

January 1 1976 the tariffs for long-distance calls were reduced by 40% in non-busy hours in Nordland, a limited geographical area in the north of Norway. The aim of this pilot survey was to study the effect of reduced rates and decide whether or not to introduce the reduced rates throughout the country.

The result was that the traffic volume in periods with reduced rates increased by 18%. It wasn't however neither possible to discover any significant changes in the busy hour traffic volume nor any shift of the busy period from morning to afternoon.

1.2 Reduced rates for long distance calls in non-busy hours

January 1 1978 the tariffs for long-distance calls were reduced 25% in non-busy hours throughout the country. The reduced tariffs were used on working-days between 8 PM and 8 AM and on Saturdays and Sundays. The aim of this tariff reduction was to improve the utilization of the network by spreading out the traffic.

1.3 Existing tariffs for long distance traffic

In Norway the tariffs also depend upon the distance between the A- and B-subscriber. There are two Zones: Zone 1 for "call distance" below 50 km, Zone 2 for "call distance" above 50 km.

Table 1.1 The interval between two subsequent meter pulses for long distance dialling.

<table>
<thead>
<tr>
<th>Time of the day</th>
<th>Working days between 8 AM and 8 PM</th>
<th>Working days between 8 PM and 8 AM, Saturday and Sundays</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long distance dialling below 50 km</td>
<td>36 s</td>
<td>48 s</td>
</tr>
<tr>
<td>Long distance dialling above 50 km</td>
<td>20 s</td>
<td>26.7 s</td>
</tr>
</tbody>
</table>

Today (1979) the price per meter pulse is kr 0.67.

2 TRAFFIC VOLUME MEASUREMENTS

2.1 Measurement arrangement

To study the effect of reduced evening rates intensive measurements have been undertaken in the Norwegian telephone network. Two types of measurement will be dealt with:

- Intensive measurements have been carried out on toll routes for a number of exchanges spread over the country. The measurements were performed one week in December 1977, March 1978 and December 1978. From these measurements we have the traffic volume for the working days accumulated at 8 AM, 9 AM, 10 AM, 1030 AM, 11 AM, 1130 AM, 5 PM, 6 PM, 8 PM, 9 PM. In addition the total traffic volume for Saturday and Sunday was recorded at 8 AM.

- More detailed measurements are carried out in 3 exchanges. In these exchanges traffic data are continuously recorded by automatic equipment.

2.2 Estimator for the change in traffic volume

In this part an estimator which gives information whether or not a significant change in the traffic pattern of the day and of the week has occurred after the introduction of reduced eve-
The estimator is to be based on the nationwide measurements of the long-distance traffic.

It is important to find an estimator which assigns changes in the traffic volume caused by the tariff reduction and not by a general increase in traffic for the period. An estimator, \( \hat{\Delta}_{t^*t} \), giving the relative increase in traffic volume for the reduced rate time intervals, is given by:

\[
\hat{\Delta}_{t^*t} = \frac{1}{n} \sum_{i=1}^{n} \frac{W_{it}^* - W_{it}}{W_{it}}
\]

where
- \( Y_{it}^* \) is the part of the traffic volume to the route \( i \) measured in the week \( t \) when the rates are reduced, \( t=t^* \)
- \( W_{It} \) is the total traffic volume on route \( i \) in week \( t \), \( t=t^* \)

\( \hat{\Delta}_{t^*t} \) is based on measurements from \( n \) routes in an unbiased estimate for the real relative nationwide change in the traffic given by:

\[
\Delta_{t^*t} = \frac{1}{N} \sum_{i=1}^{N} \frac{Y_{it}^* - Y_{it}}{Y_{it}}
\]

where \( N \) is the total number of routes carrying long-distance traffic in Norway. It is assumed that during the measurement period no significant changes in the routing have occurred. Smaller changes have been taken care of by removing the routes concerned.

2.3 The precision of the methods

The estimator is influenced by two elements of uncertainty:

1) The estimator is based on a sample survey. The statistical precision depends upon the proportion of the material included in the sample survey.

