DOMESTIC LONG-DISTANCE COMMUNICATIONS NETWORK STUDY

COMMUNICATIONS SYSTEMS ENGINEERING

FORECASTING TRAFFIC REQUIREMENTS

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1. INTRODUCTION

The objectives of this traffic requirements forecasting study are stated: source-sink traffic matrices were to be produced and the corresponding channel requirements were to be deduced from them.

A major activity forming part of the DSP Domestic Long Distance Communication Network Study involves forecasting traffic requirements in the 1980 - 1990 time-frame. This forecasting has two objectives:

a) Forecast inter-provincial traffic consisting of telephone, data, video, audio, etc.

b) Forecast the corresponding channel requirements for these.

These objectives may be described more specifically by noting that Canadian telecommunications networks can be represented in the simplified form of Figure 1.[1] This report deals with inter-provincial links; major intra-provincial links are mentioned in Section 9.

This forecasting study was concerned with producing source-sink traffic matrices, as in Figure 2, which give the traffic of various types between all pairs of provinces for forecast years. These traffic forecasts were then to be converted into forecasts of the corresponding channel requirements.[2]

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1. It is noteworthy that Nova Scotia and Prince Edward Island are aggregated as the "Maritimes", which is hereafter considered as a province.

2. In fact, traffic matrices were only produced for telephone traffic; for other services channel requirements were estimated directly in the most appropriate form.

2. SIMPLE TELEPHONE TRAFFIC FORECASTING

Using the limited amount of data available on long distance telephone calling rates, lower and upper forecasts of telephone traffic from Ontario and Quebec were produced using simple linear and exponential extrapolation. This forecasting gave partial source-sink traffic matrices.

A limited amount of Statistics Canada data is available on long distance calling by province; typical data for Ontario and Quebec combined is shown in Figures 3 and 4.

The good least-squares fits shown for both linear and semi-log plots of the data illustrate a basic problem inherent in forecasting with this data: we cannot definitely say that growth rates are either linear or exponential.

Rather than trying to resolve this difficulty, forecasting was undertaken based on both linear and exponential forecasting. Since growth of demand is not expected to grow more slowly than linearly nor more quickly than exponentially, such forecasts give lower and upper limits[3] respectively. In fact, since traffic growth rates are slightly more nearly exponential than linear, the most likely future values are expected to be somewhat closer to the exponentially derived forecasts than to those linearly derived.

While provincial traffic growth rates are of some interest, we are really concerned with the traffic over inter-provincial links. Data giving the

3. These limits are based upon the expected value forecasts shown in Figures 3 and 4; confidence bounds as shown there could also be determined for each of these lower and upper limits.

traffic between all pairs of provinces was not, however, available.

Fortunately some data, available from various sources, made it possible to divide Ontario and Quebec's traffic into the components directed to each province. Simple extrapolation (either linear or exponential) enabled partial source-sink traffic matrices, as shaded in Figure 5, to be produced for the forecast years.

3. GRAVITY MODELLING

Gravity modelling was undertaken to fill in the remainder of the partial traffic matrices. Urban provincial population forecasts were used with subjectively determined distances between provincial "centres of gravity" in this gravity modelling, which produced full telephone traffic matrices.

Since the available data only enabled partial traffic matrices to be produced, an indirect approach was needed for forecasting traffic between pairs of provinces other than those shaded in Figure 5. Gravity modelling was undertaken to extend our limited data, so that whole matrices covering all inter-provincial links could be filled in.

The gravity model hypothesizes that the traffic T between two point populations P_1 and P_2 situated a distance R apart is

$$T = k \frac{P_1 P_2}{R^n} \qquad (1)$$

where k and n are appropriate fitted constants

This can be re-written as

$$\ln \left(\frac{T}{P_1 P_2} \right) = \ln (k) - n \ln (R) \qquad (2)$$

To use this model we required data on traffic, populations, and distances between these.

Traffic data was available, giving traffic volumes between Ontario and Quebec and the other provinces, as shaded in Figure 5.

Urban provincial populations were used here rather than total populations. Equation (1) indicates that total long distance traffic N should be proportional to population; this is confirmed by Figure 6 for urban provincial populations (which give a slope nearer unity than total provincial populations). Urban provincial forecasts, such as those of Figure 7 made by the Systems Research Group[4], are readily available.

Distances between provincial "point populations" were next needed. Subjectively determined provincial "centres of gravity" were chosen, as shown in Figure 8, and distances between these were measured. (Since Canada is an essentially linear country, these distances are additive.)

With data on traffic, populations and distances available, it was possible to undertake gravity modelling. Figure 9 shows this to be quite reasonable using 1966 data. (Figure 10 shows that similar modelling can be applied to the Working Group on Inter-Regional Telecommunications' 1973 data on voice circuit requirements.)

Assuming that inter-provincial links other than those shaded in Figure 5 would have plotted values of (T/P_1P_2) against R lying on a gravity model line (fitted to data for "shaded" inter-provincial links) enabled the rest of the source-sink traffic matrix to be filled in; this is illustrated by Figure 11. The use of this assumption enabled traffic forecasts for the desired years of 1980, 1985 and 1990 to be produced.

It must be emphasized that this indirect forecasting approach, based on gravity modelling, was necessitated by the limited availability of suitable data on inter-provincial traffic.

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4. Systems Research Group, Canada Population Projections to the Year 2000, S.R.G., Toronto, 1970.

4. FORECASTING TELEPHONE CIRCUIT REQUIREMENTS

Telephone traffic matrices were converted into matrices of public switched voice circuit requirements using correlations between 1973 traffic forecasts and the corresponding 1973 public switched voice circuit requirements as determined by the Inter-Regional Working Group. Assuming these correlations to hold enabled matrices of future telephone circuit requirements to be produced.

It was next necessary to convert the telephone forecasts into voice circuit requirements. Since suitable traffic engineering data was not available, and since the traffic forecasts which were produced actually referred only to commercial inter-provincial traffic rather than to total inter-provincial traffic, an indirect approach again had to be used.

Forecasts of 1973 commercial traffic volumes were produced and these were correlated, as shown in Figure 12, with numbers of public switched voice circuits as forecast by the Inter-Regional Working Group. A good correspondence is apparent.

Assuming that such correspondence would hold through time, it was possible to convert the whole traffic matrices (as Figure 11) into matrices giving public switched voice circuit requirements for each inter-provincial link for the forecast years of 1980, 1985 and 1990. Figure 13 shows this for 1980; the lower and upper limits were obtained using linear and exponential forecasting respectively with gravity modelling. As already noted in Section 2, future requirements are expected to lie somewhat closer to the exponentially derived forecasts.

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It is interesting to compare the 1980 forecasts of public switched voice circuit requirements given in Figure 13 with those produced by the Inter-Regional Working Group. As shown in Figure 14, a reasonable correspondence is apparent between these two sets of forecasts.

While exponential forecasting is slightly preferred over linear for forecasting up to 1980, rapid exponential growth rates can produce unrealistically high results for later years. It is therefore recommended that an average of linear and exponential forecasts be used. Since algebraic averaging gives virtually no weight to linear forecasts, "geometric averaging" is recommended.[5]

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5. While the algebraic average of A and B is defined as (A+B)/2, the "geometric average" is defined as

$$\text{antilog}\left(\frac{\log(A) + \log(B)}{2}\right) = (A.B)^{\frac{1}{2}}$$

5. REQUIREMENTS FOR DATA TRAFFIC

Data traffic volumes for the 1980-1985 time-frame will probably not be significant with respect to voice traffic volumes. Circuit requirements for data are expected to be only of the order of 3%-4% of those already forecast for voice traffic.

Data traffic volumes are now very low, although their growth rates are considerably higher than for telephone.

Current forecasts are that data volumes of long haul traffic in the 1980-1985 time-frame will still be relatively insignificant in comparison with the volumes of (primarily digital) voice. Forecasts in the range of 2%-6% of total telephone system traffic volumes being data have been made in various countries. Voice circuit requirements for data are thus expected to be relatively small, of the order of 3%-4% of those already forecast for telephone voice traffic.

Further studies are, however, underway to examine new developments in the data field which might increase presently envisaged data traffic volumes by an order of magnitude or more; such developments would obviously make data traffic significant with respect to voice traffic.

6. REQUIREMENTS FOR VIDEO TRAFFIC

The very limited data available enabled only the very simple prediction to be made of "a dozen ± half-a-dozen" video channels required across Canada in 1980.

Video traffic for the 1980-1990 time-frame has not yet been forecast except in terms of video channel requirements for 1980. Several predictions of such requirements have been produced; Figure 15 illustrates those given by Mr. A.G.W. Timmers. This Figure may be summarized by the simple prediction that "a dozen ± half-a-dozen" video channels will be required across Canada in 1980.

This very simple prediction is all that can be made with the very limited amount of data now available. Further data collection studies are required to update this preliminary prediction to give more definite forecasts.

