TELEPHONE CALL PRICING IN EUROPE: LOCALIZING THE PULSE

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January 1979

P-6215

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ABSTRACT

European telephone systems have long used the periodic pulse system for billing subscriber-dialed long-distance (trunk) calls. By 1982 all of the six countries surveyed--Denmark, Norway, Sweden, Switzerland, the United Kingdom and West Germany--will have extended this form of pricing to local telephone calls so that all call charges will be based on duration, distance and time-of-day.

This paper analyzes several types of periodic pulse billing mechanisms used for the timing of local calls and describes the rate structures that have been adopted in each country. Although only limited information is available regarding changes in telephone usage that are induced by a change in rate structure, data from a sample of Trondheim, Norway subscribers permit estimation of arc price elasticities of demand for local calls.

TELEPHONE CALL PRICING IN EUROPE: LOCALIZING THE PULSE*

by

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The concept of pricing local telephone service according to each subscriber's usage is receiving increased attention from telephone companies and regulatory commissions in the United States. Traditionally, an unlimited number of local telephone calls have been available to nearly all U.S. residential customers for a flat monthly rate. By contrast, telephone subscribers in Europe have, for many years, been charged for each call that they make--local as well as long-distance.

This paper discusses the pricing of local telephone calls in six European countries (Denmark, Norway, Sweden, Switzerland, the United Kingdom, and West Germany), and analyzes the effects of changing from a fixed charge for each local call to rates based

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*This paper is copyrighted by The Rand Corporation, 1979 and was presented at the Mountain Bell Economics Seminar, Keystone, Colorado, August 27-30, 1978. I am happy to acknowledge the contributions of J. Müller, the assistance of J. Schwalbach, and the cooperation of numerous officials of several telephone administrations. The preparation of this paper has been supported by fellowships from the German Marshall Fund and the Alexander-von-Humboldt Foundation and by National Science Foundation Grant No. APR 77-16286 to The Rand Corporation. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the National Science Foundation.

on call duration.

THE PERIODIC PULSE SYSTEM

European telephone systems use various versions of a pulse system to meter telephone calls made by individual subscribers. Calls are classified by distance and time of day, and prices are established by varying the interval of time between pulses. Each pulse has a fixed billing value.

Historically, calls within the local telephone exchange were the first to be automated in Europe. Each subscriber's line was connected to a separate register located in the telephone office; for each successful call, a single pulse was transmitted and accumulated by the register. As operator-handled trunk calls between exchanges were converted to a subscriber-dialed system, the manual notation of call duration was replaced by the Karlsson system of periodic pulses. In this system, call duration is measured by the number of seconds that elapse between pulses; the longer the distance called the shorter the interval between pulses.

The subscriber's register accumulates all the pulses, for both local and trunk calls. Each month the register is read and the subscriber is billed for the total number of pulses, or units, multiplied by the price per pulse. This means that there is no itemized billing of calls. The subscriber can, however, rent an optional meter that can be attached to his telephone to register and display the pulses as he makes his calls.

North American residents, accustomed to receiving itemized monthly telephone statements, find the pulse system of consumer accountability uncomfortable. However, the system has enabled European telephone administrations to automate their trunk networks at significantly lower costs than would have been possible had a ticketing system with itemized billing been adopted. Furthermore, electromechanical exchanges can bill local calls according to usage at costs below those envisioned in U.S. exchanges that use similar equipment.*

Charges for European coin (public) telephones are also determined by pulse units, thus making fully-automatic service possible for both trunk and foreign calls. The pulse unit is equal to the value of a coin of convenient denomination (or a multiple thereof). In many coin instruments, the user can stack a supply of coins in a holding register; as each pulse arrives, a coin drops into the coin box until the conversation is completed or the supply of coins is exhausted. Some coin instruments allow the caller to use unexpired time to place a second call.

The structure of a very basic pulse-system tariff can be illustrated by employing the rate structure currently used in Sweden (Table 1). A single pulse is billed at the rate of 17 öre (3.7¢).**

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*One-time investment costs per main station for local-call periodic pulse equipment are about $4 to $10. In the U.S. ticketing system, equipment for usage-sensitive pricing is estimated to cost $5 to $50 per main station in electromechanical offices, and $2 to $5 in electronic offices. (See Mitchell, 1978a.)

**Throughout this paper, prices in U.S. dollars are based on rates of exchange prevailing in April 1978.

Table 1

TELEPHONE CALL RATE STRUCTURE IN SWEDEN, 1978

[1 pulse = 17 öre (3.7¢)]

Type of Call	Pulse Interval
Local	∞ (1 pulse per call)
Neighboring	9 min
Trunk:	
<45 km	45 sec
45-90 km	24 sec
90-180 km	15 sec
180-270 km	12 sec
>270 km	10 sec

Each completed local-exchange call receives one pulse, regardless of its duration or the time of day. Calls to neighboring exchanges receive one pulse every 9 min, and trunk calls are pulsed every 45 to 10 sec, the pulse frequency increasing with distance.*

By 1980, most European telephone systems will have extended periodic pulsing to their local exchanges, so that the *duration* and *distance* of a call will be the uniform parameters on which telephone rates are established. Local-call timing has been used in Denmark (since 1950), the United Kingdom (1958), Finland (1960), Spain (1971), Norway (1975), and Switzerland (1978). West Germany will shift to local-call timing in 1980, and Sweden will make the conversion in 1982. In the case of the latter two countries, these changes are only one component of a more wide-ranging change in the telephone rate structure. West Germany will concurrently enlarge local calling areas to include neighboring exchanges and will reduce the number of separate distance bands for trunk calls. Sweden will similarly enlarge its local calling areas and will, for the first time, institute off-peak rates throughout the network.

PULSE PRICING OF CALL DURATION

Pulses for telephone calls are generated electromechanically when a rotating disk, driven by an electric motor at constant speed, causes uniformly spaced magnetic contacts to momentarily close an

*In 1982, Sweden will follow the practice of most European systems and introduce a rate structure for trunk calls that includes reduced off-peak rates (longer pulse intervals during evening and weekend hours). Such rates are designed to increase capacity utilization and dampen peak demand. For an analysis of the effectiveness of peak-load rates, see Mitchell (1978b).

electrical circuit. The pulse generator has several sets of contacts corresponding to different pulse intervals. Each stream of pulses flows through a separate circuit to a clock that selects the appropriate pulse frequencies according to the time of day, weekend periods, and annual holidays. This technology is depicted in schematic form in Fig. 1. (In the case of trunk calls, additional equipment selects the correct pulse interval for the distance called.) The pulses are then routed to the calling subscriber, and they are accumulated in his individual register.

Electronic pulse generators have recently been developed. They have a number of advantages, including lower cost, greater reliability, substantially smaller size, and the possibility of incorporating certain supplementary functions.* Electronic units will be used exclusively in new periodic pulse systems and will gradually replace existing electromechanical units in the trunk networks.