2) The estimator correctly reflects the changes in traffic pattern from week \( t \) to week \( t^* \). It is however not certain that the weeks \( t \) and \( t^* \) are representative for the traffic patterns before and after the change in the tariff. When we consider \( \hat{\Delta}_{t^*t} \) as the relative change in traffic pattern caused by reduced rates, the precision in the estimator caused by measurements from only two weeks has to be born in mind. This precision is however difficult to calculate because of limited recording periods.

We will study the statistical precision of \( \hat{\Delta}_{t^*t} \) caused by the sample survey. Because of the complicated way in which \( \hat{\Delta}_{t^*t} \) is estimated and the strong correlations between some of the variables, it is not possible to find an unbiased estimate for the variance of \( \hat{\Delta}_{t^*t} \). There is however a method which gives a useful approximation to the variance of \( \hat{\Delta}_{t^*t} \). An alternative expression for \( \hat{\Delta}_{t^*t} \) can be found by expanding \( \hat{\Delta}_{t^*t} \) around the mean value of \( Y_{it}^* \), \( W_{it}^* \), \( Y_{it} \) and \( W_{it} \) where

\[
X_1 = Y_{it}^* = \frac{1}{n} \sum_{i=1}^{n} Y_{it}^*
\]
\[
X_2 = W_{it}^* = \frac{1}{n} \sum_{i=1}^{n} W_{it}^*
\]
\[
X_3 = Y_{it} = \frac{1}{n} \sum_{i=1}^{n} Y_{it}
\]

\[
X_4 = W_{it} = \frac{1}{n} \sum_{i=1}^{n} W_{it}
\]

\[
E[X_1] = \mu_1 \quad i = 1,2,3,4
\]
\[
\text{Var}(X_1) = \sigma_1^2 \quad i = 1,2,3,4
\]
\[
\text{Cov}(X_1,X_j) = \gamma_{ij} \quad i,j = 1,2,3,4 \quad i \neq j
\]

where \( \gamma_{ij} \) is an unbiased estimate of the relative increase in traffic pattern. When we consider \( \gamma_{ij} \) as the relative change in traffic pattern caused by the tariff reduction and not by a general increase in traffic for the period, it is not possible to find an unbiased estimate for the real relative nationwide change in traffic pattern. From (5.3) we see that \( X_1 \), \( i = 1,2,3,4 \) are mean values, which, will be close to their means when the number of observations increases.

The variance of \( \hat{\Delta}_{t^*t} \) given by:

\[
\text{Var} \hat{\Delta}_{t^*t} = \frac{4}{N} \sum_{i=1}^{N} \frac{1}{\sigma_1^2} \gamma_{ij}^2 + \frac{1}{\sigma_1^2} \gamma_{ij}^2
\]

If \( X_1 \) is close to the mean \( \mu_1 \), \( i = 1,2,3,4 \) we know that \( \hat{\Delta}_{t^*t} \) is approximately equal to \( \Delta_{t^*t} \). From (5.3) we see that \( X_1 \), \( i = 1,2,3,4 \) are mean values, which, will be close to their means when the number of observations increases.

\[
E[\hat{\Delta}_{t^*t}] = \frac{4}{N} \sum_{i=1}^{N} \frac{1}{\sigma_1^2} \gamma_{ij}^2 + \frac{1}{\sigma_1^2} \gamma_{ij}^2
\]

\[
\text{Var} \hat{\Delta}_{t^*t} = \frac{(3\hat{\Delta}_{t^*t}^2)}{\sigma_1^2} \text{Cov}(X_1^*,X_j^*)
\]

\[
E[\hat{\Delta}_{t^*t}^2] = \frac{(3\hat{\Delta}_{t^*t}^2)}{\sigma_1^2} \text{Cov}(X_1^*,X_j^*)
\]

\[
\text{Var} \hat{\Delta}_{t^*t} = \frac{(3\hat{\Delta}_{t^*t}^2)}{\sigma_1^2} \text{Cov}(X_1^*,X_j^*)
\]

\[
(\text{N-n})/\text{N} \text{ is a correction factor which depends upon the sample size.}
\]

