Concent - An Aid to the Business Management of Telephone Networks

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ABSTRACT

A method to measure telephone traffic levels in remote exchanges from a central location has been developed and the technique has been applied to a medium sized metropolitan network exceeding 200,000 subscribers. Six continuous seven day (24 hour) traffic studies have been carried out on this network over a 17 month period to establish the value of, and to observe any trends in, macro network traffic parameters. This paper discusses the reasons for these studies and outlines the results obtained to this stage. An interesting outcome has been the relative stability of the weekly load factor, which has important application for estimation of call earnings.

1. INTRODUCTION

Development of a telephone traffic measurement system known as the CENTOC (an acronym for CENtralised Traffic Occupancy) system has enabled the simultaneous measurement of traffic levels in groups of circuits physically dispersed throughout a network (Ref.1). This method is based on the extension of measurement leads from selected circuit groups in remote exchanges, via cable pairs, to measuring and recording equipment at a central location. CENTOC has been used for four years in South Australia to measure and control, on a fortnightly basis, the level of subscriber originating traffic generated in the metropolitan network during the network busy hour. Other groups measured on this regular basis include 'backbone' (final choice) routes within the metropolitan network and the more important trunk routes.

The lack of detailed and reliable information on several aspects of macro network behaviour, aspects which included daily and weekly traffic profiles and load factors for various types of traffic, and the realisation that these factors would not only vary over time but should be managed, led to CENTOC (derived from CONTinuous CENTOC). By extending and modifying the facilities and equipment used for regular CENTOC measurements, a continuous seven day (24 hour) study of selected traffic groups in the Adelaide network became feasible.

The initial CENTOC study, in June 1974, had two immediate and general objectives, viz:

- To establish the value of important macro network traffic parameters and their inter-relationships;
- To provide an information base for recording any movements, either induced by external means or long term trends, in subscriber behaviour.

Because accurate information on macro network behaviour will become increasingly important for guiding the efficient operational management of the telecommunications network, five subsequent continuous seven day studies have been carried out at irregular intervals in the 17 months to December 1975. Although this period has not been of sufficient duration to establish any changing trends in subscriber behaviour, this paper will outline the results obtained to this stage.

All CENTOC measurements have been carried out in the Adelaide Telephone District (ATD), which is a seven-digit closed numbering area encompassing Adelaide, the capital city of the State of South Australia, and environs. Within the ATD, 240,000 exchange lines and 350,000 telephone stations (instruments) are connected to 64 local subscriber exchanges ranging in capacity from 100 to 15,000 lines. This area contains a population of approximately 900,000 (73% of that for South Australia) with average telephone densities of 27 exchange lines per 100 population and 0.6 exchange lines per residence. About 94% of ATD services have access to the Subscriber Trunk Dialling (STD) network and early in 1976 an estimated 75% of trunk calls originating within this area were dialled by subscribers.

This paper will discuss the principal objectives of the initial and of a continuing series of CENTOC measurements and the possible benefits flowing from these studies. The practical methodology is briefly explained and the results obtained to this stage are analysed in some detail. In particular, the relative stability of the weekly load factor is shown to have an important application for estimation of call earnings. Future development, utilising minicomputer control of the measurement system to provide regular or instantaneous reports, is outlined.

2. CENTOC OBJECTIVES

In order to achieve the general objectives outlined previously, it is necessary to firstly establish typical network traffic properties and secondly to be able to assess the extent of any future variation from initial observed values. Thus the detailed objectives of the CENTOC studies are to establish:

- Daily and weekly traffic profiles;
- Time-dependent variation of idle capacity in the network;
- Daily and weekly load factors;
- Proportion of network traffic carried within specified time periods;
- A method to monitor network call earnings.

These five objectives are discussed in more detail.

