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ANALYSIS OF FIELD FAILURE DATA FROM GROWING POPULATIONS

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Abstract

There is a general need for field failure information from electronic systems. In case there are failure reporting routines they often face the problem of finding out the real field use time for the failed device. This paper reviews some methods for analysing failure statistics from growing populations and gives some illustrations of the different methods. In conclusion it is found that the use of computer methods can give useful field failure statistics without having to trace each failed device back to its original field placement.

Introduction

Graphical methods are normally used for evaluating the results from accelerated life testing. Electronic components are often evaluated by the use of log normal plots or Weibull plots depending on the failure mechanism. If there is a true life test that shows a wear out the plot will normally be relatively linear or in some cases curved indicating an early, freak subpopulation. This procedure is rather stright forward to-day and many references can be given as in /1/. When it comes to field failure data the problem is much more complicated due to basically two reasons. First, the amount of failures is (hopefully) very small and often in the order of % over several years. Second, the population that gives the failures is growing either in distinct steps or more or less continuousely. It is however possible to get some information on the component life distribution despite these two problems. Let us to start with study a typical service profile, Figure 1. In this figure the amount of components is shown as a function of calendar time. If there are a few distinct steps and a reasonable amount of failures it is possible to get a rough estimate of the life distribution using the graphical methods mentioned earlier. Figure 2 shows the estimated "Failure Response" from the same example and how the failures are supposed to add from each step. The method is less obvious when we have a continuously growing population like the one plotted in Figure 7 but still it is possible to make an evaluation. Conclusions drawn from field data like this must take time dependent failure rates into account in order to be reasonable valid.

Methods of analysis

1. GRAPHICAL ANALYSIS

The response from the first step is used to get an estimate of the life distribution by simply plotting the accumulated failure level in an appropriate diagram, preferably a log-normal diagram to start with, see Figure 3. The same distribution is the used to estimate the failures from the next step and the result is compared with the real data. This is shown in figure 2 in the case of a few steps. The procedure is well suited for computer assistance and usually it is possible to come to a good fit within a few iterations using a PC with a plotting facility. In the case of more continually growing populations the same procedure can be applied but one has to guess or find other inputs to get a good starting estimate of the life distribution.

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2. MAXIMUM LIKELYHOOD PROCEDURE

Ref /1/ and /2/ give the background for a more profound analysis of the material where a computer is used to optimize the model for the life distribution to get the best fit to the field data without plotting the result for each iteration. This method is more complex but in return it gives the possibility to work with mixed distributions like a main life distribution plus a small percentage of "Freak" early failures. This method is also desireable from the point that one gets a more objective estimate of the life parameters then from graphical iterations.
Finally the ML method gives the possibility to estimate confidence limits for the distribution or its corresponding failure rate that is hardly done by the graphical methods.

EXAMPLES OF APPLICATIONS

1. DYNAMIC MEMORIES

Fig re 4 shows field failure data from one of the first massproduced dynamic MOS memories, the 1k DRAM called 1103. Up to 21888 devices were followed for almost four years and it looks as about 0.5% are going to fail but not much more. By a cut and try method the distribution of these early failures were estimated to have a median life of 3000h and a dispersion (sigma) of 0.3 decades. By adding the failures from each step according to this life distribution it looks as the simple model describes the result fairly well. This model predicts that the failure rate should drop very drastically after 2.5 years. Figure 4 shows however that there is a slight increase of failures even after 3.5 years. One thus could suspect that there was also an other component in the life distribution that more relates to the whole population. The task to carry out that analysis graphically was judged as too time consuming and uncertain.

The material was then analysed by Brittish Telecom /1/ using the mathematical procedure called Maximum Likelyhood. Figure 5 is from ref./1/ and it shows the results from both methods. The ML-method has here indicated the presence of a weak subpopulation of 0.34% on top of a life distribution that we to-day know is very typical for oxide related failures. Such failures are often characterized by very large sigmas and large numbers for the median life.