7. REQUIREMENTS FOR AUDIO TRAFFIC

Only very preliminary estimates of the circuit requirements for audio traffic are available.

Mr. A.G.W. Timmers also provided a simple indication of CBC audio requirements for AM and FM channels, as illustrated in Figure 16; other requirements are not yet even vaguely defined.

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8. TOTAL TELECOMMUNICATIONS REQUIREMENTS

Total telecommunications circuit requirements for each inter-provincial link may be estimated by a simple summation of the forecast requirements for each service.

The requirements given above for voice, data, video and audio services can now be totalled for each inter-provincial link; this provides forecasts of total telecommunications requirements (for 1980 at least).

9. FURTHER WORK

Further work is required to forecast intra-provincial telephone traffic and requirements, to study audio and video requirements in detail, to relate forecasts to costs, and to update all these forecasts.

Further work is envisaged in four general areas:

a) Provide telephone traffic and circuit requirements forecasts for the major intra-provincial links shown in Figure 1 (by dashed lines), as tabulated on the diagonal in Figure 2.

b) Undertake further studies to provide detailed forecasts of audio and video telecommunications requirements.

c) Relate traffic and requirements forecasts to the costs of telecommunications usage, and thereby "close the loop" of costs → demand → requirements → costs.

d) Update all of these forecasts, particularly as more extensive and later data becomes available.