2.1 DAILY AND WEEKLY TRAFFIC PROFILES

Very little information has been available in Australia regarding typical traffic levels apart from the traditional morning, afternoon and evening week day traffic study periods for each individual exchange of some two to three hours duration. At the micro level, information regarding traffic levels at off-peak periods has proved useful for specifying the optimum periods for the withdrawal of important sections of the transmission or switching network from service for maintenance reasons without undue risk of localised congestion developing in the network. Changes to traffic dispersion patterns beyond normal traffic measurement periods may lead to congestion on backbone routes and regular continuous observation, enabling early reaction to changing patterns, tends to obviate this problem. At the macro level there are several relationships such as the relative variations of subscriber originating traffic compared with trunk traffic, which are of interest to network planners.
2.2 TIME-DEPENDENT VARIATION OF NETWORK IDLE CAPACITY

The existing trunk tariff system in Australia has seven distance dependent tariff rates which may each be charged at day or night time scales, the latter being applicable between 1800-0800 hours local time. Within the next few years new trunk systems could be introduced with significantly increased scope for greater flexibility in charging for trunk calls. For the successful implementation of these measures, it will be important to estimate accurately the amount of trunk tariff stimulation to apply to the trunk network at any particular time. In this, there are two relevant variables, the price elasticity of demand for trunk calls for various categories of subscriber and the increased volume of traffic that it is planned to generate. (Note that the stimulation could be negative, as in the case of peak-load pricing). Methods are available to estimate the former using market research techniques and pilot studies etc., but CONCENT type measurements are necessary to assess and monitor the latter.

2.3 DAILY AND WEEKLY LOAD FACTORS

In this paper two load factors are defined as follows:

- **Daily Load Factor**: the ratio of the averaged daily traffic volume over 24 hours (Monday to Friday) to the time consistent busy hour (TCBH) traffic for the same (five day) period.

- **Weekly Load Factor**: the ratio of the weekly (seven day) traffic volume to the Monday to Friday TCBH traffic.

Information of this type is essential for planning studies that require estimation of annual calls or traffic when the only information available are infrequent measurements of TCBH traffic levels.

Load factors have considerable importance in another area, examination of the possibility of relating predicted growth rates or projections of busy hour traffic to that of annual calls. Circuit dimensioning and provisioning are based on maintaining specified levels of busy hour traffic averaged over the four consecutive busiest weeks of the year. However, targets for performance and growth are often expressed in terms of annual calls. Calls within a given time period are related to traffic by the average call hold time but an additional factor is involved in converting busy hour traffic to annual calls, viz. the load factor.

An objective of telecommunications management should be to increase the load factor, within the bounds of social acceptability, by carrying additional daily and weekly traffic volumes at the same level of busy hour traffic to obtain more efficient network utilisation.

2.4 PROPORTION OF TRAFFIC WITHIN SPECIFIED TIME PERIODS

While load factors enable the variation of busy hour traffic compared with total daily or weekly traffic volume to be observed, changes may occur in the daily time distribution pattern of a given volume of traffic through seasonal, cyclical or trend effects. By noting the percentage of daily traffic volume generated during a network's busiest three consecutive hours in the morning, afternoon and evening periods respectively, the more important changes to traffic patterns can be detected. Because tariffs on trunk routes in Australia are time as well as distance dependent, it is necessary for revenue estimation to establish the proportion of trunk traffic carried at night and day tariffs respectively. Thus the proportion of 24 hour traffic carried during the day rate period of 0800-1800 is required. Because erlanghour meters have often been used in provincial trunk switching centres to record the traffic volume between 0900-1100 Monday to Friday, information is also required relating the TCBH traffic level to the average level for the time-switched period.

2.5 ESTIMATION OF NETWORK CALL EARNINGS

An important parameter for all business enterprises is accurate estimation of the current level of earnings. Because Telecom Australia must fund at least 50% of capital expenditure from internal sources, variations in call earnings compared with forecast levels could have significant repercussions on either general tariff levels or the proposed size of the capital investment programme for the ensuing year. Regular CONCENT measurements would enable fairly accurate estimates to be made of earnings trends from local and trunk calls and this information could be available to management within a few days of measurement.