The technology of the periodic pulse generator and clock is quite simple and imposes some limitations on the rate structures that can be established. For example, the daytime pulse intervals in the five distance bands of the Swiss trunk network are currently at 60, 36, 22.5, 16.3, and 12.8 sec. These values result from a fundamental 180-sec interval that is divided respectively into 3, 5, 8, 11, and 14 equal parts. As long as electromechanical generators are in use, the relative price levels for distance bands or different time periods are restricted to the set of

*For example, the new West German unit will allow free calls to be made to emergency numbers and prevent off-hook lines from blocking the network.

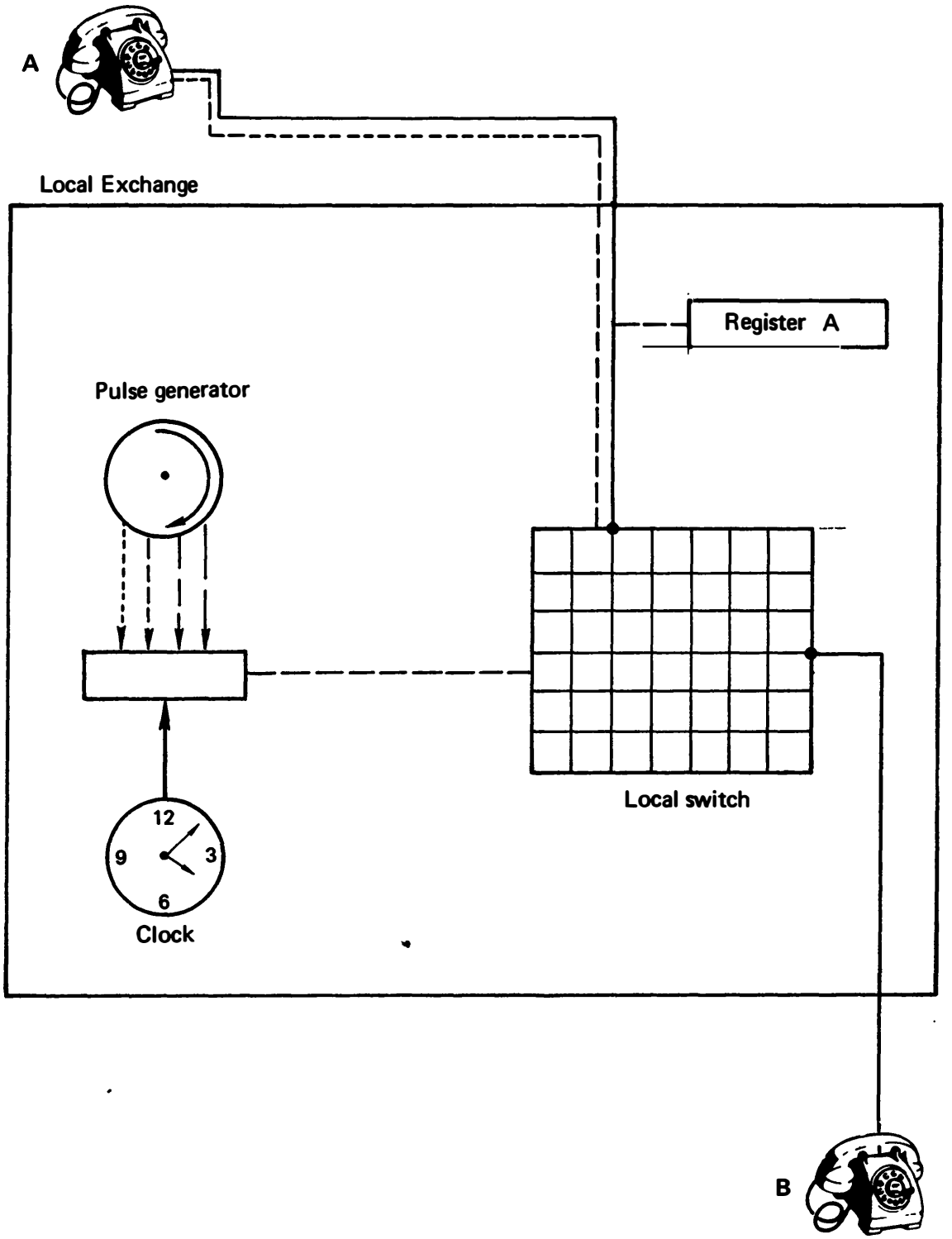


Fig. 1 — Periodic pulses in a local exchange

intervals available by integer division of the basic time unit established for the generator.*

The clock needed to switch to the off-peak pulse intervals may also have limited capabilities. In several telephone systems, when the clock shifts from its primary period to a second tariff period, it does so for pulses used for all types of calls. Thus, if trunk calls change from standard to reduced rates beginning at 6 p.m., then local-call rates must either be reduced beginning at that hour or they must remain at the standard level for the entire second period.

Telephone Calling Patterns

Telephone calls are of irregular duration. If one assumes that the probability that any randomly selected call will end is proportional to the number of calls in progress at that moment, then the number of continuing calls $n(t)$ at time t following the onset of measurement obeys

$$\frac{dn(t)}{dt} \propto -n(t) . \qquad (1)$$

This differential equation yields a negative exponential distribution for the number of calls of length t or more

*Electronic pulse generators have no practical limitations in this regard. For example, the unit that will be used in West Germany provides for some 1600 intervals from 0.3 to 1600 sec in length (Gerz and Weissbäcker, 1978).

$$n(t) \sim e^{-t/\bar{t}}, \qquad (2)$$

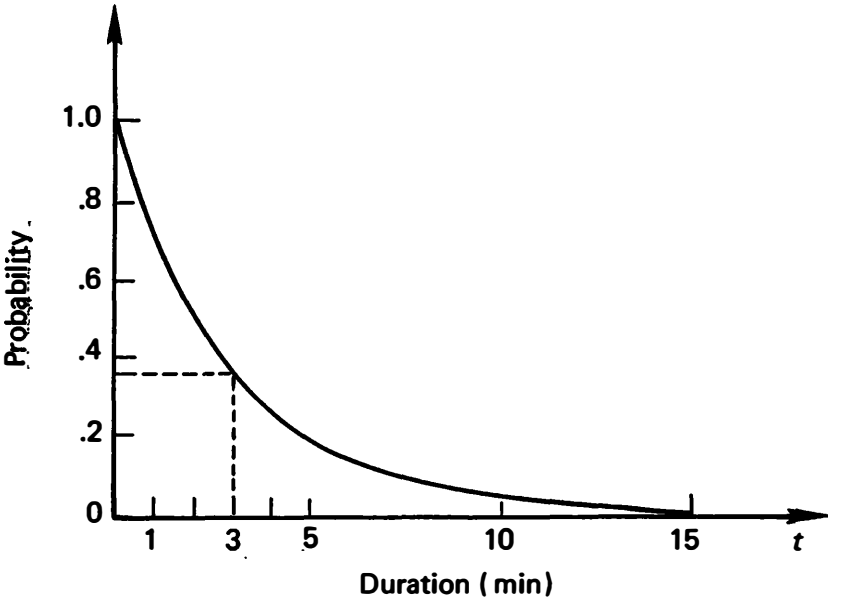
where $\bar{t}$ is the mean duration of all calls.