2. TRAFFIC STATISTICS

The same methods as mentioned before can be applied in many other areas. Ref. /2/ gives information on the use of parametric methods in analysis of survival data from medical experiments etc. One area that involves both large populations and survival statistics is the one dealing with traffic accidents. It is an area of public interest and of economical importance. The analysis of death rates in the traffic can be performed using the same principles as described before. Such an analysis will give some perspective to the raw material and also a good help in drawing valid conclusions.

2.1 Some background

In Sweden the statistics behind the traffic accidents are published annually by Statistics Sweden, S-11581 Stockholm, ref. /3/. The reports deal with many different aspects on the accidents such as influence from time of the year, time of the day, age of hurt people etc. From other sources, ref. /4/, the amount of units in field use (no of cars e g) can be retrieved. Figure 6 shows the amount of cars cept registered each year as well as the number of people killed in road traffic "accidents". The quoatations have been used because in each individual case the tragic event most certainly is considered as an accident but as an outcome from a communication system the failure rate (death rate) is rather predictable and certainly not an accident.

2.2 Analysis

Originally the material shown in figure 6 was analysed in 1981 using the data that was available at that time (up till 1978). Assuming that an additional car (unit) to the population needs an additional driver that has to learn by mistakes it is obvious that this learning curve will have a great impact on the failure rate of the system. This learning curve was modelled by a log normal distribution expressed as the time to reach 0.1% killed people in relation to the number of cars and a standard deviation expressed in decades.The analysis was of the graphical type where a computer calculated the number of failures each coming year (defined as the number of killed people) due to the number of new units installed one specific year. The process was then repeated for all coming years and the failures were all added together for each year in the same manner as was used in figure 4. After several iterative runs a good estimate of the time dependent failure rate was obtained that is presented in figure 7.

2.3 Follow-up

Since 1980 the statistics has very much followed the predicted out come. In 1983 material was presented /3/ showing the risk of getting hurt or killed in traffic vs age. This material indicates clearely that the failure rate should drop as a function of experience of the driver. The diagram is reprinted in Figure 8.

It is of interest to see if the life distribution that was estimated on data up till 1978 would give a good prediction for the data that we to-day know up till 1985. As can be seen in Figure 9 the calculated number of failures follow the actual numbers very well that is an indication that the method is useful for prediction purposes. Indeed, it is interesting that a model using only two parameters is able to give that kind of prediction.

2.3 Discussion

The model can also be used to estimate if there has been any real improvement of the traffic system reliability at all since 1935. By dividing the actual failure rate by the calculated failure rate a relative measure is obtained. This is shown in Figure 10. Fortunately it indicates that there is an improvement going on and that the increase in failure rate the last years would be even worse without it.

3. CONCLUSIONS

It has been shown that com uter aided methods substantially can improve the analysis of field failure data. It also becomes possible to deduce life distributions without actually knowing the individual life time of each failed device. As it might be much cheaper to use a computer analysis compared to introducing a strict failure reporting routine where each device have to be traced back to its individual commencing time in a particular system it should be easy to start following these lines. Suitable program software for common PCs should be made available for those who see applications in their daily work.

The development of non parametric methods is forseen as an area of importance that should be added to this field.

4. ACKNOWLEDGEMENTS

Acknowledgements are made to Dr C Johnston of Brittish Telecom for kindly supporting the memory data analysis and supplying software for the method of Maximum Likelyhood analysis .

5. REFERENCES

1. F H Reynolds and C Johnston, "Component field-failure data analysis", IEEE Electronic Components Conference, Proceedings 1981.