3. METHODOLOGY

As stated earlier, the CONCENT Series of traffic measurements utilizes the CENTOC measuring and recording system. The details of this system are described in Ref. 1 and the general principles employed in traffic occupancy measurements in Australia are discussed in Ref. 2.

3.1 CONCENT

Because CONCENT measurements are continuous over 168 hours, the measuring equipment should operate automatically for the full study period to avoid high labour costs. This objective has been achieved by using Incremental Magnetic Tape Recorders (IMTRs) to output all measurement data on to magnetic tape. Four IMTRs are used which are each time switched sequentially to record for one six hourly period in every 24 hours. By this means all traffic information for the same six hourly period each day is contained on one reel of magnetic tape. Each tape is processed individually by computer to obtain half-hourly average readings for all traffic groups. Two hard copy outputs are available, 'CONCENT A' and 'CONCENT B' respectively. CONCENT A contains relatively raw data, listing the average traffic on each route at 4-hour half-hourly intervals commencing at midnight which is further sub-divided into three periods:

- Average traffic Monday to Friday;
- Saturday traffic;
- Sunday traffic.

CONCENT B is a summary of results from elementary processing of the data from CONCENT A. For each traffic group it records:

- Monday to Friday time consistent busy hour traffic and time of occurrence;
- Saturday and Sunday busy hour traffic and times;
- Average daily (24 hour) traffic volume, Monday to Friday (erlang-hours);
- Total weekly traffic volume over 7 days (erlang-hours);
- Daily load factor Monday to Friday;
- Weekly load factor;
- Weekday afternoon and evening, Saturday and Sunday peak hour traffic levels as a percentage of average weekday morning busy hour traffic;
- Day rate traffic volume (0800-1800) as a percentage of average traffic volume over 24 hours (Monday to Friday);
- Busy hour traffic as a percentage of the average traffic level over the 0900-1100 period (Monday to Friday).

4. RESULTS

At the time of writing this paper six measurements, each of one week duration, had been undertaken in the CONCENT series. The first measurement was made in July 1974 with subsequent studies in May, July, August, September and December 1972.
In addition to the relatively slowly moving social, economic, cultural etc., changes which influence subscriber behaviour, there are some external factors which may have immediate impact. Chief among these, of course, is a change in the level of charges. Within the 17 month period under review, adjustments to telephone call charges were made on two separate occasions. These were:

October 1, 1974
- Local or unit call fee increased by 26% (to six cents);
- Most day trunk tariff rates increased, most night rates decreased;
- Fee for a trunk call booked with an operator which could have been dialled by the subscriber increased from 20 to 30 cents.

September 1, 1975
- Local call fee increased by 50% (to nine cents);
- Day trunk tariff rates (0800-1800) increased by 50% for the four lowest tariffs (up to 325 km) decreasing to zero change for calls over 645 km;
- Night trunk tariff rates increased by 50% for the lowest tariff (less than 50 km) with little other change;
- Fee for a trunk call booked with an operator which could have been dialled by the subscriber increased from 30 cents to 40 cents.

An additional factor that may be significant in its effect on telephone traffic has been the adoption of daylight saving in South Australia and some other States (but not all) by advancing local time by one hour between the end of October and the end of the following February each year.

This Section will analyse the results in two parts. Firstly, the results from a typical study will be considered and for this purpose, the July 1975 study will be reviewed. Secondly, the results from six studies extending over 17 months will be analysed in an attempt to detect any trends or changes occurring over time due either to policy and tariff changes, daylight saving or possible changes in customer calling patterns.