In practice, the distribution of call duration is highly regular, and measurements in many telephone systems have established that the negative exponential is a quite satisfactory approximation for purposes of tariff calculations and for dimensioning the network.* The negative exponential distribution of call duration is illustrated in Fig. 2. Table 2 shows the cumulative percentage of calls of length 0.5 to 15 min when the average call lasts 3 min. Because of the skewed distribution of conversation times, 63 percent of all calls are completed within 3 min. Calls of less than 1 min account for 28 percent of all calls, while only 1 percent of all calls exceed 14 mins.

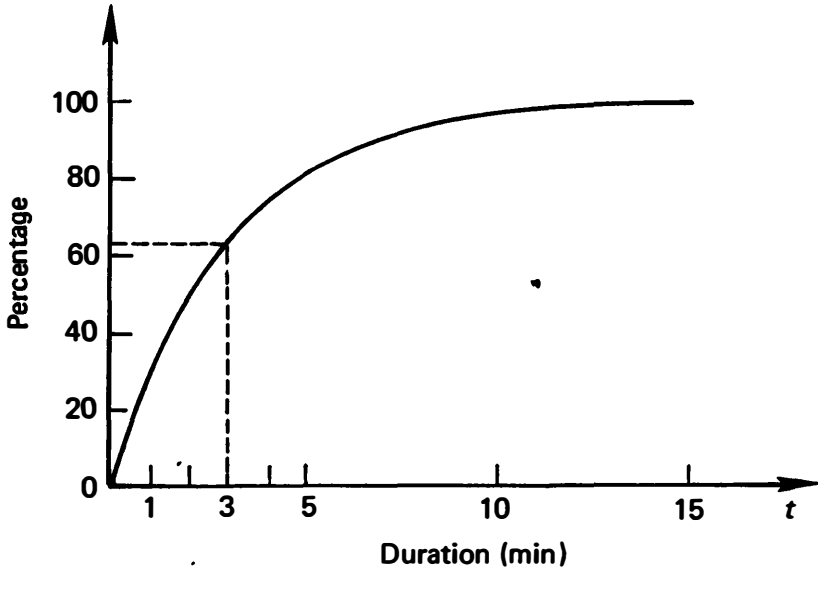
Both Fig. 2 and Table 2 assume a single distribution for all calls, with a mean duration of 3 min. But in reality, systematic differences in conversation time are found in nearly all telephone systems. Residential calls are longer than business calls. Within each subscriber category, evening calls are longer than daytime calls. Trunk calls are longer than local calls: the mean duration increases fairly regularly with the distance called. The distribution of conversation time for all calls is therefore more correctly a mixture of several exponential distributions with different mean durations.

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*See, for example, Evers and Anders (1973), Myskja and Walmann (1973), and Socher (1971).



(a) Probability that a call lasts at least t min



(b) Percentage of calls that last less than t min

Fig. 2 — Negative exponential distribution of call duration

Table 2

DISTRIBUTION OF CALL DURATION

($\bar{t}$ = 3 min)

Duration, t (min)	Percentage of All Calls	
	Shorter than t, $1 - P(x > t)$	Longer than t, $P(x > t)$
0.5	15.4	84.6
1	28.3	71.7
2	48.7	51.3
3	63.2	36.8
4	73.6	26.4
5	81.1	18.9
6	86.5	13.5
7	90.3	9.7
8	93.1	6.9
9	95.0	5.0
10	96.4	3.6
11	97.4	2.6
12	98.2	1.8
13	98.7	1.3
14	99.1	0.9
15	99.3	0.7

The Billing Mechanism

To carry out satisfactory analysis of local-call pricing in a pulse system, we must examine the operation of the billing mechanism in some detail. In almost all European systems, at the moment the telephone connection is completed (i.e., the called party lifts the receiver), an initial pulse is transmitted to the register of the calling subscriber. As long as the conversation continues, the register periodically accumulates pulses every d seconds.

Assuming that call duration follows the negative exponential distribution, the total number of pulses N_p accumulated in N_c conversations can be computed as follows:

All calls receive the initial pulse. The calls receiving the first periodic pulse are those calls that last at least d seconds, or $N_c e^{-d/\bar{t}}$. The calls receiving the second periodic pulse are $N_c e^{-2d/\bar{t}}$. The total number of pulses is thus the sum of the series

$$N_p = N_c \left(1 + e^{-d/\bar{t}} + e^{-2d/\bar{t}} + e^{-3d/\bar{t}} + \ldots\right), \qquad (3)$$

and so the average number of revenue units (pulses) per call is

$$r_o(d,\bar{t}) = \frac{N_p}{N_c} = \frac{1}{1 - e^{-d/\bar{t}}} \quad . \qquad (4)$$

This formula is based on the assumption that the arrival of pulses is synchronized with the beginning of each call, so that for every call, the first periodic pulse occurs exactly d sec after the call begins. In fact, however, conversations begin randomly, whereas the pulse generator emits the same pulse for all calls. Therefore, the length of the *first* interval (between the initial pulse and the first periodic pulse) is not d, but a random value $\tilde{d}$ ranging from 0 to d seconds with mean $d/2$. This inexactitude is of limited importance for longer-distance calls, because in those cases the pulse interval is fairly short. However, it becomes a significant factor for local calls when there is a pulse interval of several minutes.

The effects of several billing approaches for a call lasting almost three pulse intervals are compared in Fig. 3. If the start of the call coincides with the arrival of a pulse, the call will be billed for three pulses--the initial pulse and two periodic pulses. However, if the call begins at random with respect to the timing of the pulse generator, the charge for the call will not be strictly proportional to its length. Several mechanisms for dealing with this situation are illustrated in Fig. 3:

1. The randomness of the initial interval (0 to d sec) is accepted, resulting in an expected price for the first $d/2$ sec that is twice the expected price for all following seconds.
2. The initial pulse is omitted, and so the initial random interval (0 to d sec) is not billed. With