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FIGURE 1

A SIMPLIFIED REPRESENTATION OF THE CANADIAN TELECOMMUNICATIONS NETWORKS

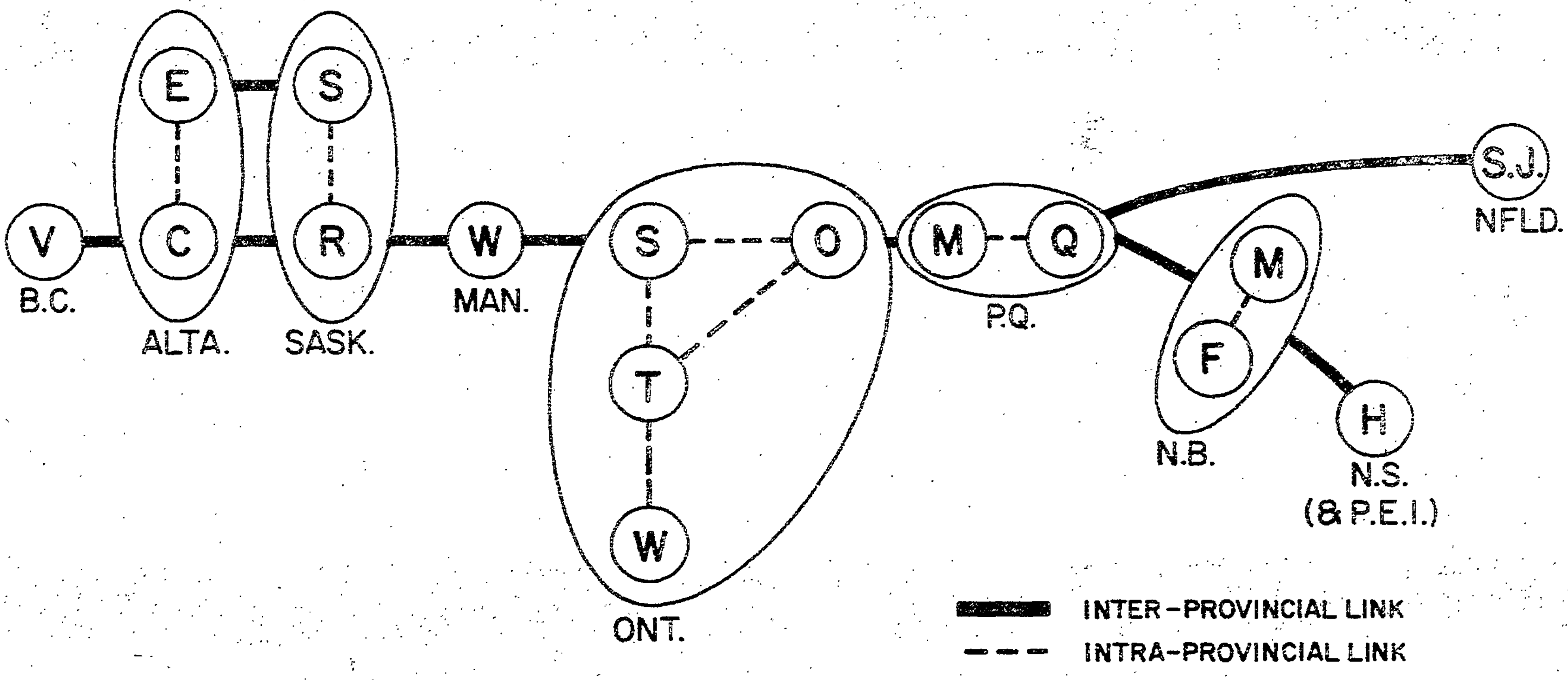


FIGURE 2

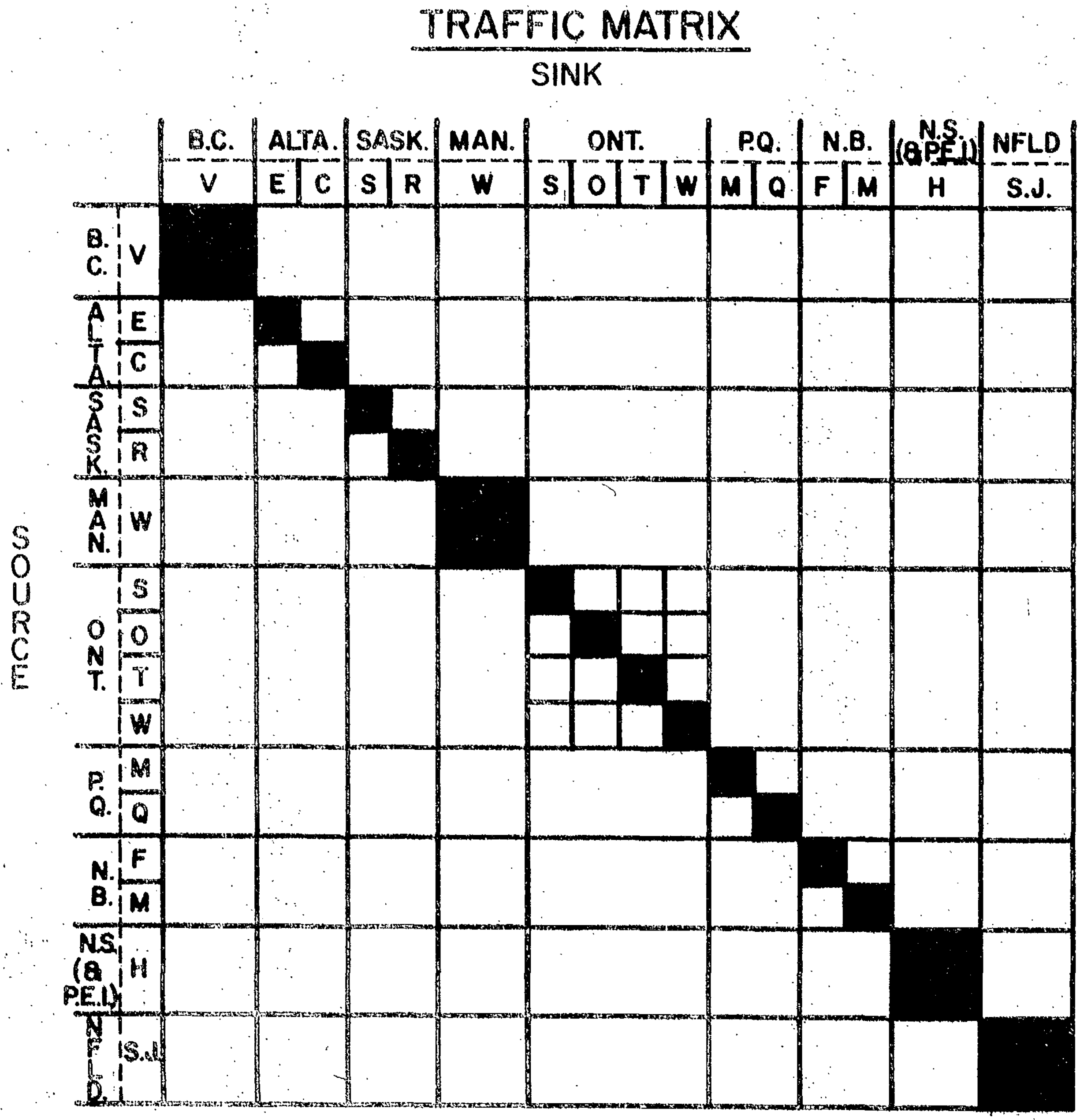