4.1 JULY 1975 STUDY

4.1.1 Traffic Profile and Busy Hour

In the CONCENT studies, the originating traffic from 34 subscriber exchanges were monitored, these exchanges all being within the ATD and exceeding 1000 connected lines in size. In July 1975, 28 or 82% had a Monday to Friday time consistent busy hour commencing either at 0900 (18 exchanges) or 0930 (10 exchanges). Only three exchanges, two of which serve the Central Business District (CBD) in the city, exhibited an afternoon busy hour, but the traffic level in each case did not exceed the corresponding morning peak by more than 1%. The combined ATD had a traffic TCBH which commenced at 0930 at a level of 8440 erlang. This represents a calling rate of 0.039 erlang per exchange line. Afternoon and evening peaks were respectively 89% and 52% of morning levels. Table 1 shows the variation of peak hour traffic levels for afternoon and evening periods as percentages of morning peak levels for the four tandem switching areas into which the ATD is sub-divided. The Waymouth tandem area includes all four exchanges serving the CBD, as well as several exchanges in predominantly residential areas. Because of the markedly different calling patterns of these two groups, the tandem area has been further split into two sub-components.

The ATD busy hour for Saturday occurred at 1030 hours, an hour later than on weekdays, and at a traffic level of 45% of the weekday morning peak. This pattern was evident for each tandem area, although for the four city exchanges, in isolation, the traffic peak was only 15% of their average weekday levels. For Sunday, the busy hour for the ATD, and for each tandem area individually, occurred at 1100 hours when traffic was 36% of the weekday maximum. After excluding the four exchanges in the CBD, each tandem area recorded busy hour traffic between 40%-48% of weekday levels.

Figs. 1 to 4 illustrate several aspects of the variation of originating traffic over a one day or one week continuous period. In Fig. 1, the variation of ATD traffic over the full week of measurement is plotted. A similar pattern is evident from Monday to Friday with prominent morning, afternoon and evening peak periods followed by much lower levels and a less definite pattern at the weekend. Fig. 2 contrasts the characteristic traffic patterns exhibited by exchanges serving the CBD with those having a much stronger component of residential subscribers. The Waymouth tandem switching area of nine exchanges has again been divided, for illustrative purposes, into groupings of exchanges serving predominantly business (City) and residential (Metro) areas. The former grouping shows only two distinguishable daily busy periods with negligible traffic at evening or weekend periods, while the latter grouping has a markedly different profile featuring a strong evening peak period. In six exchanges, throughout the ATD, all strongly residential, the evening busy period traffic measured within 10% of afternoon maximum levels. For ATD originating traffic, Fig. 3 illustrates the relative levels, over a 24 hour period, of average Monday to Friday, Saturday and Sunday traffic respectively. Fig. 4, a similar plot of activity levels for the CBD, plotted in the previous figure, highlights the busy hour time shift on Saturday and Sunday and facilitates comparison of relative traffic levels throughout each period compared with the peak level.

All ATD backbone routes between tandem exchanges carried maximum traffic loads during the morning period and most routes had a TCBH commencing at 0930, the originating traffic busy hour. Most final choice routes between a local terminal exchange and its parent tandem exchange exhibited similar traffic profiles. However, ten terminal exchanges, all having a preponderance of residential services, had an evening busy period on their backbone route, with measured traffic reaching 60% above the level carried during the originating traffic busy hour. This apparent anomaly is a reflection of a changed traffic dispersion during evening periods.

Trunk traffic originating from and terminating within the ATD exhibits a rather different profile compared with that for total originating traffic from subscriber exchanges. The afternoon and, in particular, the evening traffic peaks are relatively higher compared with the morning busy hour level and Saturday and Sunday busy periods occur during the evening. However, the principal point of interest is the contrast within the daily traffic profile depending whether the trunk call is dialled by the subscriber (STD) or is operator
connected, Fig. 5 shows this variation over one week by splitting this traffic into its two components by method of connection. It is clear that STD peak traffic occurs during business hours while operator connected traffic has an evening peak period. In Fig. 6 the variation in STD traffic penetration, the percentage of STD to total trunk traffic, is plotted on a 24 hour time scale. It is clear from these graphs that outside of normal business hours, STD penetration falls considerably thus indicating the area on which management would concentrate to increase the overall level of penetration. For this and the next Fig., the penetration has not been plotted between midnight and 0700 because the very small level of trunk traffic during this period makes the result meaningless.