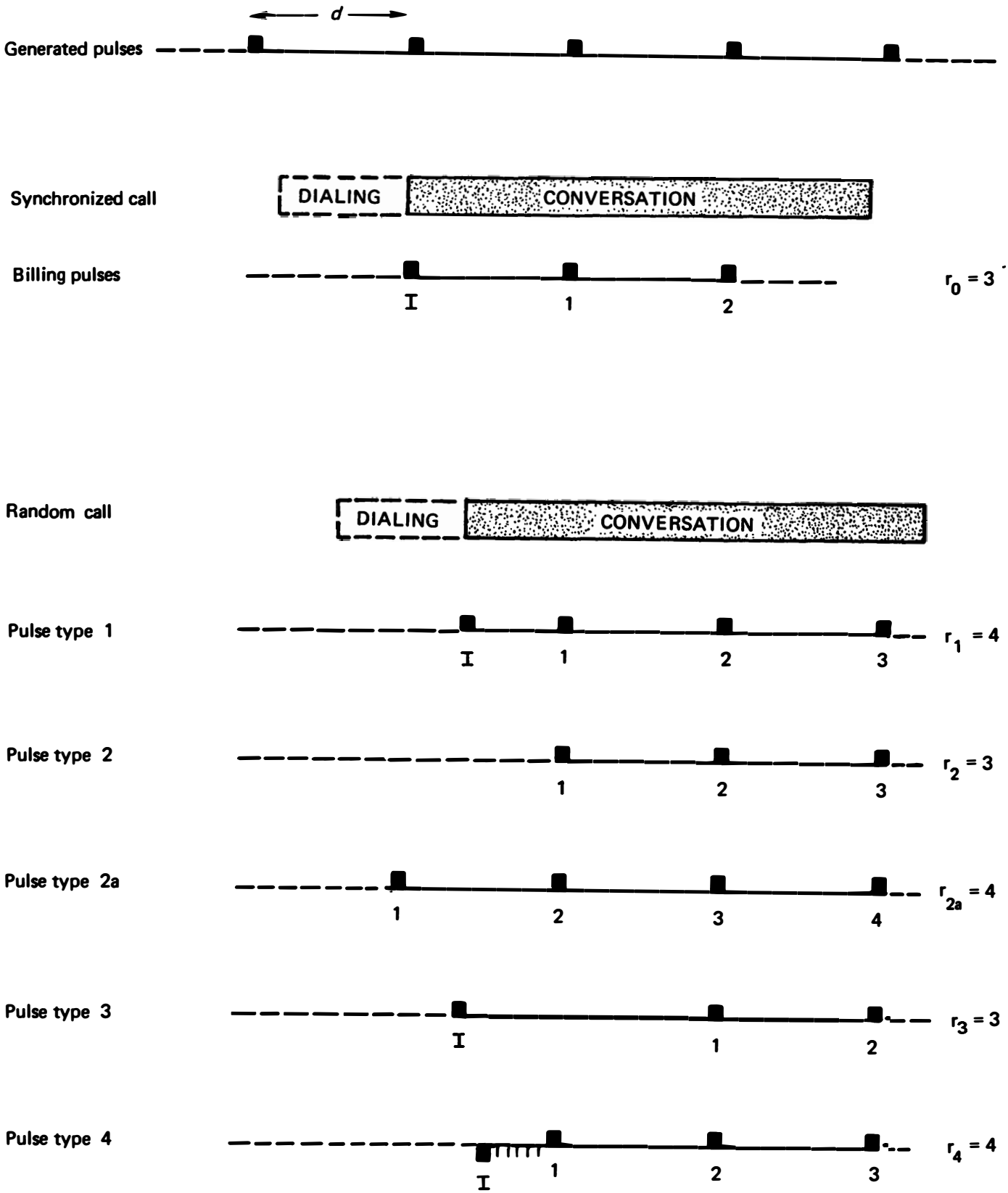


Fig. 3 — The results of various pulse billing systems when a call begins at a random time

a long pulse interval d, a substantial proportion of short calls are made without charge.

2a. The randomness of the initial interval is accepted, but the register begins to accumulate pulses as soon as the caller lifts the telephone. This approach, used in Denmark, charges for time spent in dialing and ringing.

3. Registration of the first periodic pulse is suppressed in order to lengthen the initial, billed interval from d to $2d$ sec. On average, callers can talk for $1.5\,d$ sec for the price of the first pulse and thereafter for d sec per pulse. This approach is used in Norway and Switzerland and is planned for Sweden.

4. The initial interval is divided into m subintervals by supplementary pulses and pulse registration begins when the first subpulse is received. In this way, the random variation in the first interval is confined to the first d/m sec; the length of this interval ranges only between $(m - 1)d/m$ and d, with a mean of $(1 - 1/2m)d$. This is the approach employed in West Germany, where a value of $m = 6$ has been used for trunk calls. With the introduction of periodic pulsing for local calls, a more nearly exact result will be realized by changing to a value of $m = 16$.

The mean number of revenue units per call $r_i(d, \bar{t})$ resulting from each of these methods of timing can be calculated by assuming that the length of time x between the start of the call and the

arrival of the first periodic pulse is a random variable uniformly distributed over the interval between 0 and the maximum length of time that can elapse before the first billing pulse arrives. The formulas corresponding to the four cases above are as follows:

1. Initial interval is random:

$$r_1(d,\bar{t}) = \frac{N_p}{N_c} \left\{ 1 + \frac{1}{d} \int_0^d \left[e^{-x/\bar{t}} + e^{-(x+d)/\bar{t}} \right.\right.$$

$$\left.\left. + e^{-(x+2d)/\bar{t}} + \ldots \right] dx \right\}$$

$$= 1 + \frac{1/d}{1 - e^{-d/\bar{t}}} \int_0^d e^{-x/\bar{t}} dx$$

$$= 1 + \bar{t}/d \qquad (5)$$

2. Initial pulse is omitted:

$$r_2(d,\bar{t}) = \bar{t}/d \ . \qquad (6)$$

3. First periodic pulse is suppressed:

$$r_3(d,\bar{t}) = \frac{N_p}{N_c}\left\{1 + \frac{1}{d}\int_0^d \left[e^{-(x+d)/\bar{t}} + e^{-(x+2d)/\bar{t}} + \ldots \right] dx \right\}$$

$$= 1 + (\bar{t}/d)e^{-d/\bar{t}} \qquad (7)$$

4. Initial interval is subdivided into m subintervals:

$$r_4(d,\bar{t},m) = \frac{N_p}{N_c}\left\{1 + \frac{1}{d/m}\int_0^{d/m} \left[e^{-[x+(m-1)d/m]/\bar{t}} + e^{-[x+(2m-1)d/m]/\bar{t}} + \ldots \right] dx \right\}$$

$$= 1 + \frac{m\bar{t}}{d}\,\frac{e^{d/m\bar{t}} - 1}{e^{d/\bar{t}} - 1}\,. \qquad (8)$$

The mean number of revenue units per call produced by each method of timing for a mean call duration of 180 sec are illustrated in Fig. 4 and listed in Table 3. Taking a 4-min pulse interval as an example, one finds that synchronized measurement of the length of each call would yield an average of 1.358 billing pulses per

