CONNY PALM
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Conny Palm was born on May 31, 1907 and began in 1925 his studies at the Royal Institute of Technology. He finished the essential parts of his studies around 1930-31, but did not pass his final university examination until 1940. However, since 1935 he worked within the area of telephony and wrote a number of important publications on teletraffic theory. Being the colorful personality he was, he did not take something like examinations very seriously. The main thing was, he believed, that you knew your stuff. And one dare say that Conny Palm mastered the subjects with which he worked. But one dare also say that things which did not interest him were done reluctantly, only. The combination of bohemian and genius, technician and mathematician in one person is very rare. Add to this a great respect for the mathematical quality and the technical possibilities, together with a constant wish of sound application to the problems of daily life within the telephony, it is evident that Conny Palm not only during his time, but also in the future will shine as an example within our science - the teletraffic theory.

But in order to fully understand this brief, but sparkling life - he died at the age of 44 - we will have to add that Conny Palm planted a parallelogram of forces between the manufacture by L M Ericsson, the Swedish Telecommunications Administration, the Royal Institute of Technology in Stockholm and the pure sciences in Cramér's Stockholm School of statistics and probability theory. To survive within the parallelogram of forces - with its powerful and not always concurrent forces - requires a man of quite a calibre. To enter such circles does also require surroundings of personalities possessing statures. Two personalities, who brought Conny Palm into these circles, were Nils Böhm from the Administration and Karl Lundqvist from L M Ericsson.

A few years later the probability theorist, Willy Feller, was the one who tied up the link between Conny Palm and the Cramér School at the Stockholm University. Here Conny Palm, during the term 1937-38, at Cramér's seminars on mathematical statistics talked about probability theory and its application within the telephony. According to Cramér, Palm presented a unique, mature and clarified view on his ideas of probability theory. The culmination of his work was his thesis in 1943, and the "rounding-off" of his achievements within the theory was published in 1946 in a special issue.

It is characteristic that prior to the thesis the measurements at the Östermalm telephone exchange had taken place in 1941, and after the thesis followed the construction of the traffic machine to be used for illustration of complicated traffic organizations which, in a foreseeable future, it was not possible to illustrate by usual mathematical methods.

For Conny Palm, a creative personality, respected for his work, both within the application and within the theory, by technicians, mathematicians and administrators, everything seemed laid out beautifully.

Yet, we all have, I believe, to admit that neither he nor his surroundings would characterize the final phase of his life as a bright phase, no matter whether you look at it professionally or from the human point of view.

When everything went wrong and when something was successful, it was not, one may say, a fulfilment of what he was meant for - it may have many explanations. Personally I am of the opinion that this is really more a general problem that everybody who moves in interdisciplinary areas faces when time for placing them in terminal position approaches. No one is there, and if there are some, the surroundings will make sure that they come from their own stables, in other words, not interdisciplinary persons.

We have often faced this within our own speciality, and we see it within other inter-disciplinary areas. It cannot remain interdisciplinary for ever. As a consequence, if, within a reasonable span of time, it is not successful, in securing a foothold, it will be eaten up by the neighbours who already have secured the foothold. The institutional environments within educational centers, and within those places where the product later on will be used are of paramount importance for successful result - and that especially after the initial 10 years with their more modest demands with respect to adjustment.

But let us leave this shady side of the inter-disciplinary sciences which we, when we admit it exists, in future may be able to do something about, and let us realize that the efforts of a scientist are not only his own achievements but also what he generates. If we measure Conny Palm according to that measurement, we get the directly opposite result - a unique research life which fostered many pupils who are now working at the Swedish Teleadministration, L M Ericsson and at Swedish Universities.

While Palm was still alive he gave the year prior to his death, through the thesis of Chr. Jacobaeus, his seeds of knowledge to the next generations. A more beautiful posthumous reputation than the Swedish achievements within the teletraffic theory during the past 20 years - which we all during the previous six conferences and now here during the 7th have experienced - no scientist can wish for.

I will here give you a survey of Conny Palm's thesis - "Intensitatschwankungen im Fernsprechverkehr".

I want to thank Bengt Wallström for his contribution to this.

Teletraffic theory is a fairly young science. Only about half a century has elapsed since Erlang made his fundamental studies on congestion and waiting time problems. His new probabilistic conception of telephone traffic constitutes the origin of modern teletraffic theory and of the general theory of stochastic processes as well. Since then these two subjects have developed rapidly and have derived many fruitful ideas from each other.