Fig. 7 provides a relative comparison of trunk traffic penetration for traffic originating from and terminating within the ATD. During business hours between Monday and Friday, originating penetration is higher but the relationship is more variable at other times. The level of trunk traffic originating from the ATD expressed as a percentage of total subscriber originating traffic is shown in Fig. 8. The average level is about five percent during periods of reasonable traffic activity with peak levels close to eight percent.

4.1.2 Load Factors

Originating traffic load factors (see definition, Section 2) for the ATD and for each of its four tandem areas are given in Table 2. The Waymouth tandem area has again been split in two to demonstrate the significant differences between the City exchanges, serving the city commercial and retail centre, and the other groupings.

<table>
<thead>
<tr>
<th>Exchange Grouping</th>
<th>Daily as % of M-F Traffic</th>
<th>Weekly as % of M-F Traffic</th>
<th>% Day Traffic</th>
<th>TCBH Tfc as % of 0900-1100</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATD</td>
<td>9.4</td>
<td>55.4</td>
<td>78.3</td>
<td>102.7</td>
</tr>
<tr>
<td>4th Adelaide Tandem Area</td>
<td>9.7</td>
<td>57.9</td>
<td>76.8</td>
<td>102.5</td>
</tr>
<tr>
<td>Edwardstown Tandem Area</td>
<td>9.3</td>
<td>56.5</td>
<td>74.4</td>
<td>104.1</td>
</tr>
<tr>
<td>Outer Metro Tandem Area</td>
<td>9.4</td>
<td>55.5</td>
<td>77.9</td>
<td>103.1</td>
</tr>
<tr>
<td>Waymouth Tandem Area</td>
<td>9.1</td>
<td>51.9</td>
<td>83.0</td>
<td>102.6</td>
</tr>
<tr>
<td>City Exchanges</td>
<td>8.4</td>
<td>44.4</td>
<td>91.4</td>
<td>106.7</td>
</tr>
<tr>
<td>Metro Exchanges</td>
<td>9.5</td>
<td>57.3</td>
<td>74.9</td>
<td>103.4</td>
</tr>
</tbody>
</table>

TABLE 2. Originating Traffic Load Factors

Excluding the group of city exchanges, there is considerable uniformity between these groupings for each of the four parameters listed in Table 2. The range of parameter values for the 34 individual exchanges, split into two groups, city exchanges (4) and metro exchanges (30), are given by Table 3.

<table>
<thead>
<tr>
<th>City Exchanges</th>
<th>Metro Exchanges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily Load Factor</td>
<td>7.5</td>
</tr>
<tr>
<td>Weekly Load Factor</td>
<td>8.6</td>
</tr>
<tr>
<td>% of Traffic</td>
<td>8.3</td>
</tr>
<tr>
<td>TCBH traffic as % of M-F Traffic</td>
<td>106.2</td>
</tr>
</tbody>
</table>

TABLE 3. Range of Parameter Values

Fig. 9 shows the frequency distribution of weekly load factor for these 34 exchanges. On final choice routes between tandem exchanges, the weekly load factor was generally in the range 20-40 while the percentage of daily traffic in the 0800-1800 interval ranged, in the main, between 75 and 80. That is, a percentage peak similar to that for subscriber originated traffic was carried during the traditional 'day' period although this type of traffic had a significantly different weekly (and daily) load factor.

On backbone routes between terminal exchanges and parent tandems, the range of values was, of course, far greater. The backbone route for one exchange, which is strongly residential in character and which has a significantly different traffic dispersion in the evening, recorded a weekly load factor approaching 120 with most of the traffic volume being carried after 1800 hours.