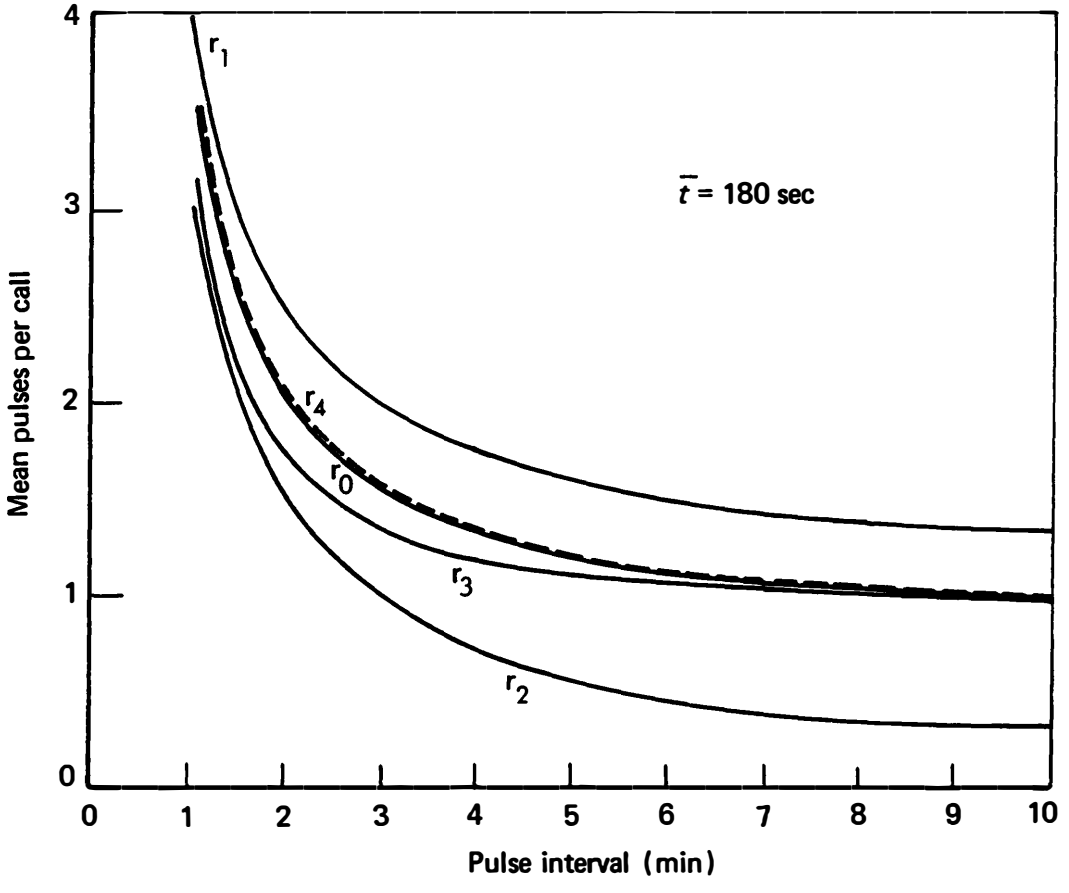


Fig. 4 — Mean revenue units (pulses) per call

Table 3

MEAN REVENUE UNITS (PULSES) PER CALL PRODUCED BY EACH METHOD OF TIMING

($\bar{t}$ = 180-sec mean call duration)

Pulse Interval, d (min)	Mean Number of Revenue Units per Call				
	Synchronized Pulse, $r_0(d,\bar{t})$	Random First Interval, $r_1(d,\bar{t})$	Initial Pulse Omitted, $r_2(d,\bar{t})$	First Periodic Pulse Suppressed, $r_3(d,\bar{t})$	Initial Interval Subdivided (m = 16), $r_4(d,\bar{t},m)$
1	3.528	4.000	3.000	3.150	3.554
2	2.055	2.500	1.500	1.770	2.077
3	1.582	2.000	1.000	1.368	1.601
4	1.358	1.750	0.750	1.198	1.373
5	1.233	1.600	0.600	1.113	1.245
6	1.157	1.500	0.500	1.068	1.167
7	1.107	1.429	0.429	1.042	1.116
8	1.075	1.375	0.375	1.026	1.081
9	1.052	1.333	0.333	1.017	1.058
10	1.037	1.330	0.300	1.011	1.041
11	1.026	1.273	0.273	1.007	1.029
12	1.019	1.250	0.250	1.005	1.021
13	1.013	1.231	0.231	1.003	1.015
14	1.009	1.214	0.214	1.002	1.011
15	1.007	1.200	0.200	1.001	1.008
16	1.005	1.188	0.188	1.001	1.006

call. By accepting the randomness of the first billing interval, it is possible to collect greater revenue, 1.75 units per call. If, instead, the initial pulse is omitted, only three pulses will be registered for every four calls placed. However, in the Karlsson system used in Denmark, this loss of revenue is offset by including the dialing and ringing time in measuring the length of a call.

Suppression of the first periodic pulse yields 1.198 units per call, which comes closer to the exact value. The West German approach of dividing the first interval into 16 parts results in a value of 1.373, an error of only slightly more than 1 percent.

RATES FOR LOCAL CALLS

Rate Structure

In each of the six European countries surveyed, the telephone system has a four-part rate structure, with separate charges for installation, monthly subscription, local calls, and trunk calls.* The current or proposed rate structures for local calls in these countries are shown in Table 4. In most of these telephone systems, the value of one pulse was first established when local calling was automated and each call was billed for a single pulse. At that time, the price per pulse was related to the average cost

*See Mitchell (1978b) for a description of trunk call rate structures and of fees for installation and monthly subscription.

Table 4

RATE STRUCTURES FOR LOCAL CALLS IN SIX EUROPEAN COUNTRIES

Country	Price per Pulse	Peak Period			Off-Peak Period	
		Hours in Effect	Basic Pulse Interval (min)	Mean Length of First Billed Interval (min)	Basic Pulse Interval (min)	Mean Length of First Billed Interval (min)
Denmark (Copenhagen)[a]	20 øre (3.5¢)	08-18 Mon.-Sun.	2.13	(b)	4.27	(b)
Norway	67 øre (12.5¢)	08-17 Mon.-Fri.	3	4.5	∞	∞
Sweden (1982)	17 öre (3.7¢)	08-18 Mon.-Fri.	6	9	12	18
Switzerland	10 Rp (5.4¢)	All	4.8	7.2	---	---
United Kingdom	3 p (5.6¢)	09-13 Mon.-Fri.	2[c]	2.1	12[c]	12.6
		08-09, 13-18 Mon.-Fri.	3[c]	3.15		
West Germany (1980)	23 pf (11.4¢)	06-18 Mon.-Fri. 06-14 Sat.	8	7.8	12	11.6

NOTE: Prices in U.S. currency at rates of exchange prevailing April 10, 1978.

[a]Slightly different pulse intervals apply in four other regions of Denmark.

[b]Dialing and ringing time are included in the first billed interval.

[c]Actual length of billing intervals is 110 percent of the basic pulse intervals.

of a local call. Over the years, rising costs have occasioned some increases although local rates have not necessarily continued to reflect unit costs. Today, the unit price of a pulse is in the range of 5¢ to 13¢.

The basic daytime pulse interval in these European systems ranges from 2 to 8 min. The mean length of the first billed interval varies according to the approach used to measure the initial interval. In Denmark, this first interval also includes dialing and ringing time.

With the exception of Switzerland, standard local call rates are in effect during a daytime peak period and are reduced at night and on weekends. In Sweden, the United Kingdom, and West Germany the hours for the standard and reduced local rates are the same as those for trunk calls, despite the fact that local-call peaks frequently occur during the early evening in residential areas. Reduced-rate periods provide lower prices principally to residential customers and are probably important in obtaining political support for local-call timing.*

The rates shown in Table 4 for Sweden, Switzerland, and West Germany are those of the plans recently adopted for converting to periodic pulses for local calls. In a system that has been charging one pulse for each local call, the introduction of periodic pulses will substantially increase the average price of a local call unless a very long pulse interval is used.

