ABSTRACT
Since January 1973 the UK Post Office has been using an experimental traffic recorder at one of its medium sized trunk exchanges which records the number of circuits engaged minute by minute throughout the day directly onto magnetic tape, thus producing actual information on traffic flow. The paper describes the measurements taken, indicates the aims and area of study, summarises the results obtained, and enumerates any conclusions reached.

INTRODUCTION
Knowledge of actual traffic behaviour and its effects are an essential prerequisite in the determination of a provisioning policy and meaningful comparison of possible future traffic recording and route dimensioning systems. Whilst much theoretical work has been done, reliable information on the actual behaviour of live traffic over extended periods has been lacking. An experimental traffic recorder, based on proprietary equipment, was therefore developed by the UK Post Office which would record the number of circuits engaged minute by minute throughout the day directly onto magnetic tape thus producing actual data on traffic flow. This data has been used and analysed as described in this paper to assess how closely our dimensioning policy meets traffic behaviour.

MEASUREMENTS TAKEN
2 Until recently traffic records were taken by the experimental recorder in 4 week cycles starting on the first Monday in each month. The recorder ran from 09.00 hours to 23.00 hours and 03.00 hours to 01.30 hours daily for 7 days in one week in every 4 week cycle and for 5 days for the other 3 weeks. Checks were incorporated to ensure that the recorder was correctly connected. The number of circuits engaged was directly recorded onto magnetic tape at one minute intervals so making available a considerable body of data which could be analysed by computer in a variety of ways to provide information about actual traffic behaviour.

3 Information printed out on a regular basis for every trunk circuit group included:

a. Start time of, and the traffic carried in, the busiest hour for each route falling in each of the morning, afternoon, and evening periods.

b. Start time of, and traffic carried in, route busy hour assessed on a time consistent basis.

c. Start time of, and traffic carried in, exchange time consistent busy hour.

d. Other supporting information including, arithmetic summaries, traffic balances for each switching stage and the exchange as a whole.

Both daily and 5 day average figures were given in each case. As a deliberate policy the aim was to gather too much information rather than too little so that standard information which might be sought in the future would not be based on guesswork as to what could be omitted. Less detailed measurements were taken at a number of other exchanges to supplement and confirm the information obtained by the experimental traffic recorder.

AIMS OF STUDY
1. Dimensioning under the traditional concepts of grade of service, traffic flow and protection against overload normally involves the concept of 'busy hour', the busy hour traffic level being that level of traffic which we attempt to cater for. Its definition is therefore important. For an individual day it is easy to define as the busiest 60 consecutive minutes, but how should this be used for dimensioning purposes? Should we take the busiest hourly traffic recorded on any one day, or given number of days, or should we average the traffic in some way, for example should we take the average of the 3 busiest hours in the week or should we use yet some other combination, as the average over the week, month or what? CCITT recommend that the average of the 3 highest busy hours of the year be used. Deciding the definition to be used for dimensioning purposes requires study of busy hour variations.

5 Study of variations in the busy hour of individual circuit groups is of importance not only in considering the provisioning policy but also in the measurement of achievement in meeting the provisioning aims. Current recording techniques use the time consistent busy hour (TCBH) concept (Reference 1). Many of the comparisons carried out were in relation to this as we wished to know the sort of traffic variation which this system might fail to cater for.

6 Cost is an important factor in determining the service to be given. Not only must the quantity of equipment to be provided be taken into account but also the cost of determining that amount of equipment. Traffic recording is an important part of this latter process and its cost is directly related to the amount of information recorded. This might also govern the type of recording equipment that may be used. Thus, it is also considered important to establish the minimum number of measurements to be taken relative to the service effect.

AREA OF STUDY
7 With the foregoing aims in mind the following have been studied:

7.1 The effect on recording accuracy of varying certain recording parameters including the number of busy hour recordings used in assessing traffic; the scanning rate taking account of the effects of loss of scans and lost busy hour records due to possible recording malfunctions.

7.2 The difference between mean TCBH and mean post selected busy hour (PSBH) traffic quantities measured on a route by route basis.

7.3 The difference between route TCBH and exchange TCBH traffic quantities measured on a route by route basis.

7.4 The difference between peak (busiest hour) traffic levels and mean traffic levels.
7.5 The difference between peak PSBH and mean TCBH traffic levels.