Substitution of (5.4), (5.5) and (5.6) into (5.9) gives:

\[
\text{Var} \hat{\Delta}_{t^*t} = \frac{(3\hat{\Delta}_{t^*t}^2)}{\sigma_1^2} \text{Cov}(X_1^*,X_j^*)
\]

\[
\frac{(3\hat{\Delta}_{t^*t}^2)}{\sigma_1^2} \text{Cov}(X_1^*,X_j^*)
\]

\[
(\text{N-n})/\text{N} \text{ is a correction factor which depends upon the sample size.}
\]

The variances of \( X_1 \), \( X_2 \), \( X_3 \), \( X_4 \) depend on \( \sigma_1^2 \), and the covariances between them \( \gamma_{ij} \) are unknown. Therefore they have to be estimated to get an estimate for \( \text{Var} \hat{\Delta}_{t^*t} \). Because \( X_1, X_2, X_3 \) and \( X_4 \) are known in one point only, it is not possible in a direct manner to estimate the variance or covariance of the variables.

This can however be done indirectly by using (5.3)

\[
\text{Var} U = \sigma_U^2 \quad \text{for } U = Y_{it}^*, Y_{it}^*, W_{it}^*, X_1^*
\]

\[
\text{Cov} (U,V) = \gamma_{UV} \quad \text{for } U,V = Y_{it}^*, Y_{it}^*, W_{it}^*, X_1^*, X_2^*, X_3^*, X_4^*
\]

Then:

\[
\sigma_U^2 = \text{Var} X_1 = \frac{1}{n} \sum_{i=1}^{n} Y_{it}^* = \frac{\sigma_Y^2}{n}
\]
Measurements were carried out on 11% of the routes. In a similar way we get:

\[ Y_{12} = \frac{1}{n} \sum_{i=1}^{n} (\hat{y}_{it} - \hat{y}_{nt})^2 \]

\[ Y_{13} = \frac{1}{n} \sum_{i=1}^{n} (\hat{y}_{it} - \hat{y}_{nt}) (\hat{w}_{it} - \hat{w}_{nt}) \]

By inserting \( \sigma^2 \) and \( \gamma_{ij} \) in stead of \( \sigma^2 \) and \( \gamma_{ij} \) into (5.10), we get an unbiased estimate for the variance of \( D_t \) and hence an approximated unbiased estimate for the variance of \( D_t \). Then an approximated standard deviation for \( D_t \) will also be known.

### 2.4 Results from the traffic measurement

#### 2.4.1 The sample survey

Traffic measurements have been carried out in all telecommunication regions of Norway except Oslo. The measurements used are taken in December 1977 and December 1978.

Table 2.1 The number of selected routes and the total number of routes in the different regions.

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of selected routes</th>
<th>Total number of routes</th>
</tr>
</thead>
<tbody>
<tr>
<td>East</td>
<td>24</td>
<td>257</td>
</tr>
<tr>
<td>South</td>
<td>47</td>
<td>236</td>
</tr>
<tr>
<td>West</td>
<td>23</td>
<td>202</td>
</tr>
<tr>
<td>Trøndelag</td>
<td>7</td>
<td>191</td>
</tr>
<tr>
<td>North</td>
<td>14</td>
<td>205</td>
</tr>
<tr>
<td>Total</td>
<td>115</td>
<td>1091</td>
</tr>
<tr>
<td>Total-North</td>
<td>101</td>
<td>886</td>
</tr>
</tbody>
</table>

Measurements were carried out on 11% of the long-distance routes. A greater part of the long-distance traffic is incorporated, however, since most of the traffic is carried on two or more routes.

Although Oslo Telecommunication region is not included the measurements should be representative because routes from other regions to Oslo are incorporated. In the tables shown, the total is also given with the North region excluded. This is, as earlier mentioned, because in this region there was a 40% reduction in the long-distance tariffs before 1978. This implies that the subscribers in this area have got a real increase in the tariffs for non-busy hours.