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*The allocative distortions created by this price structure will be limited if off-peak and cross-price elasticities are low. There is only limited evidence on this point. See the analysis of Norwegian data below, and also Hopley (1977).

Public discussion of plans to introduce timing of local calls interpreted the change as a form of rate increase even when, in West Germany and Sweden, local-call timing was combined with major enlargements of local calling areas. A second sensitive factor was the presumed distributional effect of such a rate change. Rate increases were perceived to fall disproportionately on residential subscribers as a class, and particularly on older persons, who tend to have long telephone conversations. In West Germany, this factor is being dealt with by providing 30 free pulses per month to the aged and socially disadvantaged subscribers.

The proposed rates and those finally adopted are compared in Table 5, in which the calculations assume the average length of a call to be 3 min and zero price elasticity of demand. In both Sweden and Switzerland, detailed cost studies by the telephone authorities have established that local calls fall substantially short of covering their economic costs. The proposed 2-min pulse interval in Switzerland would have increased the average price per call by 77 percent and eliminated this shortfall. In Sweden, where a similar subsidy of local calls exists, only a 20-percent increase, in the form of a 4-min interval, was proposed. No information is available on the costs of local calls in West Germany, but the 4-min interval initially advanced by the Bundespost would have helped to offset revenue losses incurred by the substantial enlargement of local calling areas. In each of these countries, a much longer pulse interval was adopted than had been initially proposed by the telephone authorities.

Table 5

PROPOSED AND ADOPTED DAYTIME RATES FOR LOCAL CALLS

Country	Proposed Rates			Adopted Rates		
	Pulse Interval (min)	Calls Exceeding One Interval (percent)	Average Increase in Price per Call (percent)	Pulse Interval (min)	Calls Exceeding One Interval (percent)	Average Increase in Price per Call (percent)
Switzerland (1978)	2	51.3	77.0	4.8	~ 20	~ 13
Sweden (1982)	4	26.4	19.8	6	13.5	6.8
West Germany (1980)	4	26.4	37.3	8	6.9	8.1

NOTE: Based on an average call duration of 180 sec and zero price elasticity of demand.

New Local-Calling Areas

European telephone rate structures have developed out of the structure of the telephone network itself. Within the local exchange, only local loop cables and basic switching equipment are needed to complete a call, and rates for local service were at first based simply on a single pulse for each call. In contrast, connections to neighboring exchanges and distant cities require the use of a complex of switching points and trunk lines, and so interexchange calls were billed according to the duration of the call and the distances between exchanges or switching centers.

At the time that it was introduced, this basic rate structure worked fairly well. But as the communities expanded, the requirements of many subscribers were not being met by the typical local exchange. In this system, subscribers who live at the border of the exchange have to pay a toll rate to call a neighbor living across the street. Also, small neighboring villages are increasingly being amalgamated into a commonly governed community, thereby compounding the problem.

In response to complaints about this situation, telephone administrations have often resorted to grafting together individual neighboring exchanges that had a high volume of common traffic. But in the countries surveyed, the result has been a pattern of highly variable local calling areas. This variability can be remedied either by abandoning the policy of a nationally uniform rate for all local calls (and a uniform rate for telephone subscriptions) or by making basic changes in the geometry of local

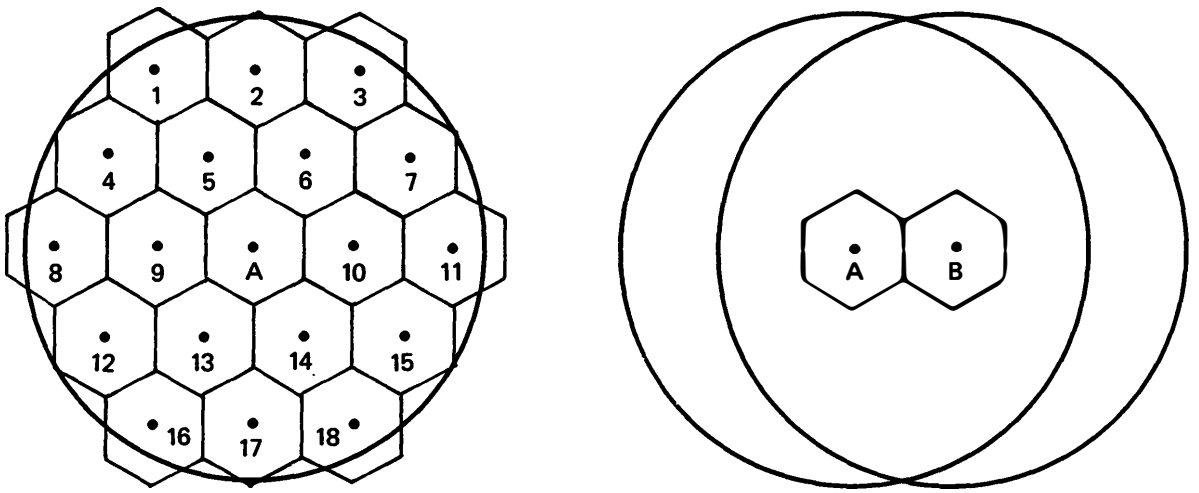
calling areas. Since national telephone administrations have not generally wished to depart from uniform pricing policies, boundary changes take on particular importance.*

The conversion from calling areas based on the local exchange to areas based on a neighborhood district is well illustrated by the new West German rate structure that will go into effect beginning in January 1980. A local exchange area in West Germany has a radius of about 5 km, determined by technical considerations. The new local calling district is based on two principles: (1) inclusion of all contiguous local exchanges, and (2) inclusion of all exchanges whose centers are within 20 km. In an idealized network, the local calling area for exchange A would therefore encompass the 18 nearby exchanges shown in Fig. 5a and two adjacent exchanges would share much of the same calling area (Fig. 5b). This fish-scale pattern of overlapping calling areas ensures that no subscriber will be confronted by a tariff boundary in front of his door.

The practical results of the fish-scale calling-district system are illustrated in Fig. 6. Subscribers in rural areas of West Germany (such as Grosskitzighofen) will obtain sizable increases in their local calling areas, and their telephone service will more nearly equal that of residents of urban areas (such as Munich), whose local calling area often includes several compact local exchanges and many more subscribers. Calling areas for exchanges located near national borders and seacoasts, and on islands, will be expanded

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*Limited variations in monthly subscription rates based on the size of the local calling area are, however, a characteristic of many systems.