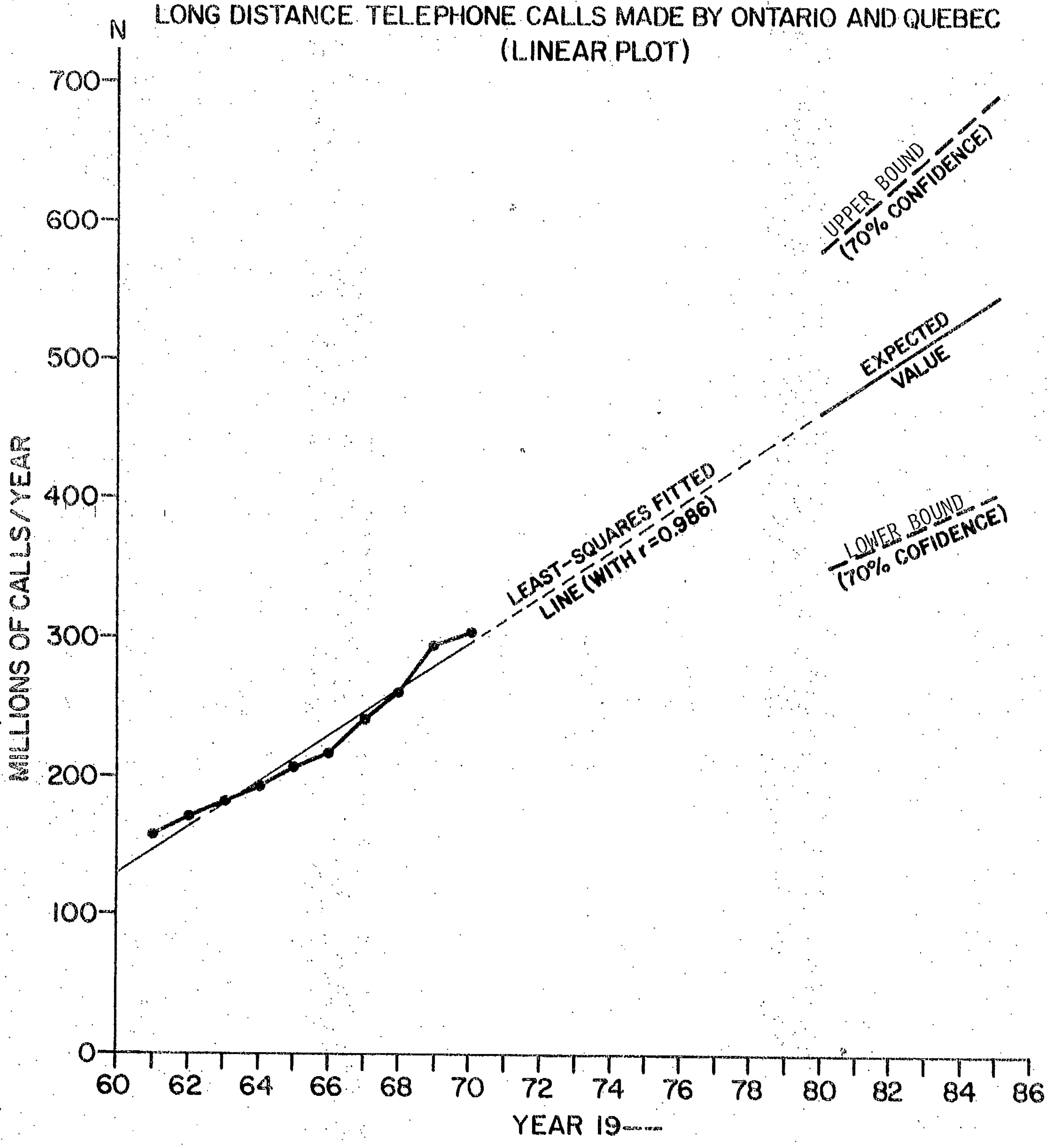
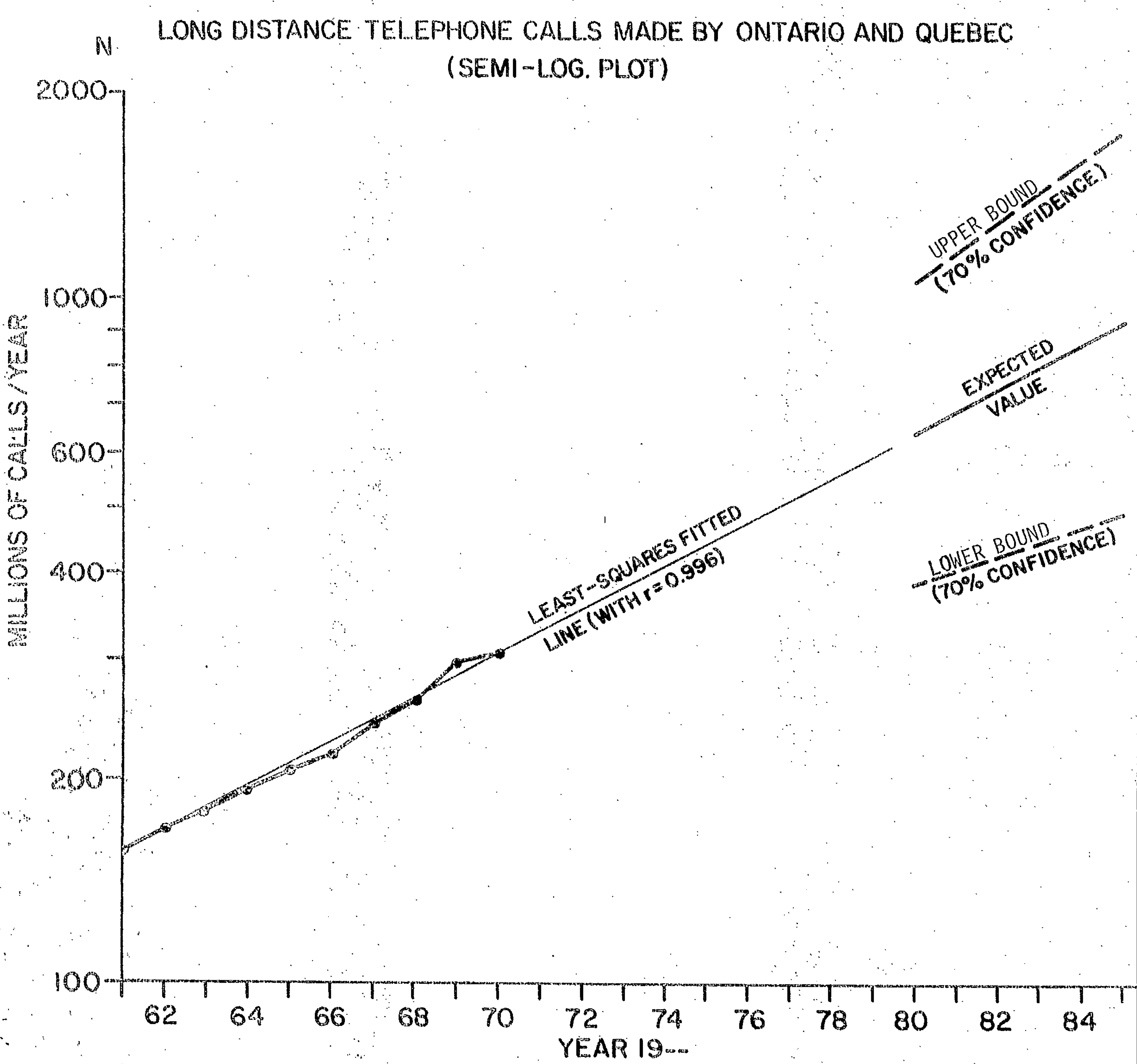

TRAFFIC MATRIX
SINK
B.C.
ALTA.
SASK.
MAN.
ONT.
P.Q.
N.B.
N.S. (& P.E.I.)
NFLD
V
E
C
S
R
W
S
O
T
W
M
Q
F
M
H
S.J.
SOURCE
B.C.
ALTA.
SASK.
MAN.
ONT.
P.Q.
N.B.
N.S. (& P.E.I.)
NFLD.