#### 2.4.2 The traffic volume per week

In the period December 1977 to December 1978 the total long-distance weekly traffic volume has, according to the measurements, increased from 75593 Eh (Erlang-hours) to 82482 Eh. This gives a 9.1% general increase in the traffic.

#### 2.4.3 Traffic volume working-days 8 PM to 8 AM

The long-distance traffic volume in reduced-rate periods is of special concern. In Table 2.2 the changes in the traffic volume and estimated standard deviation based on the estimator from chapter 2.3 are presented. The table shows that the standard deviations are less than the estimated values. This means that the estimated values are to be regarded as significant. In order to determine that a significant change has occurred the following rules are useful: If estimated change and standard deviation are approximately equal, the probability for a significant change is 60%. If the change is of order two times the standard deviation, the probability for a significant change is 95%. These rules are based upon the assumption that \( D_t \) is approximately normally distributed.

Table 2.2 The change in traffic volume on working-days between 8 PM and 8 AM relative to total weekly traffic volume from December 1977 to December 1978.

<table>
<thead>
<tr>
<th>Region</th>
<th>Percentage change in traffic volume on working-days between 8 PM and 8 AM</th>
<th>Standard deviation of change in traffic volume on working-days between 8 PM and 8 AM</th>
</tr>
</thead>
<tbody>
<tr>
<td>East</td>
<td>10.4</td>
<td>9.4</td>
</tr>
<tr>
<td>South</td>
<td>14.7</td>
<td>13.5</td>
</tr>
<tr>
<td>West</td>
<td>12.0</td>
<td>11.3</td>
</tr>
<tr>
<td>Trøndelag</td>
<td>14.1</td>
<td>13.6</td>
</tr>
<tr>
<td>North</td>
<td>14.3</td>
<td>13.7</td>
</tr>
<tr>
<td>Total</td>
<td>13.2</td>
<td>12.7</td>
</tr>
<tr>
<td>Total-North</td>
<td>13.1</td>
<td>12.6</td>
</tr>
</tbody>
</table>

The table shows that there has been a significant increase in traffic volume between 8 PM and 8 AM after the introduction of reduced rates. This applies to all regions. If North is excluded we see that the proportion of weekly traffic volume on working-days between 8 PM and 8 AM has increased 2.5%. The relative increase in traffic volume on working days between 8 PM and 8 AM has been 23.4%.

#### 2.4.4 Traffic volume in mean busy hour

One of the reasons for reduced rates in the evening was to verify whether or not it was possible to move some of the busy-period traffic, especially the busy-hour traffic, to periods with reduced rates. Table 2.3 shows how the concentration factor has changed after the introduction of new tariffs.

Table 2.3 Change in traffic volume in mean busy hour relative to total day and night traffic volume (change in concentration factor) from December 1977 to December 1978.

<table>
<thead>
<tr>
<th>Region</th>
<th>Concentration factor December 1977</th>
<th>Concentration factor December 1978</th>
<th>Percentage change in concentration factor</th>
<th>Standard deviation of the concentration factor based on measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>East</td>
<td>11.4</td>
<td>11.5</td>
<td>-0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>South</td>
<td>10.9</td>
<td>10.8</td>
<td>-0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>West</td>
<td>10.7</td>
<td>10.5</td>
<td>-0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Trøndelag</td>
<td>11.1</td>
<td>11.5</td>
<td>-0.4</td>
<td>0.7</td>
</tr>
<tr>
<td>North</td>
<td>10.2</td>
<td>10.8</td>
<td>-0.6</td>
<td>0.3</td>
</tr>
<tr>
<td>Total</td>
<td>10.3</td>
<td>10.4</td>
<td>-0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Total-North</td>
<td>10.4</td>
<td>10.5</td>
<td>-0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

The table shows small changes in the concentration factor. Nationwide the traffic volume in mean busy hour has been reduced from 10.4% to 10.3%. The standard deviation indicates that the change is not significant.

#### 2.4.5 Traffic volume on saturday and sunday

January 1 1978 reduced rates on Saturdays and Sundays for long-distance dialling was introduced. In spite of this the nationwide measure-
ments have shown no increase in traffic volume on Saturdays and Sundays. On the contrary a decrease has occurred. Table 2.4 shows this.