Much of Conny Palm's work on teletraffic has a very general and originative character and has been widely adopted in statistical theory. In 1950 Feller /1/ wrote the following about these matters:
"Waiting time and trunking problems for telephone exchanges were studied long before the theory of stochastic processes was available and had a stimulating influence on the development of the subject. In particular Palm's impressive work over many years has proved useful to several authors," since then many important works have appeared which confirm that statement. Palm's thesis, "Intensitätsschwankungen im Fernsprechverkehr" is particularly rich in new and stimulating ideas. Still it may not be so well known as it deserves to be, because it is yet available in one language only (in German). It is indeed a very stimulating and useful reading. A prominent feature of the thesis is its imaginative and careful discussions of the various mathematical models and the reality they are to describe.

The thesis consists of two parts. The first one is a general theoretical study of point processes and their applications to telephone traffic problems. The second one is a more specialized study that is focused on traffic intensity variations. It is natural, perhaps, that the more general study of the first part has had a particularly great influence on the theory of stochastic processes.

Earlier works on teletraffic assumed - apart from simple modifications - pure random call arrivals, i.e. an essentially constant call intensity. For many purposes, however, such a description had proved too rough. Palm builds up his new theory from very general assumptions. To start with he just postulates the existence of a probability at every point of time that a call shall occur, multiple calls having zero probability. A process of calls is then characterized by the joint probability density function (p.d.f.) of the intervals \( x_1, x_2, \ldots, x_n \) between consecutive calls in a randomly chosen sequence of \( n+1 \) calls. This p.d.f. is denoted

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F_n(x_1, x_2, \ldots, x_n).
\]

(It should be noted that Palm's notations are not always in accordance with modern practice.)

The definition of \( F_n \) includes a very weak stationarity assumption. This is essentially that \( F_n \), the p.d.f., shall be the same function for randomly chosen call sequences that are infinitely distant in time. Thus the process must not change character in the long run.

So far the theory is clearly general enough to include, e.g. periodic and stochastic call intensity variations as well as various types of dependence between calls.

The next step is to look for useful specializations. In doing that, Palm developed new lines of thought that would prove extremely fruitful. Some of the pertinent sentences of the thesis might be translated into English as follows:

"The common structure of all call processes treated in this work appears as a phenomenon that may suitably be referred to as equilibrium points. In such a point the probability of the future development of the process is independent of the positions of preceding calls. A knowledge of the positions of equilibrium points will clearly imply substantial possibilities of simplifying the description of the processes. Sometimes the equilibrium points coincide with a call. When this is not the case, they will be determined by comparison with other processes. In general, the equilibrium points appear in intervals where every point is an equilibrium point. These intervals may be called equilibrium intervals.

A special type of process, which constitutes the next generalization of the Poisson process, is of great importance for the following developments. These processes are characterized by the condition, that every call is an equilibrium point. But this does not prevent other points from being equilibrium points as well. The process might then be called equilibrium intervals where every point is an equilibrium point. This is not the case, they will be determined by comparison with other processes. In general, the equilibrium points appear in intervals where every point is an equilibrium point. These intervals may be called equilibrium intervals.

The second one is a more specialized study that is focused on traffic intensity variations. It is demonstrated by several examples that the typical structure and operation of telephone plant implies repeated merging and splitting of traffic streams. Further it is found that these procedures may be characterized to a great extent by conditions of independence and randomness.

The ultimate objective of Palm's thesis is to obtain a sufficiently realistic description of real telephone traffic, that is also as simple as possible. It is very instructive, indeed, to study his method of achieving that objective. Particularly interesting is his heuristic reasoning about the origination of traffic and the investigations on the superposition of call processes. It is demonstrated by several examples that the typical structure and operation of telephone plant implies repeated merging and splitting of traffic streams. Further it is found that these procedures may be characterized to a great extent by conditions of independence and randomness.

For the case when a number of independent call processes are superposed, Palm derives a very important limit theorem. It is imagined that the number of component processes is increased towards infinity, while the call intensity of each process is decreased towards zero in such a way that the sum of the call intensities tends to a finite constant. The general limiting result is that combined sequence tends to a Poisson process, provided that multiple calls have zero probability in all component processes.

It is unnecessary to stress the importance of these lines to the present audience. The principal thing, of course, is the discovery of "equilibrium points", or, in modern terminology, points of regeneration or recurrence. This concept, as we know, was the key to an exceptional development that would appear as one of the major contributions to the theory of stochastic processes.