FIGURE 3



LONG DISTANCE TELEPHONE CALLS MADE BY ONTARIO AND QUEBEC
(LINEAR PLOT)
N
700
600
500
400
300
200
100
0
MILLIONS OF CALLS/YEAR
UPPER BOUND
(70% CONFIDENCE)
EXPECTED
VALUE
LEAST-SQUARES FITTED
LINE (WITH r =0.986)
LOWER BOUND
(70% COFIDENCE)
60
62
64
66
68
70
72
74
76
78
80
82
84
86
YEAR 19—

FIGURE 4



LONG DISTANCE TELEPHONE CALLS MADE BY ONTARIO AND QUEBEC
(SEMI-LOG. PLOT)
N
2000
1000
600
400
200
100
MILLIONS OF CALLS/YEAR
62
64
66
68
70
72
74
76
78
80
82
84
YEAR 19--
UPPER BOUND
(70% CONFIDENCE)
EXPECTED
VALUE
LEAST-SQUARES FITTED
LINE (WITH r=0.996)
LOWER BOUND
(70% CONFIDENCE)

FIGURE 5

NUMBERS OF LONG DISTANCE TELEPHONE CALLS MADE IN A GIVEN YEAR

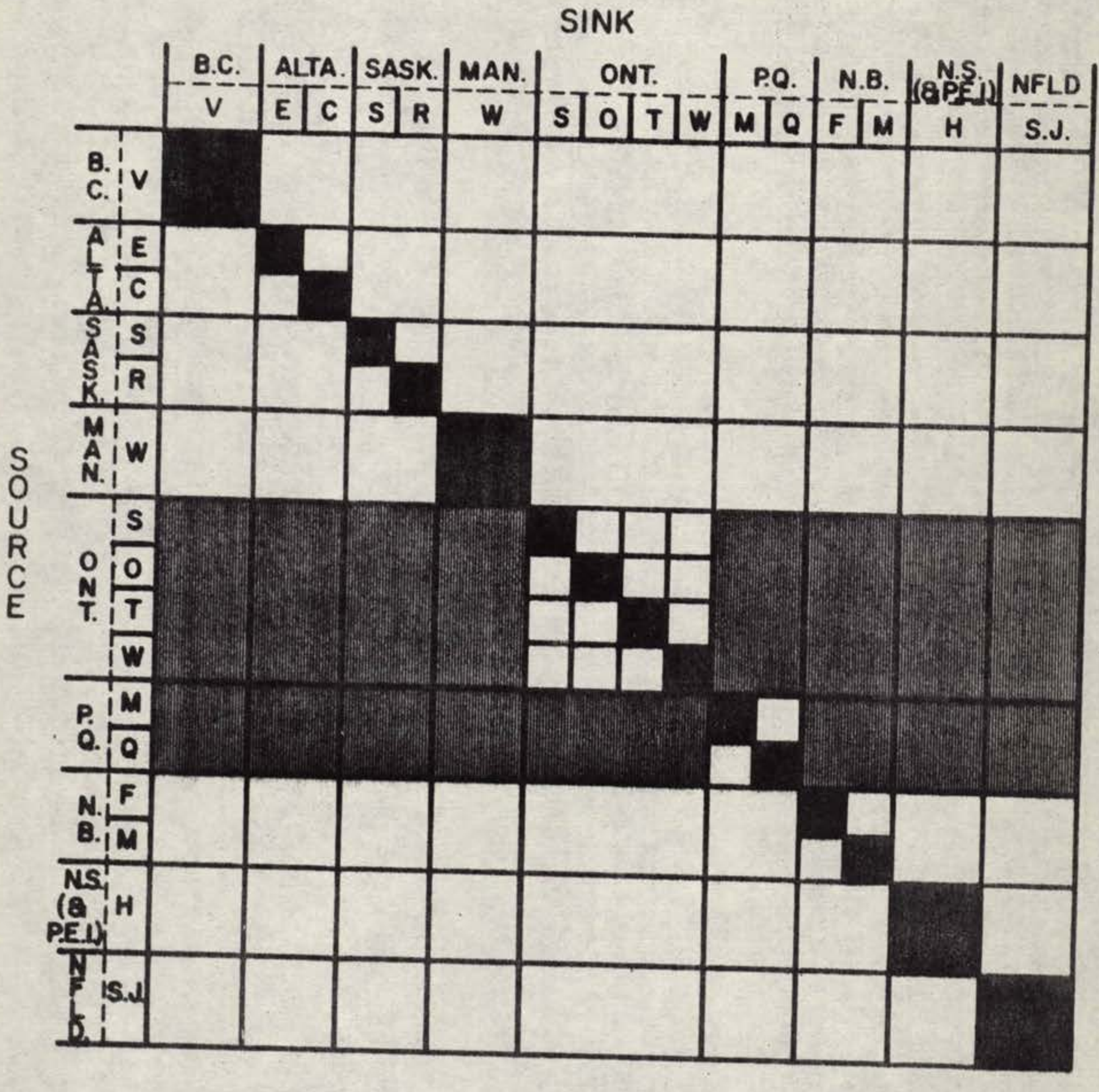


FIGURE 6

1966 URBAN POPULATIONS OF PROVINCES AND TOTAL NUMBERS OF LONG DISTANCE TELEPHONE CALLS MADE. (LOG-LOG PLOT)

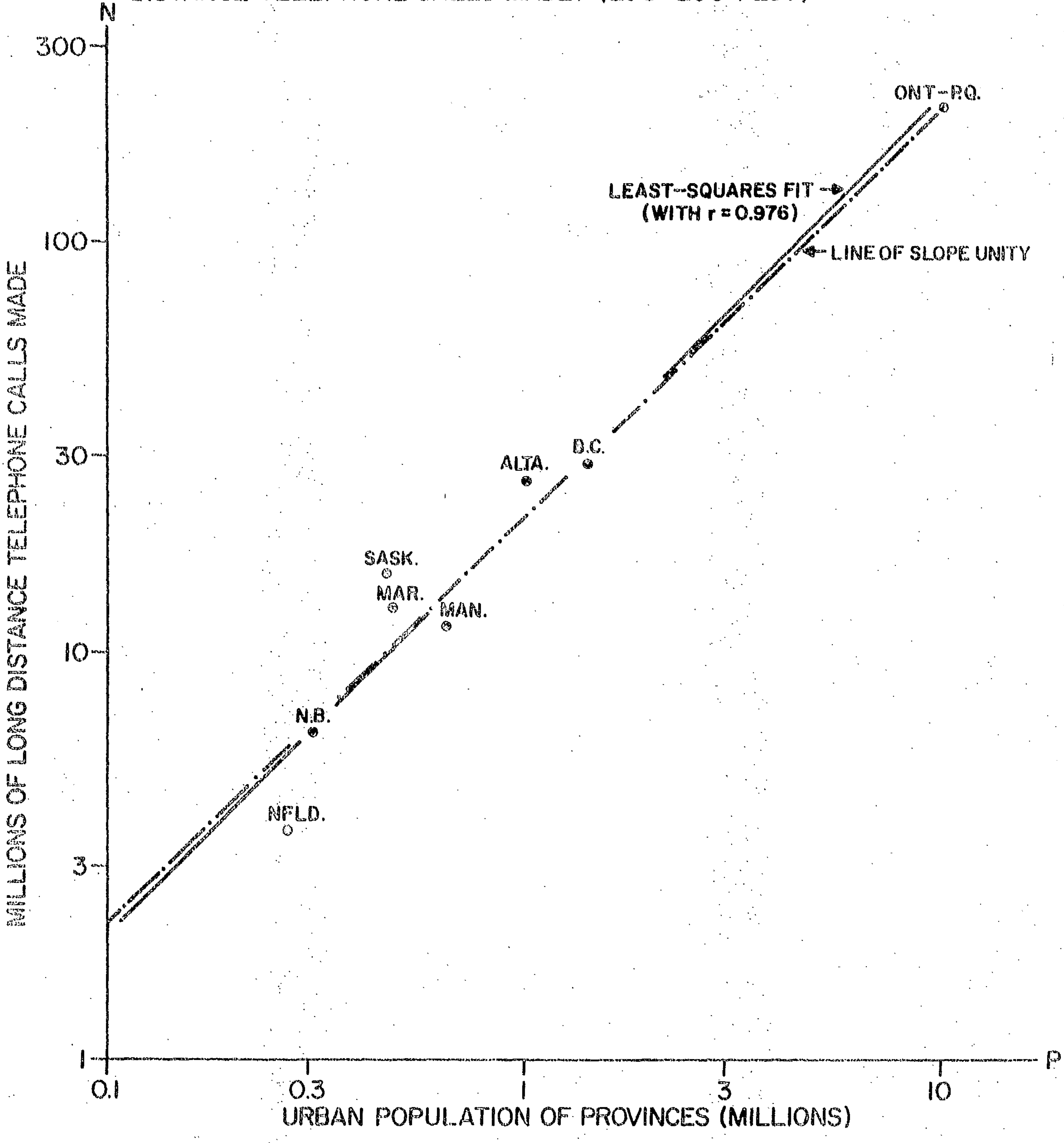


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FIGURE 7

PROJECTIONS OF URBAN PROVINCIAL POPULATIONS

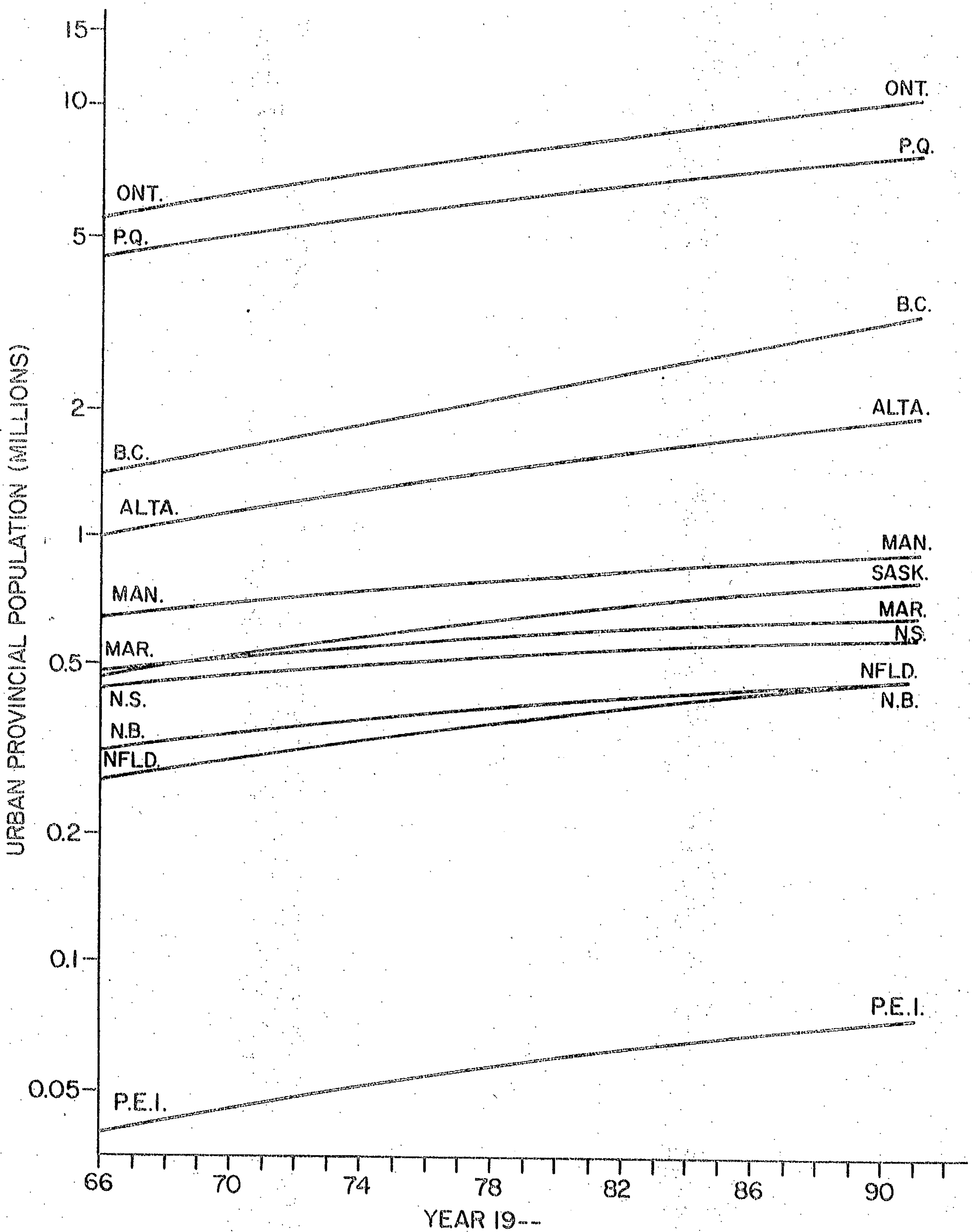


FIGURE 8

DISTANCE IN MILES BETWEEN SUBJECTIVELY DETERMINED PROVINCIAL "CENTRES OF GRAVITY"

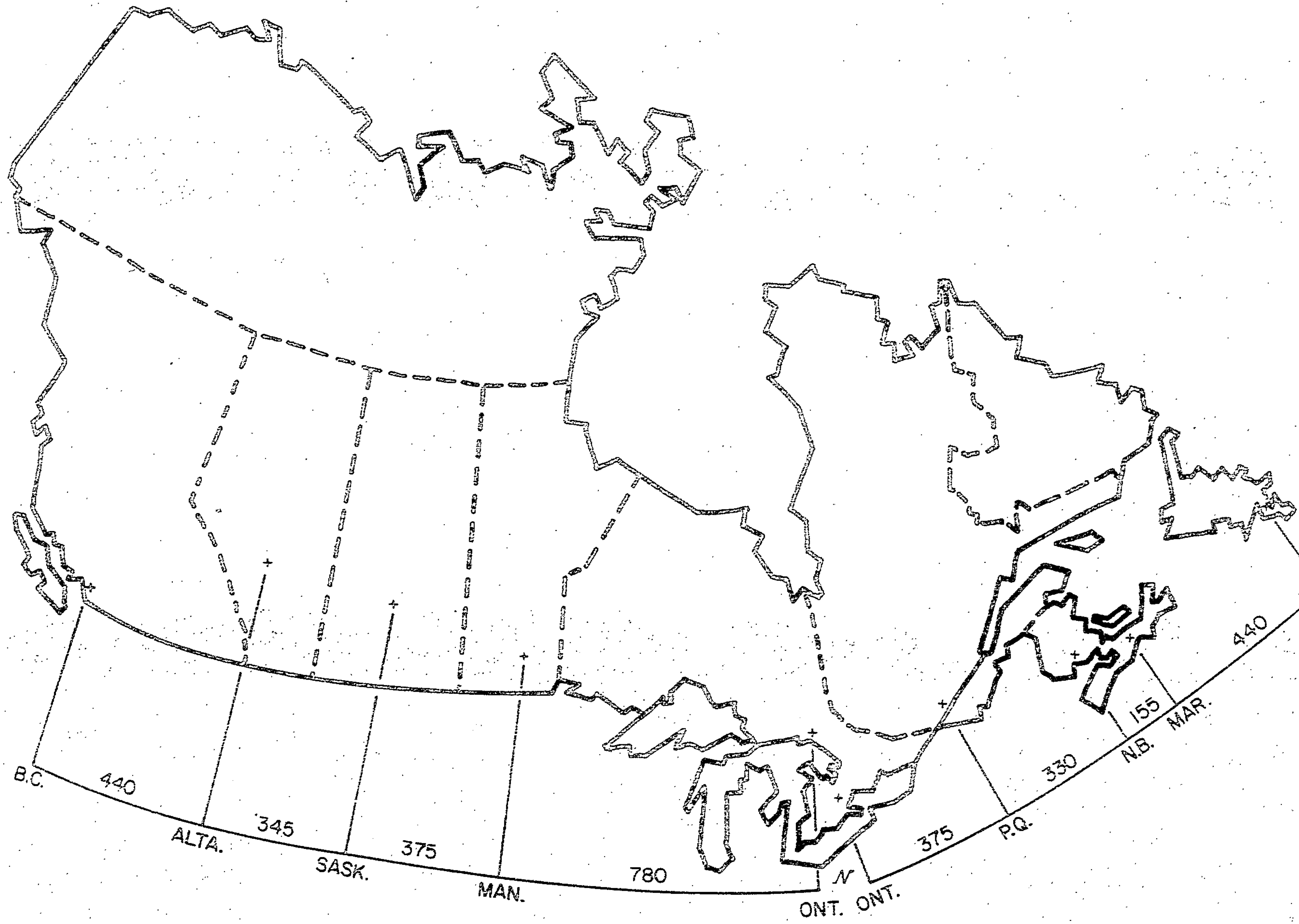
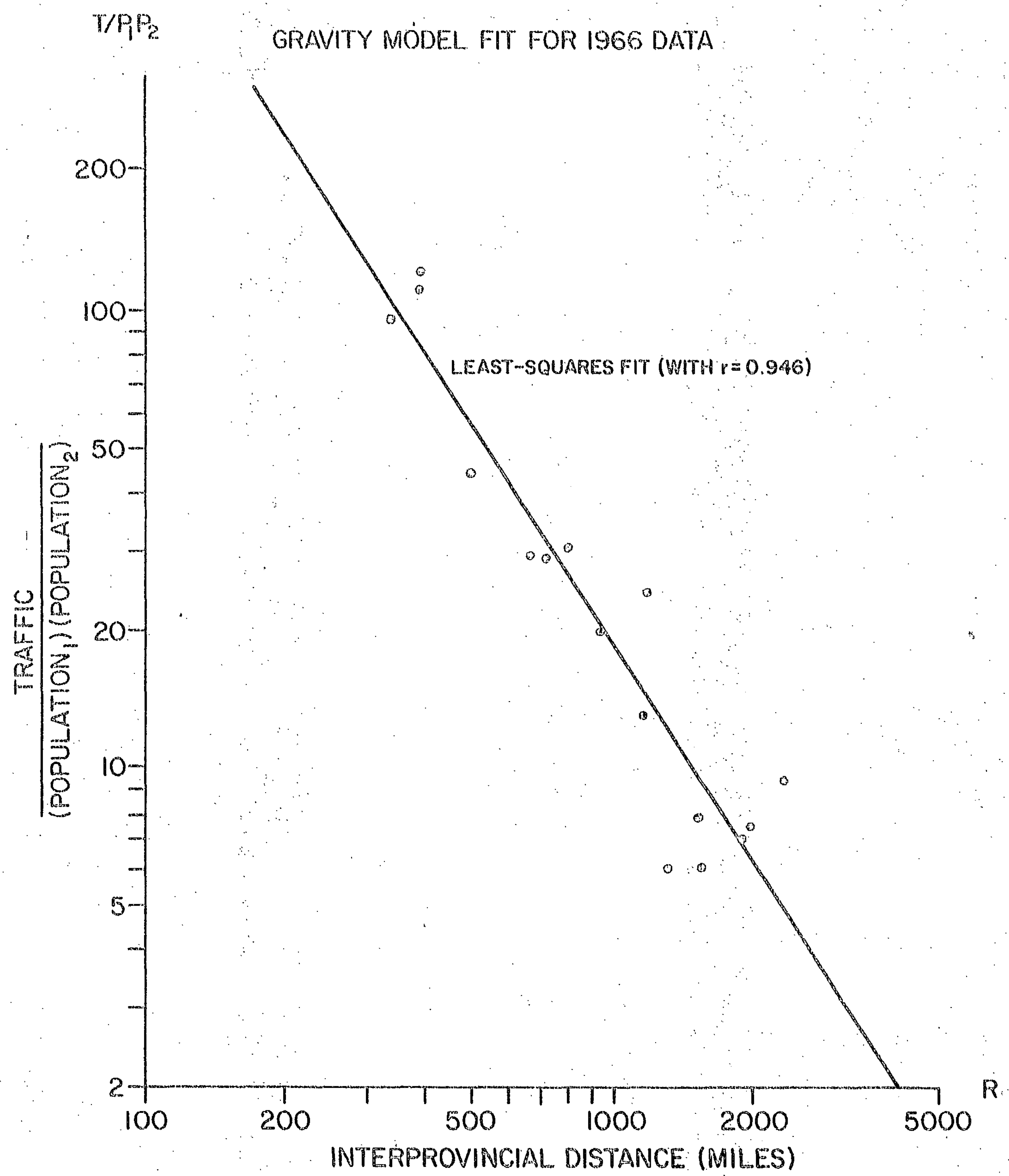