Table 2.4 The change in traffic volume on Saturdays and Sundays relative to total weekly volume from December 1977 to December 1978.

<table>
<thead>
<tr>
<th></th>
<th>Percentage proportion of weekly traffic volume on Saturday and Sunday</th>
<th>Percentage proportion of weekly traffic volume on Saturday and Sunday</th>
<th>Percentage proportion of weekly traffic volume on Saturday and Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td>East</td>
<td>12.7</td>
<td>13.8</td>
<td>-1.1</td>
</tr>
<tr>
<td>West</td>
<td>16.7</td>
<td>17.4</td>
<td>-0.9</td>
</tr>
<tr>
<td>South</td>
<td>15.8</td>
<td>15.4</td>
<td>-0.4</td>
</tr>
<tr>
<td>North</td>
<td>16.4</td>
<td>15.7</td>
<td>-0.7</td>
</tr>
<tr>
<td>Total</td>
<td>15.7</td>
<td>16.1</td>
<td>-0.4</td>
</tr>
<tr>
<td>Total + North</td>
<td>15.6</td>
<td>16.3</td>
<td>0.5</td>
</tr>
</tbody>
</table>

From the table we see that the proportion of the weekly traffic volume on Saturdays and Sundays in December 1977 was 16.1%, while the same figures for March 1978 and December 1978 were 15.1% and 15.7% respectively. This estimate for the decrease of the traffic volume can not be explained by lack of precision caused by the sample survey only. There must obviously be other factors influencing the result, e.g. temperature, weather and so on.

As a consequence of this we have decided to ignore the decrease in traffic volume on Saturdays and Sundays. This view is also supported by special measurements done on 32 routes from Lillestrøm and Jessheim exchanges.

These measurements are done on Saturday and Sunday of week 48 in 1977, week 09 in 1978 ans week 48 in 1978. We notice that these measurements are done on slightly different Saturdays and Sundays. The results are shown in table 2.5.

Table 2.5 Percentage proportion of weekly traffic volume on Saturdays and Sundays for Lillestrøm and Jessheim, respectively.

<table>
<thead>
<tr>
<th>Exchange</th>
<th>Period</th>
<th>Week 48 - 1977</th>
<th>Week 09 - 1978</th>
<th>Week 48 - 1978</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Saturday 6.9</td>
<td>8.0</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sunday 7.0</td>
<td>7.5</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Saturday + Sunday 13.9</td>
<td>15.5</td>
<td>14.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Saturday 7.1</td>
<td>7.8</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sunday 7.0</td>
<td>8.2</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Saturday + Sunday 14.1</td>
<td>16.1</td>
<td>15.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Saturday 7.0</td>
<td>7.9</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sunday 7.0</td>
<td>7.8</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Saturday + Sunday 14.0</td>
<td>15.7</td>
<td>16.0</td>
<td></td>
</tr>
</tbody>
</table>

According to the measurements from week 48, 1977 and week 48, 1978, the proportion of the weekly traffic volume on Saturdays and Sundays has increased from 14.0% to 16.3%. This means a 14.3% increase. It has to be born in mind that these measurements are not nationwide, but just from two exchanges.

2.4.6 Traffic profiles

In figure 3.1, 3.2 and 3.3 are shown traffic profiles for long-distance traffic outgoing from three different exchanges. The profiles of one week in December 1977 and one week in December 1978 are compared. As can be seen from the curves there has been a significant change in the traffic-pattern starting from about 8 PM. All the exchanges show the same increase in evening traffic resulting from the reduced rates. The curves are normalised to take care of general increase in traffic.
Percentage of daily traffic volume

Figure 3.3 Normalised traffic profile for long-distance traffic, Lillestrøm group exchange, mean of 5 working-days.

- week 48, 1977 (before the reduction)
- week 48, 1978 (after the reduction)

Figure 3.4 and 3.5 show the traffic profiles of Saturday and Sunday. For both days the curves show a uniform increase in traffic from December 1977 to December 1978. It is however impossible to find any significant changes in the traffic pattern. It has to be born in mind the lack of precision due to the short measuring period of only one day.