8 In these studies:-

8.1 The TCBH (ie the same preselected Busy Hour each day of a recording period - 5 or 20 days - Monday to Friday) during which traffic is measured was selected with greater confidence than is normal, this resulted in slightly higher figures being recorded than would normally be the case.

8.2 The term PSBH refers to the 60 consecutive minutes during a day when traffic was subsequently found to be at its highest.

8.3 The word mean when used in conjunction with TCBH or PSBH signifies that these measured figures have been averaged over a given number of days.

9 The data used was the record of minute by minute scans of busy circuits on each route measured by the experimental Stafford traffic recorder during the first half of 1973. Some of this information was processed to give traffic levels measured at various scanning rates (1-10 minutes) over a number of TCBHs and PSBHs; covering periods of 5 and 20 days (Monday to Friday). Periods of longer than 20 days were not examined in order to eliminate as far as was reasonably possible the effects of items such as seasonal variation.

EFFECT ON RECORDING ACCURACY OF VARYING RECORDING PARAMETERS

10 In assessing the accuracy of the system of recording used it was noted that there is a widely accepted theoretical formula which relates the accuracy of a measured traffic figure to the various parameters of traffic recording. This formula originally derived by Hayward (Reference 2) refers to the confidence limits which can be attached to a measured average traffic value considered as an estimate of the corresponding notional mean. The formula may be expressed as:

\[ \Delta = z \sqrt{\frac{Y}{T} \cdot \coth d \cdot 2tm} \]

where \( \Delta \) is a confidence interval in erlangs
\( z \) is a confidence coefficient expressed as a number of standard deviations
\( Y \) is the measured traffic carried in erlangs
\( T \) is the number of busy hours used in assessing traffic
\( d \) is the scanning interval expressed in hours
\( tm \) is the average call holding time expressed in hours

11 It was decided to check the results obtained in practical circumstances against the formula since its application would enable the accuracy of measured traffic quantities to be predicted without the need to assess each case empirically on every occasion of measurement. It would also enable the relative importance of the traffic recording parameters to be studied and their optimum values for general use assessed.

12 Measured values were therefore compared with the confidence intervals calculated theoretically using the formula, as the following parameters were varied.

a. Scanning Interval
b. The number of busy hour records used in assessing traffic
c. Measured traffic

13.1 In addition the effects of lost scans and lost busy hour records due to possible recorder malfunctions were simulated for study. It was not possible to assess the effect on accuracy of variations in the average call holding time (tm) since the investigation was based on live traffic where this parameter is outside the direct control of the Post Office. Since it was necessary to have a value for tm to enable the formula to be evaluated a figure of 0.058 hours (3 minutes) was assumed; however it should be noted that the formula is relatively insensitive to the value of tm used.

13 Examples of measured results and the effects of varying recording parameters are given below.

13.1 Figure 1 shows the difference (in traffic measured over a 20 day period) between measurements taken at a...
1 minute scanning interval and at a 10 minute scanning interval. Each point on the graph represents a route. It will be seen that the differences are very small from an operational viewpoint, nearly all being within 0.5 erlang.

11.2 Figure 2 shows the difference (in traffic measured at a 10 minute scanning interval) between measurements taken over 5 days and over 20 days. Again the differences are small, most being within 1 erlang but larger than those noted for variation in scanning intervals.

A number of graphs were produced, b) which Figure 3 is a typical example, comparing confidence intervals predicted by Hayward's formula using a 95% confidence coefficient, with those found in practice. Again each point on the graph represents a route.

![Figure 3: Comparison of theoretically predicted confidence intervals with those found in practice](image)

The general conclusion reached was that the effect on accuracy in assessing notional mean busy hour traffic (i.e., the underlying level of traffic which could reasonably have been expected during the period concerned — whether TCBH or PSBH) of varying the scanning rate (from 1 to 10 minutes) and the length of recording period (from 5 to 20 busy hours) for traffic levels up to 65E, is small and can be adequately predicted from an operational viewpoint by the use of Hayward's formula. The effect of varying these factors beyond the limits stated was not tested although the formula may still be applicable.