Overall, total trunk traffic generated in the ATD had quite similar load factors to those for total originating traffic but once again there were significant differences between the subscriber dialled and manual assistance components. The factors for both ATD originating and terminating traffic are given in Table 4.

<table>
<thead>
<tr>
<th>Daily</th>
<th>Weekly</th>
<th>% Day</th>
<th>TCBH Tfc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Originating Trunk Traffic</td>
<td>10.0</td>
<td>56.3</td>
<td>74.9</td>
</tr>
<tr>
<td>STD</td>
<td>9.2</td>
<td>50.6</td>
<td>80.5</td>
</tr>
<tr>
<td>Manual Assistance</td>
<td>10.2</td>
<td>61.5</td>
<td>61.0</td>
</tr>
<tr>
<td>Terminating Trunk Traffic</td>
<td>10.0</td>
<td>57.5</td>
<td>73.4</td>
</tr>
<tr>
<td>STD</td>
<td>9.6</td>
<td>54.1</td>
<td>76.9</td>
</tr>
<tr>
<td>Manual Assistance</td>
<td>11.0</td>
<td>66.4</td>
<td>65.2</td>
</tr>
</tbody>
</table>

TABLE 4. Trunk Traffic Load Factors

Compared with ATD originating traffic, the weekly load factor for trunk traffic (originating) is within 2%, and the ratio of traffic generated within the 'day' is within 5%.

4.2 THE SIX STUDIES - A COMPARISON

In this Section, the results from the six studies spanning the 17 month period July 1974 to December 1975 will be compared.

4.2.1 Traffic Profiles

For ATD originating traffic, the Monday to Friday time-consistent busy hour varied between 0900 (4 studies) and 0930 (2). For all except one study (August 1975), the Saturday busy hour lagged the weekday period by an hour or half-hour. Similarly, the Sunday busy hour generally lagged the Saturday busy period by an hour. For three of the four tandem area groupings, the collective weekday busy hour was consistent for each of the six studies. Afternoon, evening, Saturday and Sunday traffic maxima for the ATD all maintained a relatively steady ratio to the morning peak level with the exception of the December 1975 study where the afternoon relative level was significantly lower than for the five earlier studies. This seemed to reflect a high Christmas peak in morning traffic rather than any decrease in afternoon traffic levels. A similar pattern was observed for each tandem area including the four city exchanges. Busy hour traffic details for the ATD including relative levels during other periods are given in Table 5.

<table>
<thead>
<tr>
<th>Date of Study</th>
<th>M-F Busy Hour Tfc</th>
<th>% of M-F TCBH Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 1974</td>
<td>8010</td>
<td>90</td>
</tr>
<tr>
<td>May 1975</td>
<td>8670</td>
<td>87</td>
</tr>
<tr>
<td>July 1975</td>
<td>8640</td>
<td>88</td>
</tr>
<tr>
<td>Aug 1975</td>
<td>8650</td>
<td>88</td>
</tr>
<tr>
<td>Sept 1975</td>
<td>8590</td>
<td>87</td>
</tr>
<tr>
<td>Dec 1975</td>
<td>9250</td>
<td>82</td>
</tr>
</tbody>
</table>

TABLE 5. ATD Traffic Levels

These figures do not however reveal the interesting and significant change in traffic profile that occurred in the December 1975 study. Fig. 10 is a normalised plot of average 24 hour Monday to Friday traffic variation for each of the six studies. The cross-hatched area is an envelope containing the traffic profiles for the first five studies with the December traffic profile plotted separately. This diagram clearly shows the half to one hour delay for the December evening traffic pattern compared with the earlier studies. This movement is probably due to a change in traffic profile in the summer months assisted by the adoption of daylight saving from November to February. Thus subscribers' evening traffic...
distribution is correlated to sun time rather than clock time. This contrasts with the morning traffic profile which is remarkably narrow and obviously dependent on clock time throughout all seasons of the year.