A special study is devoted to the process of calls overflowing from a fully available group when the offered calls are described by a recurrent process and the holding times follow a negative exponential distribution. This investigation yields among other things an explicit congestion formula constituting a remarkable generalization of Erlang's loss formula.

Among Palm's contributions it seems that the theory of regeneration points has proved more useful to other authors than anything else. But still there are several other originative ideas and studies in his thesis, the importance of which may increase in the future. For instance he solves the full availability loss system for the general stationary call process, defined by the p.d.f. \( F_n(x_1, x_2, \ldots, x_n) \) and obtains the state probabilities as infinite series. The solution may be too general and complex to allow direct application to practical problems. It should be possible, however, to specialize the model in various ways and so obtain useful results. For instance one could specify particular types of intensity variations and dependencies between calls.

The feature of time that a call shall occur, multiple calls having zero probability. A process of calls is then characterized by the joint probability density function (p.d.f.) of the intervals \( x_1, x_2, \ldots, x_n \) between consecutive calls in a randomly chosen sequence of \( n+1 \) calls. This p.d.f. is denoted

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It might be added that a similar limit theorem can be derived for the case when a traffic of great intensity is split at random into many small traffics. In such a case the resulting partial processes behave asymptotically as Poisson processes.

During very short time intervals the relations of pure random traffic are valid, but the call probability varies with absolute time. This variation is partly random, partly common to most subscribers. Thus the probability of a call in a small time interval \((T, T+dT)\) may be written \(y(T)\), where \(y(T)\) is the call intensity at time \(T\). As usual the holding times are assumed to follow a negative exponential distribution. Further specialization of the model is made in two main steps.

Firstly it is assumed that the call intensity \(y(T)\) varies so slowly with time that the results for pure random traffic are nearly always valid. This makes it possible to calculate average losses and other useful data from a limited knowledge about the call intensity function \(y(T)\) (which cannot possibly be predicted in detail). For instance average congestion values may be calculated by averaging the Erlang loss formula over the distribution of call intensities.

Secondly it is necessary to specialize that distribution function so as to obtain practically useful results. This procedure is based on the conception that the character of traffics must depend strongly on the merging and splitting operations taking place in the plant. The essence of the approach is that traffics are considered to emerge through the superposition of large numbers of small components, the latter being chosen at random out of a large traffic pool. The individual component processes may exhibit intensity variations that are partly common, partly independent, but they must, of course, be "slow" in the sense explained above. From these basic ideas, Palm derives a number of important theorems for traffic processes, which are useful for the final choice of distribution model. But above all, this part of the thesis is characterized by a lot of new, imaginative thinking about telephone traffic fundamentals. Indeed the whole thesis is rather exceptional in that respect and will no doubt serve as a rich source of inspiration for traffic theorists for many years to come.

I shall then give you some comments on the works of Conny Palm within the field of teletraffic measurements.

I wish to thank Villy Baek Iversen for his contribution here.

Conny Palm's work within teletraffic measurements may be divided into two classes:

- the creation of a general measurement philosophy in connection with the verification of the theories in his thesis (9, 10, 14, 15);
- deductive statistical works in continuation of his traffic model (10, 16, 22) and the solution of basic problems like the reliability of traffic volume estimates obtained by the scanning method (6) and call charging problems (8, 25).

We shall have a closer look at some of these works taking our starting point in his thesis, where he as mentioned, develops a generalization of the Poisson process. His intention was to construct a traffic theory, yielding better agreement with practical observations than the classical stationary Poisson process applied to the Busy Hour traffic value as a parameter.

To do this, his manner of working necessarily had to be inductive. In the construction of alternative models, Palm got his ideas from practical experience and put up mathematical models based on the theory of stochastic processes.

From these models he then derived certain properties that could be tested through practical investigations. Not until this verification had been successfully performed did he place any value on the model. As his models, furthermore, were to be applied daily by people without knowledge of teletraffic theory, he put as a selfevident requirement to all new models 1) that the model must be simple to apply to practical dimensioning, and 2) that it must be possible to check the correspondence between theory and real traffic without too great difficulties.

This way of working requires, in order to be able to put up a good model, a deep insight into the very nature of telephonetraffic. In this way, the applications become the main point and not the theory itself. When studying Palm's work this becomes apparent very soon. No matter how complex his mathematical tools may be, he always had a practical application in mind.