FIGURE 9



T/P1P2
GRAVITY MODEL FIT FOR 1966 DATA
LEAST-SQUARES FIT (WITH r = 0.946)
TRAFFIC / (POPULATION1)(POPULATION2)
200
100
50
20
10
5
2
100
200
500
1000
2000
5000
R
INTERPROVINCIAL DISTANCE (MILES)

23

FIGURE 10

GRAVITY MODEL FIT TO 1973 DATA OF WORKING GROUP ON INTER-REGIONAL TELECOMMUNICATIONS

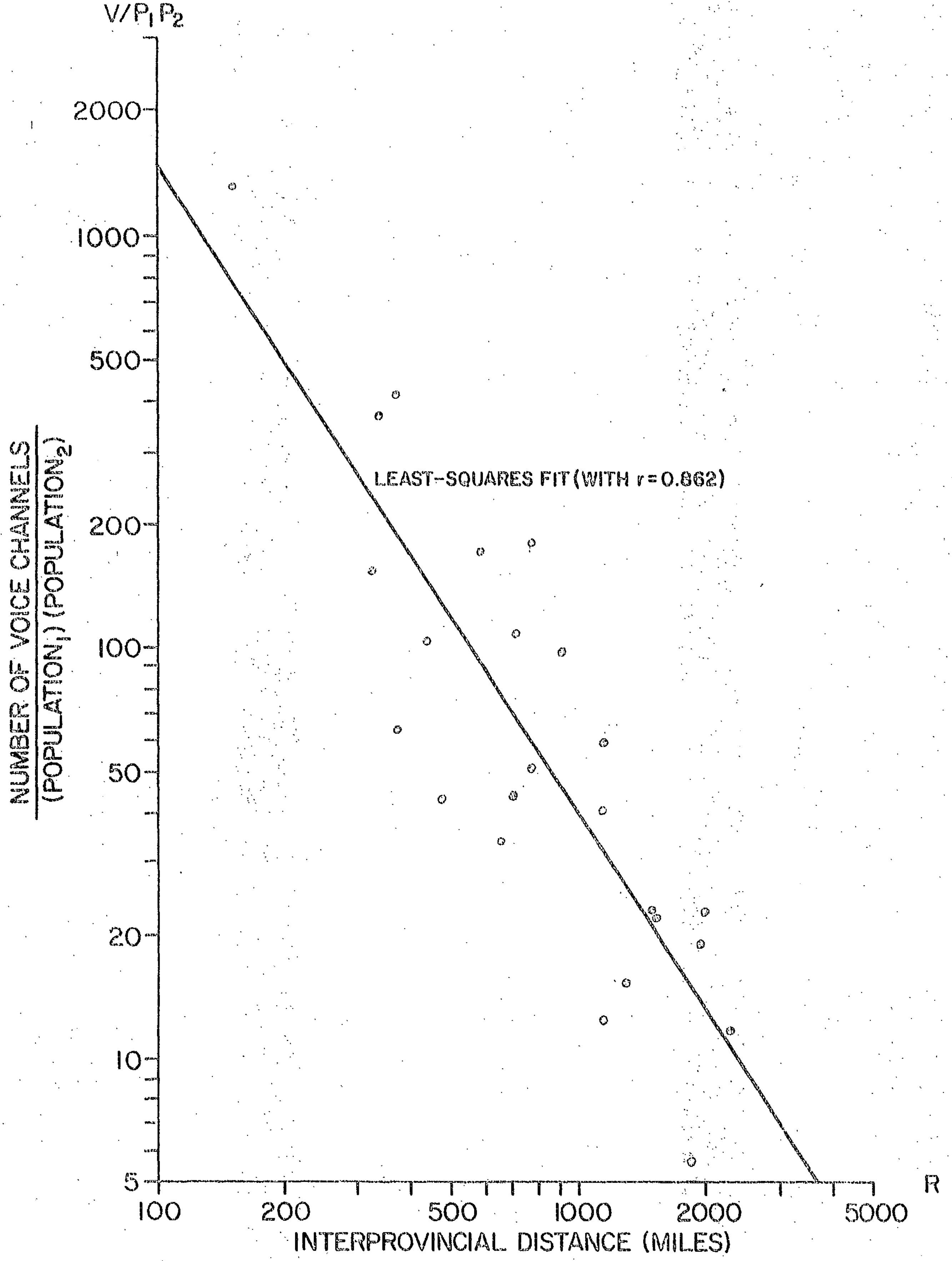


FIGURE 11

NUMBERS OF LONG DISTANCE TELEPHONE CALLS MADE IN A GIVEN YEAR

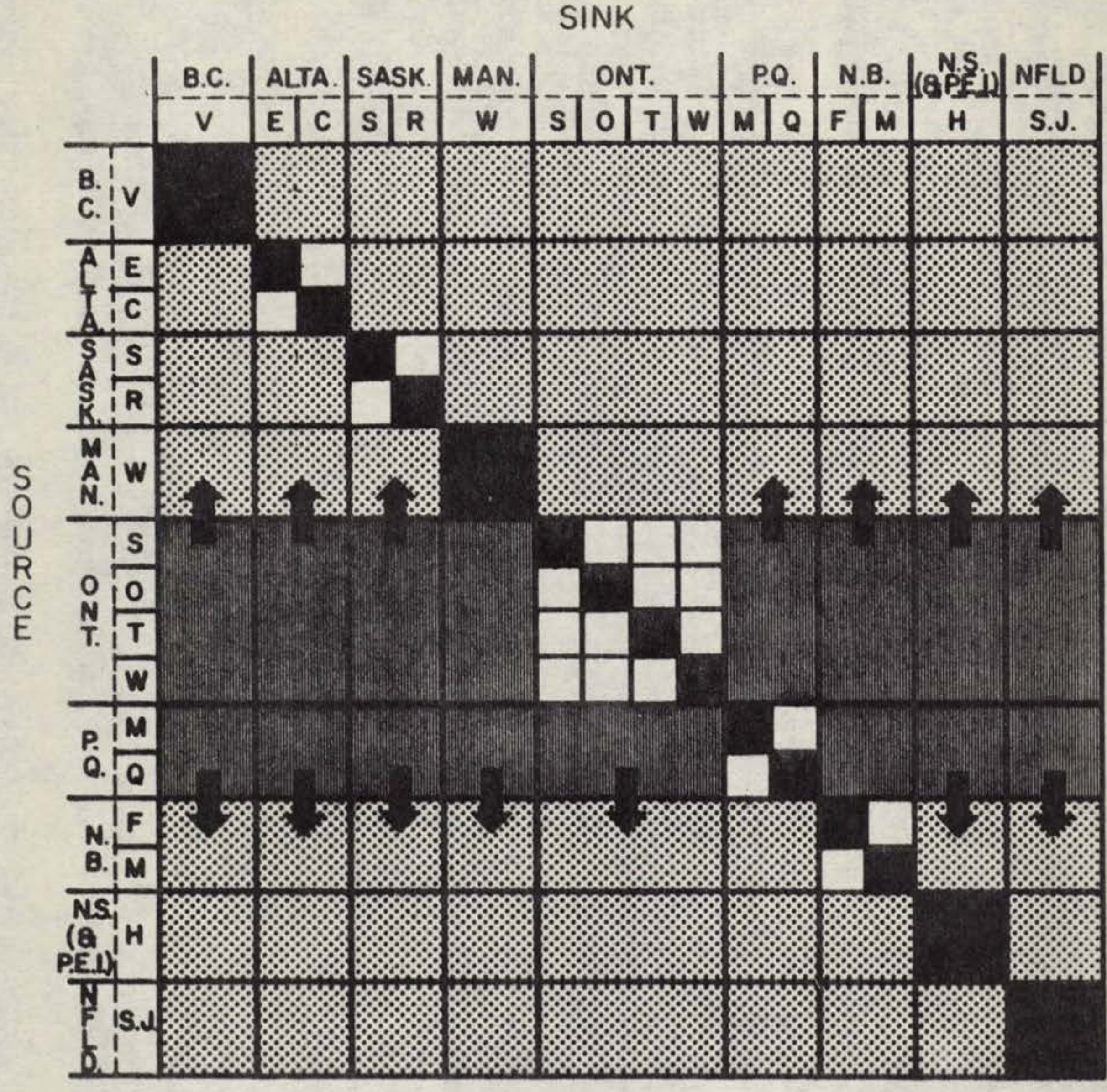


FIGURE 12

CORRESPONDENCE BETWEEN NUMBERS OF PUBLIC SWITCHED VOICE CHANNELS FORECAST BY WORKING GROUP FOR 1973 (V) AND THOUSANDS OF COMMERCIAL LONG DISTANCE TELEPHONE CALLS FORECAST FOR THE SAME YEAR (T)

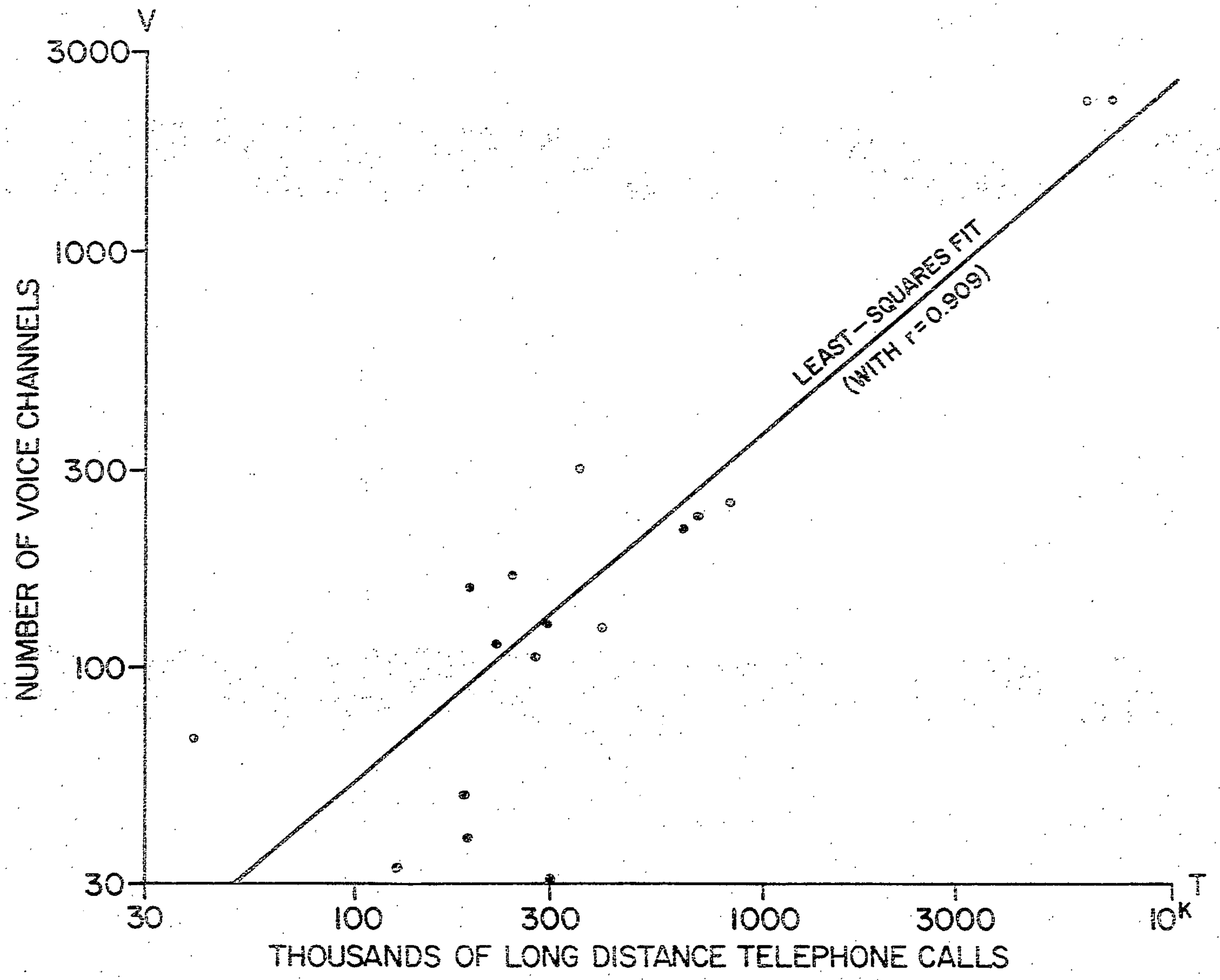


FIGURE 13

FORECASTS OF NUMBERS OF PUBLIC SWITCHED VOICE CHANNELS REQUIRED FOR 1980. (END-TO-END REQUIREMENTS)

		B.C.	ALTA.	SASK.	MAN.	ONT.	P.Q.	N.B.	N.S. (& P.E.I.)	NFLD
		V	E, C	S, R	W	S, O, T, W	M, Q	F, M	H	S.J.
B.C.	V (upper)		436	159	150	1414	590	53	70	44
	V (lower)		270	82	68	313	165	18	24	14
ALTA.	E, C (upper)			176	137	1572	465	41	54	33
	E, C (lower)			117	72	274	152	15	20	11
SASK.	S, R (upper)				99	376	261	22	29	18
	S, R (lower)				64	150	38	8	11	6
MAN.	W (upper)					1417	359	30	39	23
	W (lower)					284	134	12	16	8
ONT.	S, O, T, W (upper)						3831	480	621	393
	S, O, T, W (lower)						2368	172	251	95
P.Q.	M, Q (upper)							400	445	670
	M, Q (lower)							232	209	104
N.B.	F, M (upper)								81	26
	F, M (lower)								69	14
N.S. (& P.E.I.)	H (upper)									42
	H (lower)									26
NFLD	S.J.									

FORECAST LIMITS: UPPER / LOWER

FIGURE 14

CORESPONDENCE BETWEEN NUMBERS OF PUBLIC SWITCHED VOICE CHANNELS FORECAST FOR 1980 BY WORKING GROUP (V_{WG}) AND NUMBERS FORECAST USING GRAVITY MODELLING OF FORECASTS (V_G)