For total trunk traffic, the weekday busy hour fluctuated between 0930 and 1030 with consistent morning busy periods for STD traffic (commencing between 0930-1030) and evening busy periods for manual assistance trunk traffic (commencing between 1900-1930). However, on Saturday and Sunday, the daily peak traffic always occurred in the evening, commencing at 1800-1830 for Saturday and 1800-2030 for Sunday (the latter being for December 1975).

4.2.2 Load Factors

Daily and weekly load factors and the proportion of traffic occurring between 0800-1800 for ATD originating traffic for each study are shown by Table 6.

<table>
<thead>
<tr>
<th>Date of Study</th>
<th>Daily Load Factor</th>
<th>Weekly Load Factor</th>
<th>Percent Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 1974</td>
<td>9.4</td>
<td>55.1</td>
<td>78.9</td>
</tr>
<tr>
<td>May 1975</td>
<td>9.4</td>
<td>55.4</td>
<td>77.3</td>
</tr>
<tr>
<td>July 1975</td>
<td>9.4</td>
<td>55.4</td>
<td>78.4</td>
</tr>
<tr>
<td>Aug 1975</td>
<td>9.3</td>
<td>55.8</td>
<td>78.7</td>
</tr>
<tr>
<td>Sept 1975</td>
<td>9.4</td>
<td>55.2</td>
<td>77.4</td>
</tr>
<tr>
<td>Dec 1975</td>
<td>9.6</td>
<td>56.7</td>
<td>76.2</td>
</tr>
</tbody>
</table>

TABLE 6. ATD Load Factors for Each Study

The values of daily and weekly load factor are remarkably uniform over the period, particularly when the result for the December 1975 study is excluded. Under this condition, the mean and standard deviation of the weekly load factor for the first five studies are 55.18 and 0.25 respectively.

Using a small sample distribution, the 99% confidence limits are 54.8, 55.5. It follows then, with high probability, that the December weekly load factor is significantly different compared with the five earlier studies. It is interesting to note, however, that the weekly load factor for the earlier five studies has a maximum/minimum ratio range less than 1.25% of the minimum while the busy hour traffic range is 8.3%. The comparative statistics when the December study is included are approximately 3.5% and 15.5% respectively. This uniformity over widely varying conditions has some important implications for revenue estimation. With regard to proportions of busy traffic occurring in the 0800-1800 period, there is again a broad degree of uniformity. Although the December study again diverges by the widest margin from the mean of the earlier five studies, this is not statistically significant at the 95% confidence level. No significant changes were observed in the volume of daily traffic carried within the morning, afternoon and evening busiest three hourly periods.

Load factors for trunk traffic, although not as consistent as for originating traffic, do show reasonable uniformity. Table 7 gives the load factor variations for trunk traffic originating within the ATD.

<table>
<thead>
<tr>
<th>Date of Study</th>
<th>Daily Load Factor</th>
<th>Weekly Load Factor</th>
<th>Percent Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 1974</td>
<td>9.6</td>
<td>53.7</td>
<td>77.7</td>
</tr>
<tr>
<td>May 1975</td>
<td>10.1</td>
<td>61.8</td>
<td>73.2</td>
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<tr>
<td>July 1975</td>
<td>10.0</td>
<td>56.3</td>
<td>74.9</td>
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<tr>
<td>Aug 1975</td>
<td>10.3</td>
<td>59.0</td>
<td>73.7</td>
</tr>
<tr>
<td>Sept 1975</td>
<td>10.0</td>
<td>56.9</td>
<td>74.6</td>
</tr>
<tr>
<td>Dec 1975</td>
<td>10.1</td>
<td>57.6</td>
<td>71.8</td>
</tr>
</tbody>
</table>

TABLE 7. Trunk Traffic Load Factors

There are, however, significant differences within this general category between STD calls and operator connected (or manual assistance) trunk calls. These differences are clearly evident from Table 8, where the mean and standard deviation, taken over the six studies, have been calculated for each load factor and method of call establishment.