Figure 3.4 Traffic profile for long-distance traffic, Lillestrøm group exchange, Saturdays.

- Saturday week 48, 1977 (before the reduction)
- Saturday week 48, 1978 (after the reduction)

Figure 3.5 Traffic profile for long-distance traffic, Lillestrøm group exchange, Sundays.

- Sunday week 48, 1977 (before the reduction)
- Sunday week 48, 1978 (after the reduction)

3 INFORMATION ABOUT REDUCED EVENING RATES FOR LONG-DISTANCE CALLS

3.1 Distributed information to the subscribers

Since the introduction of reduced rates December 1, 1978, the Norwegian Telecommunication Administration has in stages informed the subscribers about the reduced rates.

- During January 1978 a folder giving the rates was distributed to the subscribers throughout the country. The reduced rates were explained, but not stressed.
- Early March 1978 the Administration published an advertisement (A4-format) in all the newspapers. The advertisement, tells that the rates are reduced by 25% after 8 PM.
- During September 1978 all subscribers of Oslo region, one of the 6 regions, got with their telephone bill an informative pamphlet on the new reduced tariffs.
- During September-October 1978 the Telecommunication Administration went through a "Phone more" campaign using advertisements in the newspapers throughout the country to inform the subscribers among other about the reduced rates.

3.2 Market surveys

No doubt there is a interaction between the long-distance traffic in evenings and the subscribers' knowledge of the reduced rates. During 1978, two market surveys have been carried out, one in March and one in December, to examine to what extent the subscribers had noticed the reduced rates.

Both the surveys consist of interviews with 1500-1600 persons each representing one household. The interviews are done throughout the country on a representative sample survey basis.
3.3 Knowledge of the reduced rates

In the surveys the respondents were, among other things, asked about:

- whether they had a telephone in the household
- whether they knew the reduced rates
- percentage decrease of the evening rates relative to the rates the rest of the day
- how often they made long-distance calls
- whether or not they actively tried to make their long-distance calls in periods with reduced tariffs.

Table 3.1 Percentage proportion of the respondents being aware of the reduced evening tariffs. March 1978 and December 1978.

<table>
<thead>
<tr>
<th>Month</th>
<th>Telephone in the household</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>March</td>
</tr>
<tr>
<td></td>
<td>75</td>
</tr>
<tr>
<td>Yes</td>
<td>22</td>
</tr>
<tr>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td>Don't know</td>
<td>100</td>
</tr>
<tr>
<td>Number of respondents</td>
<td>915</td>
</tr>
</tbody>
</table>

The table shows that the proportion of the respondents with knowledge of the reduced rates has, from March to December, increased from 68% to 84%. For subscribers, the same proportion has increased from 75% to 88%.

Although most of the subscribers say they have heard about the reduction, it is of some interest to examine their knowledge about the size of the reduction. This is shown in Table 4.2.

Table 3.2 Distribution of the size of the evening tariff reduction, as given by the respondents (with and without telephone).

<table>
<thead>
<tr>
<th>Month</th>
<th>Telephone in the household</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>March</td>
</tr>
<tr>
<td>Percentage reduction of the evening rates</td>
<td>Yes</td>
</tr>
<tr>
<td>Below 10</td>
<td>2</td>
</tr>
<tr>
<td>10 - 19</td>
<td>5</td>
</tr>
<tr>
<td>20 - 24</td>
<td>1</td>
</tr>
<tr>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>26 - 29</td>
<td>0</td>
</tr>
<tr>
<td>30 - 39</td>
<td>5</td>
</tr>
<tr>
<td>40 and more</td>
<td>6</td>
</tr>
<tr>
<td>Don't know</td>
<td>56</td>
</tr>
<tr>
<td>Number of respondents</td>
<td>100</td>
</tr>
</tbody>
</table>

Only 16% and 19% in March and December, respectively, knew the exact size of the evening tariff reduction 25%. After the Administration had stepped up the level of information in the period between March and December the proportion which answered "don't know" decreased from 58% to 44%. It is however interesting to notice that most of the people leaving the "don't know" group gives a reduction of 40% or more. This group have increased from 6% to 18%.