(a) Local calling area with 20-km radius

(b) Local calling areas of two adjacent exchanges

Fig. 5 — Theoretical local calling areas for West Germany, 1980

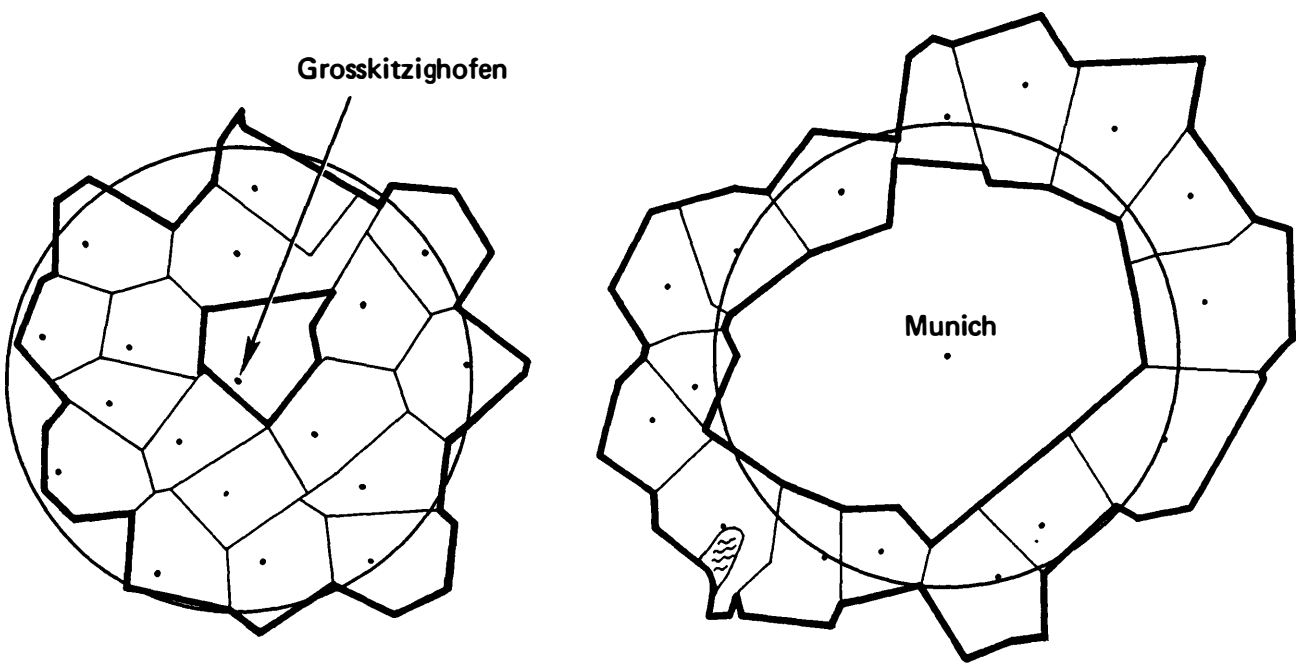


Fig. 6 — Local calling areas for Grosskitzighofen and Munich, West Germany, 1980

to a radius of 25 or 30 km to offset the lack of neighboring areas.

The enlargement of local calling areas in West Germany will mean that much of the shorter-distance, daytime trunk traffic, now billed by pulse intervals of 90 to 30 sec, will be included in the local calling area and callers will be charged on the basis of an 8-min pulse interval. The Bundespost anticipates an 8-percent reduction in telephone revenues nationwide, based on detailed calculations for reclassified traffic and an assumed revenue elasticity with respect to the net price reduction of about -0.5.*

ANALYZING DEMAND ELASTICITIES

Changes in telephone usage in response to changes in rate structures for local calls have not as yet been studied empirically to any great extent. Data for such investigations can be collected in two ways: (1) by introducing a new rate structure in selected exchanges on an experimental basis or (2) from a systemwide conversion to a new rate structure.

Experimentation: the German Experience

In March 1977, the West German Bundespost initiated an experiment with new local telephone rates in six predominantly rural offices encompassing some 2000 households. This undertaking was primarily a feasibility experiment (a) to test technical and administrative

*See Schön (1971) for an example of such calculations.

procedure for merging neighboring exchanges to create enlarged local calling areas and (b) to test the operation of the local periodic pulse equipment. Several months later, when the Bundespost proposed nationwide implementation of the 8-min periodic pulse and adoption of expanded local calling areas, this experiment had provided very little data on changes in traffic, and, at this writing, an analysis of the first year's experimental data has not yet been completed. Ongoing measurements of consumer responses in the test areas may, however, be useful in providing an advance indication of the degree to which capacity must be expanded in particular distance zones.*

Systemwide Conversion: the Norwegian Experience

The alternative to experimentation is to make special traffic measurements before and after a systemwide change in local rates has been made. At present, such data are available only for Norway. However, the Swiss system is undertaking a detailed study of its introduction of local periodic pulses in January 1978. The West German system will have a similar opportunity to collect data when its new rates take effect in January 1980.

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*In the United States, General Telephone is conducting a systematic study of the conversion of three Illinois exchanges from the prevailing flat rate for local calls to a measured service rate based on charges for messages, minutes of use, and time of day (see Cohen, 1977). Data are being collected on individual subscriber usage before and after the experimental rate went into effect and are being supplemented by interview data from sample households. The GTE test is a significant innovation in the study of telephone markets and promises to expand the knowledge of consumer behavior substantially.

In January 1975, the Norwegian telephone administration introduced national periodic pulse pricing for local calls made between 8 a.m. and 5 p.m., Monday through Saturday.* The pulse interval is 3 min and the price per pulse, at that time, was 61 øre (11.7¢). However, because the first periodic pulse is suppressed, the initial interval has an average length of 4.5 min. After 5 p.m. and all day Sunday the former rate of a single pulse per local call remains in effect. Specialized measuring equipment was installed to collect detailed traffic data from a sample of 500 subscriber lines in Trondheim. Bø, Gaustad, and Kosberg (1976) have analyzed the traffic patterns during the period covering this change in local rate structure (September 1973 through April 1976). The following analysis is based on their data.

The mean number and duration of local calls per day before (1974) and after (1975), and the traffic changes, are summarized in Table 6. Prior to periodic pulse pricing, the average local call in the sample was almost exactly 3 min long. The data show the customary pattern of longer calls by residential subscribers (averaging over 4 min) compared with those of business and private-exchange (PABX) users (about 2.5 min). The category of "business" subscribers includes a large proportion of telephones that are also available to household members in the evenings. Thus, business subscribers make more than five times as many calls during the day as residential subscribers, but virtually the same number in the evening. PABX

*Since January 1976, Saturday calls have again been priced at a single pulse per call.

Table 6

TRAFFIC CHANGES IN RESPONSE TO TIMED LOCAL CALL PRICING: TRONDHEIM, NORWAY[a]

Type of Subscriber[c]	Peak Period (08-17, Mon.-Fri.) Rate: 1974--61 øre per call 1975--61 øre per 3 min[b]						Off-Peak Period (17-08, Mon.-Fri.) Rate: 1974--61 øre per call 1975--61 øre per call					
	Calls per Day per Line			Mean Duration			Calls per Day per Line			Mean Duration		
	Number of Calls		Percent Change	Number of Seconds		Percent Change	Number of Calls		Percent Change	Number of Seconds		Percent Change
	1974	1975		1974	1975		1974	1975		1974	1975	
Residence (268)	0.99	0.82	-17.2	260	154	-40.7	0.45	0.48	+7.9	365	389	+6.5
Business (113)	5.56	5.02	-9.7	154	143	-7.1	0.41	0.44	+8.8	230	243	+5.6
PABX (86)	14.37	12.61	-12.2	164	153	-6.7	0.23	0.23	0.0	257	198	-22.9
All	5.14	4.65	-9.5	176	154	-12.5	0.48	0.49	+2.7	288	312	+8.3

SOURCE: Bø, Gaustad, and Kosberg (1976).