The stability of the weekly load factor for subscriber originating traffic over a wide range of traffic levels and under varying conditions has been a feature of these studies. By scheduling no more than, perhaps, two or three continuous seven day studies each year to observe for any long term trend in the load factor or for changes caused by a new tariff schedule, reasonably accurate observations of trends in call revenue earnings should be possible. Network busy hour traffic levels, measured on a weekly or fortnightly basis using the CENTOC system, would be averaged over a month and compared with the corresponding month or accumulated period for the previous year. Given the observed stability in the load factor, this method should provide an estimate of local call earnings for the current year accurate to within a few percentage points. This estimate would be a valuable aid to management.

STD call revenue earnings can be measured accurately by using either the CENTOC method or by using calibrated erlanghour meters (a current system). It is not always possible to measure traffic at each trunk charging rate within the central automatic trunk switching exchange. Estimation of earnings from trunk calls booked through the manual assistance operators is currently available on a monthly basis.

Hence CENTOC has provided the opportunity to economically and accurately estimate the level of total call revenue being earned within the ATD.

For a given load factor, three other variables could influence the rate of local call earnings - call hold time, the proportion of calls to non-revenue earning destinations, e.g., number information etc., and the level of congestion in the network. The first two parameters are derived from regular dispersion studies conducted at each terminal exchange over 1000 lines within the network, while estimates of congestion can be derived from several indicators. Thus, changes to these factors can be allowed for, if necessary, when estimating call earnings.

5. FUTURE DEVELOPMENT

There are two principal limitations preventing a full-time, continuous measurement system covering large regional areas at this time. Firstly, remote traffic groups are at present extended to the central measuring point over physical circuits and the cost of expanding this method beyond metropolitan boundaries becomes prohibitive. However, a new system is being developed which will measure and transmit distant traffic information on up to eight traffic groups upon command from a
central facility. This system, which will operate over carrier frequency derived circuits, uses telegraph channel bandwidth (120 Hz). Secondly, the cost of data processing becomes excessive. However, by using a minicomputer as the central controller, the data could be analysed, validated and corrected as it is received and average traffic levels or accumulated traffic volumes could be either recorded on magnetic tape for further processing or printed out at appropriate intervals.

When both of these developments have been implemented, it will be possible to monitor the complete network continuously and traffic congestion in any section of the network would be immediately identified.

6. SUMMARY

This paper has outlined the aims and objectives of a series of measurements using the CONCENT system and has briefly discussed the methodology adopted. The results obtained from an investigation covering some 34 local terminal exchanges serving over 200 000 exchange lines have been reviewed. An important outcome has been the stability of the weekly load factor for subscriber originating traffic over a wide range of traffic levels and conditions. This has opened the way to accurate estimation of local call earnings by regular measurement of network busy hour traffic levels. Future development and refinement of the system should lead to continuous monitoring and measurement of the network - an important network and business management tool.

7. ACKNOWLEDGEMENTS

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8. REFERENCES


Fig. 1 Profile of ATD Originating Traffic Over One Week.

Fig. 2 Traffic Profile for Business and Residential Exchanges.

Fig. 3 Profiles of ATD Orig. Traffic over 24 hours.

Fig. 4 Normalised Profiles of ATD Orig. Traffic
Fig. 5 Comparison of Trunk Traffic Profiles

Fig. 6 STD Orig Trunk Traffic Penetration over 24 hours

Fig. 7 STD Penetration Over One Week

Fig. 8 Relationship of Trunk to Subscriber Orig. Traffic

Fig. 9 Frequency Distribution of Weekly Load Factors

Fig. 10 Normalised ATD Orig Traffic for Six Studies.