In addition it has been of some interest to study whether or not the subscribers, being 58% of the material, actively try to make their long-distance calls in periods with reduced rates.

Table 3.3 Distribution of to what extent the subscribers actively make long-distance calls in periods with reduced rates.

<table>
<thead>
<tr>
<th>Frequency of making long-distance calls in periods with reduced rates</th>
<th>Yes</th>
<th>No</th>
<th>Don't know</th>
</tr>
</thead>
<tbody>
<tr>
<td>Least 1 time a month</td>
<td>46</td>
<td>54</td>
<td>14</td>
</tr>
<tr>
<td>1 to 3 times a week</td>
<td>41</td>
<td>43</td>
<td>12</td>
</tr>
<tr>
<td>1 to 3 times a month</td>
<td>40</td>
<td>46</td>
<td>8</td>
</tr>
<tr>
<td>Least 1 time a month</td>
<td>53</td>
<td>38</td>
<td>7</td>
</tr>
</tbody>
</table>

From the table we see that approximately half of those having answered this question have changed their long-distance call-behaviour as a consequence of the tariff reduction. It also indicates that the willingness to change the behaviour is independent of how often long-distance calls are made.

4 TARIFF DIFFERENTIATING

4.1 The welfare gain

One of the goals of society consisting of The Telecommunication Administration and the subscribers, is to achieve the greatest possible total welfare by producing calls. The total welfare is defined by social benefits minus social costs.

Trunk calls at different time of the day can be considered as different products with different marginal costs since the trunk traffic varies over the day. The trunk traffic in mean busy hour due to the capacity costs has the highest marginal cost.

In Norway the introduction of the reduced tariff has not moved the mean busy hour in the trunk network to periods with reduced rates. By the same assumption for the local network it follows that the traffic increase in reduced tariff periods will not cause any increase in the capacity costs. Hence, since the tariff differentiation has caused an increase in the traffic volume, the total welfare has also increased.

4.2 Economic model

Table 2.3 showed that the mean busy hour traffic had decreased by 18%. Uncertainty due to the sample survey indicates that this change is not significant. As a consequence of this we ignore the possible reduction in capacity-costs caused by this reduction.

We will now model the Administration's profit/loss from the introduction of reduced rates. The model is based upon the change in traffic pattern.

We define $x_{t1}$ as the proportion of the traffic volume in week $t$ going in the $i$-th period of the week

$$i = 1 \text{ assigns the reduced rate periods of the week}$$

$$i = 2 \text{ assigns the rest of the week}$$

$t = 49, \text{December 1977}$

$t = 49, \text{December 1978}$

Then $x_{t2}$, the traffic volume of week $t$ is given by:

$$x_t = x_{t1} + x_{t2}$$

The relative increase, $\Delta$, in traffic volume from week $t$ to week $t'$ is given by:
\[ \Delta = \frac{X_t^1}{X_t^2} - 1 \]

The problem then is to find the proportion of the increase \( \Delta \) which is caused by the reduced evening tariffs.

We define the following variables:

\( g \): change in traffic volume caused by the general increase in traffic volume

\( n \): change in traffic volume caused by the reduced rates

\( a \): proportion of traffic volume moved to reduced tariff periods from periods with no change in tariffs.

If the reduced rates had not been introduced, then:

\[ X_t^1(l+g) = X_t^1 \]

With the same assumptions the traffic volume in periods with no change in rates would have increased from \( X_t^2 \) to \( X_t^2(l+g) \). A part of this traffic volume \( X_t^2(l+g) \cdot a \) will, however, move to reduced rate periods. Hence we obtain

\[ X_t^2(l+g)(1-a) = X_t^2 \]  

(4.1)

In a similar way we get the relation between \( X_t^1 \) and \( X_t^1' \):

\[ X_t^1'(l+g)(1+n) + X_t^2'(l+g)a = X_t^1' \]  

(4.2)

where \( X_t^2'(l+g)a \) is the moved traffic, and \( X_t^1'(l+g)(1+n) \) is the traffic caused by the general increase in traffic and the reduced rates.