[a]Based on 500 subscriber lines (33 not in use) in Trondheim; sampling was continuous for 1 week in January through May (for calls) and January through June (duration).

[b]See text for precise rate.

[c]Number of lines are shown in parentheses.

lines have the highest concentration of calls during business hours, and account for very little traffic after 5 p.m.

The introduction of timed local-call pricing resulted in reductions in both the number and the duration of daytime calls by every type of subscriber. Residential subscribers showed the most elastic response, reducing the number of their calls by 17 percent and their conversation time by 41 percent. However, business and PABX users also made significant reductions in both the number of calls (10 to 12 percent) and their duration (7 percent). The right-hand section of Table 6 indicates that a portion of the response by residential and business subscribers is accounted for by their shifting some calls to the evening (off-peak rate) period; increases in this time period amounted to 8 to 9 percent for number of calls and 6 to 7 percent for length of calls. PABX users did not measurably change their number of off-peak calls.*

The concept of price elasticity of demand is not very well defined for the type of price increase at issue here. During the daytime period, the price is unchanged for some calls--those shorter than 3 min--whereas it has increased, in varying percentages, for all others, depending on their duration. On average, if residential customers (with a mean conversation time of 240 sec) had not changed their calling behavior at all, they would have paid 72.3 percent more for daytime local telephone service under the Norwegian system of suppressing the first periodic pulse.** But, in fact, residential

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*The decline in PABX call-duration in the evening is not borne out by data for the first months of 1976, which have a mean of 250 secs.

**Calculated from $r_3(d,\bar{t})$, using $d = 3$, $\bar{t} = 240$.

subscribers reduced both the number and length of their calls, so that a 50.9-percent contraction in traffic (calls x mean duration) resulted.

The combined effect of the price change on the number and duration of calls can be summarized in terms of the arc elasticity of traffic with respect to average revenue per call. Evaluated at the mid-point of the before-and-after price and quantity values, the arc price elasticity of demand is

$$\bar{\varepsilon}_T = \frac{\Delta ct/(c_0 t_0 + c_1 t_1)/2}{\Delta \bar{p}/(\bar{p}_0 + \bar{p}_1)/2} \qquad (9)$$

where c is the calling price, t is the mean duration, and $\bar{p}$ is the mean number of billed pulses per call.* The value of $\bar{p}_1$ is calculated for the new rate structure at the initial traffic level $c_0 t_0$.

The resulting arc elasticity values for traffic are shown in Table 7. In simplified terms, consumer behavior can be represented by two interdependent, demand equations for peak and off-peak telephone

*Calculated for $r_3(3, t_0)$.

Table 7

ARC PRICE ELASTICITIES OF DEMAND FOR LOCAL CALLS: TRONDHEIM, NORWAY, 1974-1975

Type of Subscriber	Peak Period (07-17, Mon.-Fri.)		Off-Peak Period (17-08, Mon.-Fri.)	
	Own-Price Elasticity		Cross-Price Elasticity	
	Traffic Units	Revenue Units	Traffic Units	Revenue Units
Residence	-1.29	-.92	+.28	+.36
Business	-.75	-.44	+.53	+.46
PABX	-.76	-.60	-.98	-.65
All	-.78	-.55	+.33	-.27

SOURCE: Calculated from Table 6.

traffic:

$$\textit{peak period:} \qquad Q_P = c_P t_P = f(p_P, p_{OP}),$$

$$\textit{off-peak period:} \qquad Q_{OP} = c_{OP} t_{OP} = g(p_P, p_{OP}).$$

This natural experiment in the Norwegian telephone system identifies two of the four price elasticity coefficients--the own-price coefficient in the peak period, $\partial Q_P / \partial p_P$, and the cross-price coefficient, $\partial Q_{OP} / \partial p_P$ in the off-peak period.

The high own-price elasticity of -1.29 for residential customers is noteworthy. Additional data from the study establishes that prior to the introduction of local timing, calls from one residential subscriber to another were nearly twice as long as calls of all other types. A large proportion of the elastic residential response in Trondheim is accounted for by a 56-percent reduction in mean conversation time of residence-to-residence calls. Since residential calls were, on average, significantly longer than the 3-min pulse interval that was introduced, it is perhaps not surprising that in this subscriber category, call duration contracted disproportionately more than did the number of calls.

Business and PABX users have inelastic demands but, nevertheless, show substantial sensitivity to the peak-period price. Both residential and business subscribers have positive cross-elasticities of demand as well, indicating that intraday substitution of local calling does occur in response to peak-load pricing. The negative cross elasticity

for PABX users appears to be an aberration; the following year (1976) the cross elasticity value is almost zero.

The second set of values shown in Table 7 are arc elasticities of revenue units with respect to the daytime price, calculated from

$$\bar{\varepsilon}_R = \frac{\Delta R/(R_0+R_1)/2}{\Delta p(p_0+p_1)/2} , \qquad R_i = c_i r(d,t_i) , \tag{10}$$

where $r(d,t_i)$ is the mean revenue per call for pulse interval d and mean duration t_i. The overall revenue arc elasticity of -0.55 in Trondheim is not greatly different from the approximation -0.5 used earlier by Socher (1971) to evaluate proposed changes in the West German local tariff structure.

For lack of more detailed data, our elasticity calculations have been based on the assumption that following the introduction of periodic pulse pricing, call duration continues to follow a negative exponential distribution, but with an altered mean. It is possible, however, that in addition to reducing their mean length of call, consumers react to timing by concentrating relatively more calls within the first pulse interval and thus give the distribution a thinner tail than the one generated by the exponential curve. If this, in fact, does occur, smaller revenue increases will be achieved than are calculated from tabulations of pulse counts.

CONCLUSION

The decisions of the Swedish and West German telephone administrations to introduce periodic pulses in local exchanges mean that telephone calls in almost all areas of Western Europe will soon be priced according to usage and duration. A distinct trend toward simplification of telephone rate structures has been emerging. Distance bands for trunk calls are being combined and reduced in number, and, at the same time, local calling areas are being updated and expanded for the first time. The timing of local as well as long distance telephone calls make it possible to consider the concept of a single rate for all domestic calls.

As the technology of telecommunications has evolved, the importance of distance has been decreasing as a major element of the total costs of communication. Thus, a unitary rate based simply on call duration and capacity utilization of the network (presently indicated by time of day) may be appropriate for many national systems. A remaining question is: will telephone prices that are *proportional* to call duration accurately reflect the structure of telephone costs? If the fixed costs of establishing a telephone connection are significant, a rate structure that includes an initial charge per call plus a price for call duration will have superior allocative properties to proportional rates. But here, too, basic changes in switching technology are occuring, and a fundamental analysis of the cost structure of a modern telephone system is needed to provide a reliable answer.

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