Sometimes you can see a conflict between his formulation and the formulation one would like to make, if not restricted by reality. The verification of models implied that Palm had to consider all existing possibilities for collecting data and to investigate to what extent these data were applicable in order to obtain a satisfactory verification. Therefore he went through all the principles of measuring: continuous versus discrete, preprocessing versus fixing of the traffic process, etc., and compared this with the technical and economical possibilities at that time.

The conclusion he arrived at was that the measuring equipment should be based on electro-mechanical components, and the scanning principle was preferred. Furthermore, the data (preprocessed by the exchange and the measuring equipment) were registered on callimeters, which were photographed at fixed times. Only the time generator was non-mechanical, a crystal-controlled frequency standard.

Furthermore, he took into account all obtainable statistics (measuring functions). Theoretically an infinite number exists, but only very few were found appropriate. They may all be divided into two classes:

- incoming traffic statistics, i.e. statistics for each call;
- internal traffic statistics, i.e. statistics for each time unit.

In the first class the inter-arrival times are of the greatest importance when verifying his model. Therefore, in spite of technical difficulties, a special measuring equipment was designed for recording these, although this did not record the chronological order of the observations. Also the distances between each \(n\)th call were desirable, but these were for technical reasons not obtained.

In the second class the state probabilities and state combinations were recorded, among these the usual traffic volume measurement.

The measurements starting in 1957 were carried out during several years in Östermalm's telephone station in Stockholm. As a result of the first measurements he gained experience which had its changes and extensions of the equipment. In his thesis he applied data covering a period of 2 months in 1941, comprising about 400,000 calls.
To illustrate the difficulties in connection with the measurements, it may be mentioned that
- for technical reasons inter-arrival times were not recorded whereas inter-departure times were recorded.
- only one group comprising 30 devices was connected. Congestion was not allowed as this would imply unwanted effects in the first step of verification. Random hunting was assumed when treating the state combinations.

So, in spite of the extensive measurements, he did not obtain sufficient data to allow, e.g., a verification of his general superposition theory.

In the light of these technical limitations, it is astonishing to note how Palm was able to obtain accurate data, and, by making approximations to complex formulae, to calculate the wanted statistics, thus allowing a verification of the basic model. The reason for this is that he always for every step estimated all sources of errors. This resulted, among other things, in the solution of some fundamental problems in traffic measurement and call charging.

In 1941 Conny Palm (8) analyzed the scanning method applied to measurement of holding times and traffic volumes assuming pure chance traffic of first type. In accordance with the measurement equipment he did not calculate the distribution of the observed individual holding times, as these were not recorded, but found the reliability of the mean holding time for one call. On the assumption of independence he then obtained the reliability of a traffic volume composed of a given number of calls.

In his definition of the problem he looked away from the limited measuring period, thus avoiding correlation between errors caused by the measuring principle and errors deriving from the statistical sampling. (This has later been done by K.M. Olsson and the error is shown to be of no importance as far as practical measurements are concerned.) On the same occasion he also showed that time displacement arising from sequential scanning of a whole group, does not influence the reliability.

He applied the results to call charging according to the Karlsson principle, letting a certain proportion of the calls being charged according to the number of calls. He looked especially at the question - important from the viewpoint of subscriber - of the probability of over-charging a subscriber.

The abovementioned problems were handled in a way typical of Palm. He looked at all possible assumptions and eliminated those, which were of no significance. In this way he obtained an elegant mathematical solution. The results have later on been fundamental for all traffic measurements and charging problems.

In (24) in 1947 Palm further analyzed the very important problem of charging arising in connection with fully automatic telephone exchanges.

He outlines the different requirements in connection with charging. While in (6) he analyzed the Karlsson charging, he now, in detail, analyzes charging, also by equidistant pulses, but with the first pulse always placed at the starting time of the call. He considers the deviation from charging by a constant amount per call + constant amount per time unit. Flat and steep time distributions are investigated and compared with measurements.

In later works (16, 22) the fluctuations of measured traffics are obtained for the continuous measuring method. He uses the traffic model in his thesis, and besides the usual variation of the traffic volume he thus also includes a term caused by variations in the intensity. This extra term often dominates the usual term, thus being very important.

Compared with traffic measurements today Palm lacked two things very badly. Easy access to record data and storage of details of the traffic process, sometimes the total process. In advance Palm had to decide which statistics he wanted and to get them by means of specially constructed equipment.

He also lacked automatic computing machines. Palm shows much talent when it comes to developing approximation formulae for numerical calculations. However, many investigations were not possible because of the numerical work.