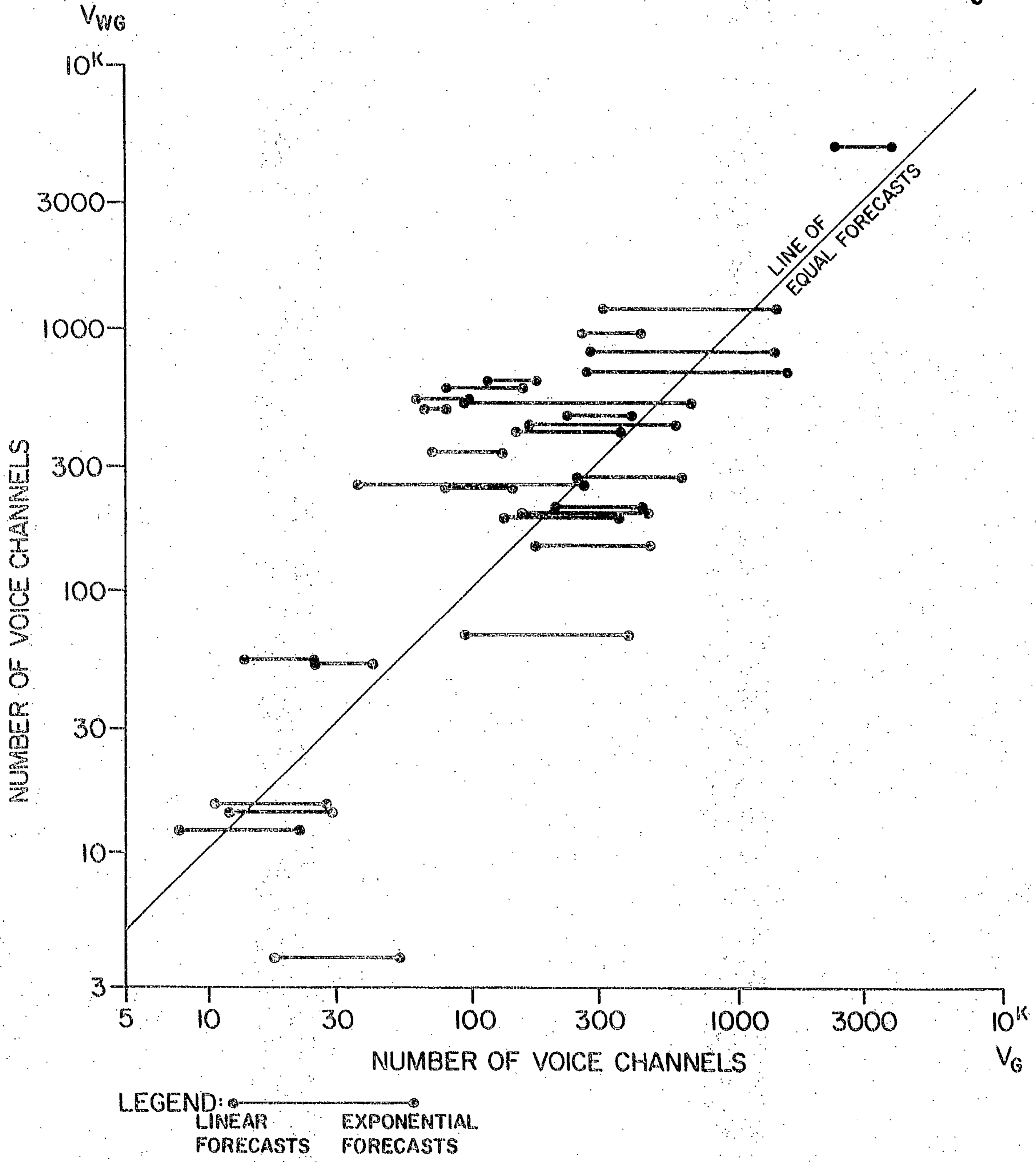


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FIGURE 15

VIDEO CHANNEL REQUIREMENTS PREDICTED FOR 1980

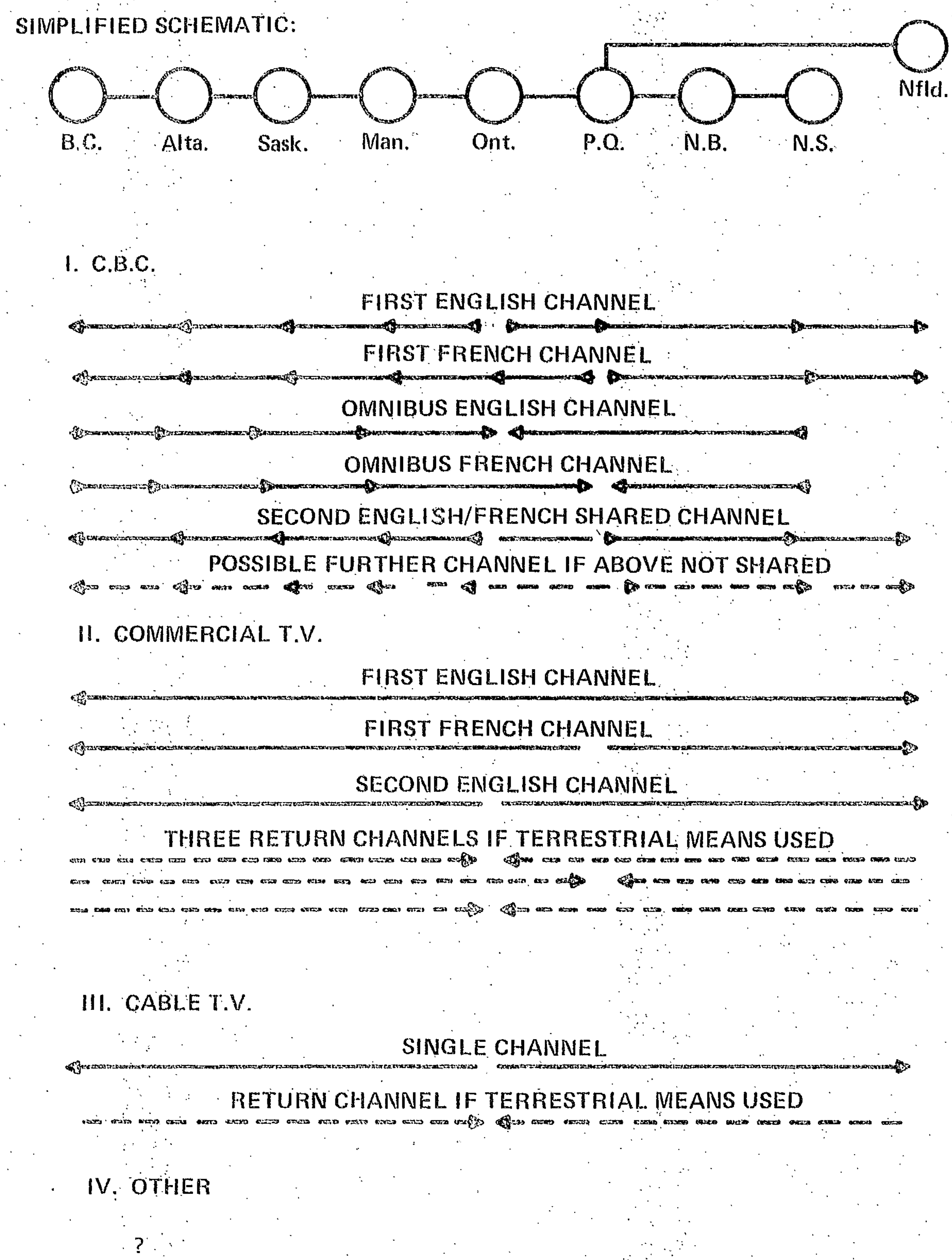
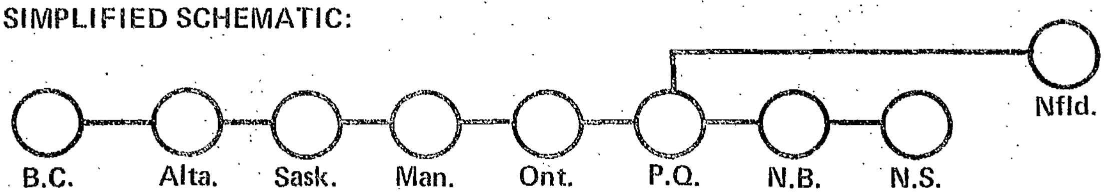


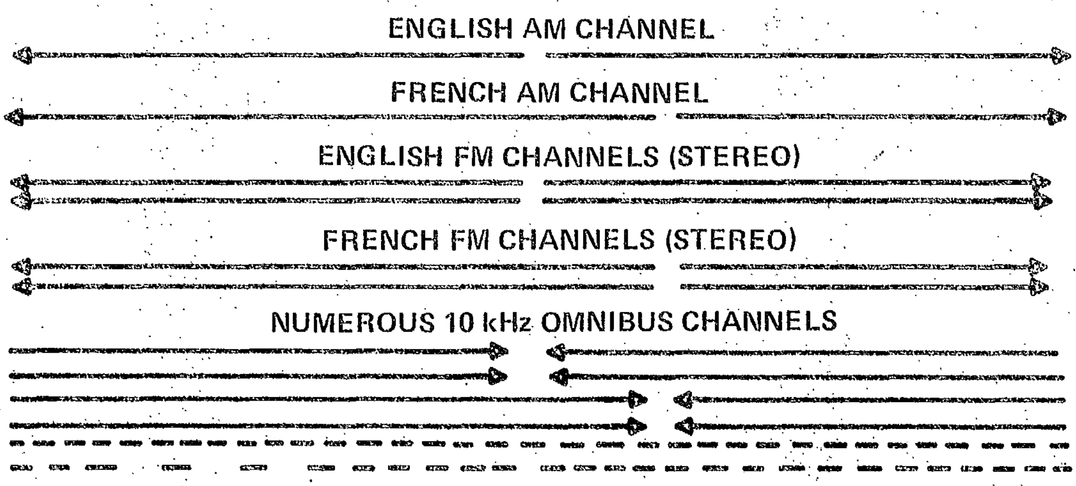
FIGURE 16

AUDIO CHANNEL REQUIREMENTS PREDICTED FOR 1980

SIMPLIFIED SCHEMATIC:



I. C.B.C.



II. COMMERCIAL AND OTHER

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