<table>
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<tr>
<th>ROUTE</th>
<th>MEAN TCBH</th>
<th>MEAN PSBH</th>
<th>PEAK PSBH</th>
<th>% DIFFERENCE (3) - (2) (L) - (2)</th>
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<tr>
<td>1</td>
<td>5.18</td>
<td>7.89</td>
<td>8.26</td>
<td>52</td>
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<td>38.65</td>
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Table 1: Extract from a typical 5 day record

15. It should however be noted that the effect on accuracy of reducing the scanning rate is less than that of reducing the length of recording period (number of busy hours covered). This could be of considerable importance for any future computer processed traffic recording system since the processing costs could vary almost directly with the total number of scans processed.

EFFECT OF CHOICE OF BUSY HOUR

16. A number of other comparisons were carried out as set out in the following paragraphs with a view to assessing the effect of various busy hour choices (see paragraphs 7 and 8) on the measured traffic. Space limitations prevent full presentation of the evidence but Table 1 is an extract from a typical week's (5 day) record showing the sort of effect found.

17. The time of the busy hour varied from route to route and even on the same route for different days and different weeks in an unpredictable manner. In many cases this time was not consistent to the morning, afternoon or evening periods.

COMPARISON OF MEAN TCBH AND MEAN PSBH TRAFFIC

18. The differences between mean traffic quantities measured during the TCBH and the PSBH on a route by route basis was examined in order to assess the relationship and difference between the two methods. Graphs were drawn of the traffic difference found against nominal traffic level when the Post selected quantities were compared with the quantities measured during a TCBH beginning at 9.30 am each day. It will be recognised that the PSBH figures will always be greater than or equal to the TCBH figure for any given route. The traffic differences were marked and random. No operationally usable relationship between the two quantities could be established, thus neither can be estimated from the other.

COMPARISON OF PEAK AND MEAN TRAFFIC QUANTITIES

19. Peak busy hour traffic quantities and mean PSBH traffic quantities were extracted on a route by route basis. The differences found in traffic quantities measured were marked, random and of a greater order than those described in paragraph 11. It was concluded that no blanket factor can be used to eliminate congestion on some days without resulting in over-provision on some routes. Peak PSBH traffic is of course the maximum level of traffic to be carried on a single day and can give rise to the most serious amount of congestion.

20. TCBH traffic quantities were treated similarly and graphs relating to the differences between peak traffic recorded in the TCBH on a single day and mean TCBH quantities were drawn. Again it was found that the
differences found were marked, random, and of a greater order than those described in paragraph 18.

**COMPARISON OF PEAK PSBH AND MEAN TCBH TRAFFIC QUANTITIES**

21 This comparison was of special interest since circuits are at present related to mean TCBH traffic while peak PSBH traffic is of course the maximum level to be carried. The amount by which the peak PSBH traffic levels exceeded the mean TCBH traffic figures were compared for different routes, sampling rates, and months. The differences between peak PSBH traffic and mean TCBH traffic were both marked and random. It was concluded that no operationally usable adjustment factor applied in a blanket fashion to TCBH measurements can alleviate all serious congestion without resulting in excessive over-provisioning on other routes.

22 Figure 4 illustrates the differences in total recorded traffic levels over all outgoing routes obtained by using different busy hour assessments.

![Graph showing traffic levels](image)

**PRACTICAL COMPARISON OF TCBH AND PSBH RECORDING**

23 The time instability of the busy hour referred to in Paragraph 17 and the variability of the busy hour traffic levels have brought into question the adequacy of TCBH recording for circuit dimensioning purposes. However, because of the convenience and practical advantages of exchange TCBH recording compared with post-selection from all-day measurements, the possibility has been examined of taking measurements during three TCBHs (morning, afternoon and evening) on each recording occasion. A study of a number of routes was made, comparing the post selected route BH traffic for each route with that measured on that route during the nearest exchange TCBH. As equipment quantities cannot be adjusted in steps of less than one circuit this comparison was made by converting the measurements into "equivalent-circuit" quantities. For 95% of the circuit groups studied the differences between the Route PSBH (5 day average) traffic level and the highest TCBH 5 day average traffic level for each route were judged to be acceptable.

**CONCLUSION**

24 Consideration of the foregoing results emphasises the need for a clear definition of provisioning aims. In particular the degree to which peak traffic levels should be taken into account needs to be decided having regard to overall service effects, traffic variations (day to day, week to week) seasonal effects and costs. All these are areas for further study.

25 Whilst the paper contains no formal statistical tests of the assertions made, the conclusions reached have generally been rigorously investigated elsewhere (Reference 3).

**ACKNOWLEDGEMENTS**

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