The result of these needs was that Palm began constructing a traffic machine for generating artificial traffic and with the assistance of Stellan Ekberg studied complicated gradings. Thus, the relay computer BARK was completed in 1952, and one year later B EK D, a first generation (vacuum tube) digital computer.

Today we have the digital computers, allowing large collection and storage of data to be handled in short time without much work compared to real data collection followed by manual data treatment. Also, for example when carrying out a traffic measurement for research purposes, we do not have to decide in advance which statistics are to be calculated. We are able to record the complete traffic process and repeat it in the computer as many times as we want, as we will hear at this Congress.

We all admire Conny Palm's great respect for the proper use of theory and technique. His measurement techniques are saturated with this. But Conny Palm also tried to build a bridge from teletraffic theory to the outside world. Let me mention "Palm's Model for the Machine Interference Problem".

The problem of machine interference is usually stated in terms of a group of machines that breaks down from time to time. This set of machines is served by a number of repairmen. However, it may happen that the number of machines out of service at the same time is greater than the number of repairmen available, so that some machines have to wait. Thus, in addition to the normal loss due to time spent in servicing machines, there is the interference loss due to the fact that sometimes servicing is delayed.

Conny Palm gave in 1947 a numerical method for calculating the optimal number of machines per worker under the following, very reasonable assumptions:
- All machines are similar as to the average number of breakdowns which each experiences per unit time.
- All repairmen are similar as to skill in servicing the machines and vice versa; all machines are similar as to skill needed to restore them to work.
- Uninterrupted working time of a machine is exponentially distributed.
- Repair time of a machine by a repairman is also exponentially distributed.
- The system is in a state of statistical equilibrium.

This is nowadays known as Palm's model.

The machine interference problem is well known in the field of industrial engineering, and before Palm's work several solutions had been proposed. Referring to these Palm wrote:
"The solutions proposed hitherto do not seem to be consistent in the mathematical treatment nor to have been trusted by professional people."

Palm's article and the way how he attacked the problem antedates the time when operations research workers regarded themselves as such. I believe that for Conny Palm it was not difficult to solve this practical problem due to his background with problems of telephony, as he wrote: "In the following, a new treatment of the problem is given, which seems to be mathematically correct, and which makes the numerical work rather simple. The results have, therefore, been presented in a diagram which will probably suffice for most practical purposes. Here we might mention that the mathematical treatment of the problem is very similar to certain waiting time problems occurring in telephony. For the problems of telephony, which are usually much more complicated than the problem treated here, good mathematical methods of solution have long existed."

I think we all agree with these words of Conny Palm.

I am confident that I speak on everybody's behalf when I conclude this review of Conny Palm's work by saying that no matter whether our background is technical, administrative or mathematical, we are all filled with admiration for this Swedish achievement within the teletraffic theory, and its application within administration techniques and planning, and filled with admiration for its Nestor Conny Palm. With gratitude we think of Nils Hönnblom and Karl Lundqvist who guided Conny Palm. We think of Nils Hönnblom who gave everything he had in order that this genius might blossom, and we thank Harald Cramér for what his school did for Conny Palm and his development. Last, but certainly not least, we thank you, Christian Jacobaeus. You have in your own way and in your own work carried the torch Conny Palm handed over to you into the future for the benefit of all of us. Thank you for the dignity and warmth, with which you, through successful technical and scientific efforts, animating inspiration and patient support to the next generation, have preserved Conny Palm's luminary in Sweden.

Publications by Conny Palm

Main Parts: Conny Palm


Published in English: Research on Telephone Traffic Carried by Full Availability Groups. Tele, English Edition. No. 1, 1957. 109 pp. (Please see table of contents below)

Publications in Chronological Order


4. Trans.: Some Investigations into Waiting Times in Telephone Plants. Published in French, see No. 4.


9. Trans.: Service Quality of Telephone Plants.


16. Intensitetsvariationernas inverkan vid trafikmätningar. 1945. 7 pp. Not published. (Telestyrelsen Sua 693.)


Some Propositions Regarding Flat and Steep Distribution Functions. pp. 3-17.


Trans.: Teletraffic Research in Sweden.


Trans.: Recording of Calls.

25. Arbetskraftens fördelning vid betjäning av automatmaskiner. Industritidningen Norden, 1947. No. 8, pp. 75-80; No. 9, pp. 93-94; and No. 11, pp. 119-125.

Published in Danish: (revised by K Rander Buch) "Om arbejdskraftens fordeling ved betjening af automatiske maskiner."

Tidsskrift for Textilteknik, Copenhagen, 1952, Vol. 10, No. 5.