Adding (4.1) and (4.2) gives:

\[ X_t^2(l+g)+X_t^1'(l+g)(1+n) = X_t^1' \]  

(4.3)

The equations (4.1), (4.2) and (4.3) are mutually dependent, and we are left with two equations to determine \( g \), \( n \) and \( a \). It does not seem possible to find any further exact relations between the variables. We solve this problem by using the nationwide forecasts for the long-distance traffic volume for the determination of \( g \) and \( n \). The estimate \( g \) will express the expected general increase in traffic volume.

From equation (4.1) and (4.3) we get:

\[ a = 1 - \frac{X_t^1}{X_t^1(l+g)} \]  

(4.4)

\[ n = \frac{X_t^1}{X_t^1(l+g)} - \left(\frac{X_t^2}{X_t^2(l+g)} + 1\right) \]  

(4.5)

We will now derive an expression for the economic result, as seen from the Norwegian Telecommunications Administrations point of view, due to the 25% reduction of tariffs.

The Administration will get an income caused by the reduced rate traffic \( X_t^1(l+g)n \). This income equals \( 3/4 \cdot X_t^1(l+g)n \).

On the expense side comes firstly the reduced income in reduced rate periods, \( X_t^1(l+g) \) due to a 25% reduction in rates \((1/4)\). In addition, comes the loss caused by the traffic volume \( X_t^2(l+g)a \) which is moved to reduced rate periods.

The administrations result \((pr)\) week from the reduction will be given by:

\[ I^* = \frac{3}{4} X_t^1(l+g)n - \frac{3}{4} X_t^1'(l+g) - \frac{1}{4} X_t^2'(l+g)a \]  

(4.6)

Dividing (4.6) by \( X_t^1 + X_t^2 \) gives the relative change in traffic income:

\[ I = \frac{3}{4} \frac{X_t^1(l+g)n - \frac{1}{4} X_t^1'(l+g) - \frac{1}{4} X_t^2'(l+g)a}{X_t^1 + X_t^2} \]  

(4.7)

where \( p = \frac{X_t^1}{X_t^1 + X_t^2} \).

Measurements from 1977 gives \( p = 0.246 \). Assuming the general increase in traffic volume \((g)\) equal to 6% reduces the traffic income by 5%.

4.2 Increase of traffic and information

The question is whether the Administration, in the present situation, will profit from a new information campaign for the reduced rates, or not. If it is possible to influence the subscribers to make more long-distance calls (in evenings), this will of course be an advantage for the administration. If the campaign leads to an increased number of subscribers moving their long-distance calls to reduced rate periods, the Administration will loose money unless the reduction of busy-hour traffic is sufficient. From table 4.3 we know that 43% of the subscribers do not actively try to make their long-distance calls in reduced-rate periods.

4.3 Different strategies for differentiating the tariffs

The optimal way to use the network would be to have a uniform traffic throughout the day. This is however hard to achieve because most of the business traffic is linked to the working hours.

A more uniform traffic distribution will ensure higher utilization of the network. This will cause a decrease in the busy hour traffic, reduce needs for traffic equipment and investments. Measurements has shown that a 25% reduction in tariffs from PM to AM on working-days has not influenced the mean busy-hour traffic. Obviously the reduction should be made bigger or start earlier in the evening to reduce the busy hour traffic.

There are several ways to improve the utilization of the network by the tariff means. One is to divide the day and night into three or more periods with different rates. In this case the rates for the lowest traffic period should be reduced by more than 25%. If welfare gain are not taken into account it is then probably necessary to introduce higher rates than today in busy periods to prevent reduced income.

Another way is to introduce reduced rates earlier in the evening, this will make it easier for the subscribers to move their calls from the busy hour till reduced rate periods.

The effect of differentiated rates depends upon how well the subscribers know the tariff system. Market have a limited knowledge about the tariff system. The information to the subscribers should be taken into account when the policy for a differentiated tariff system are worked out.