2. Alan J. Gross, "Parametric methods in the analysis of survival data", Microelectronics and Reliability, Vol 20,pp 477-481

3. Official Statistics of Sweden, Traffic Injuries 1985

4. AB BILSTATISTIK, "Bilismen i Sverige, 1985"

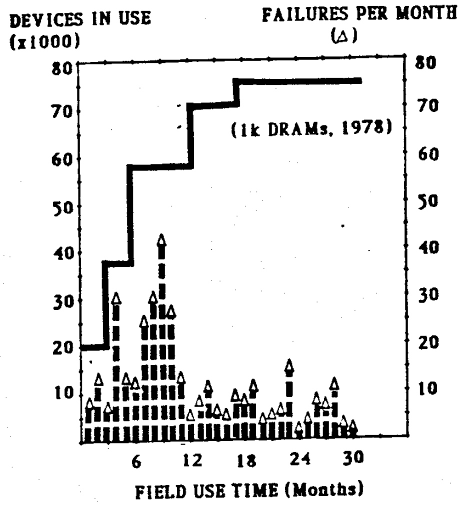

Figure 1
Example of stepwise growing population with failure indications.

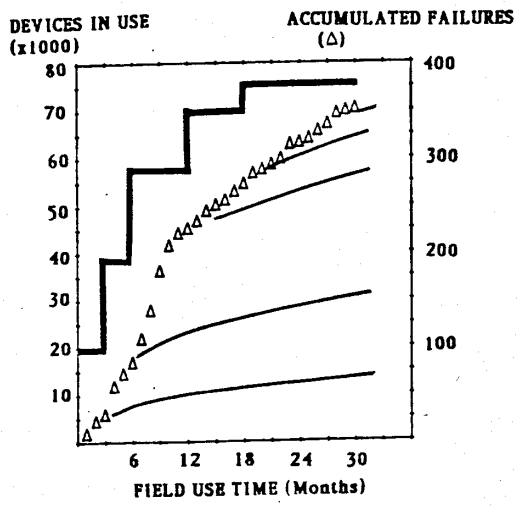

Figure 2
As Figure 1 but with accumulated no of failures

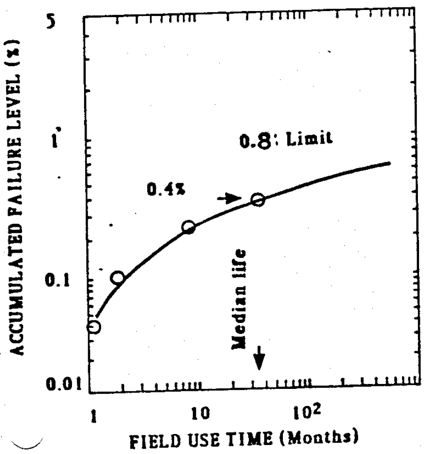

Figure 3
Using the response from the first step to get an initial estimate.

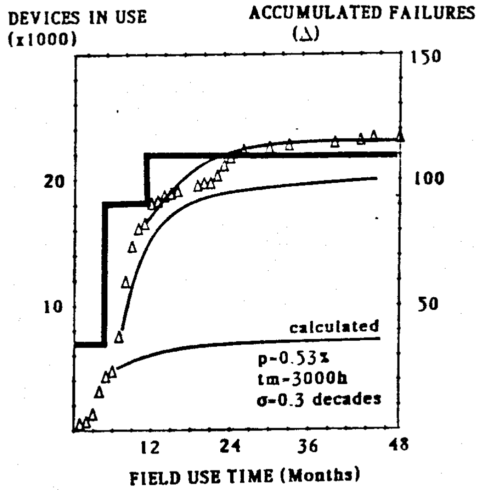

Figure 4
Service profile for dynamic memories with cumulative failures.

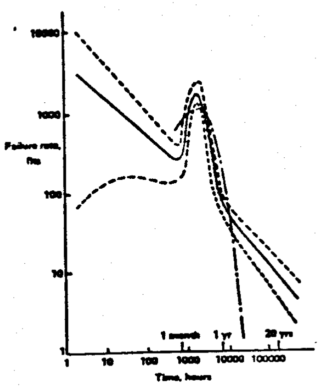

Figure 5
Failure rate for dynamic memories (1k DRAM)
__: Calculated from ML-solution
---- : Graphical solution (Hallberg) /1/

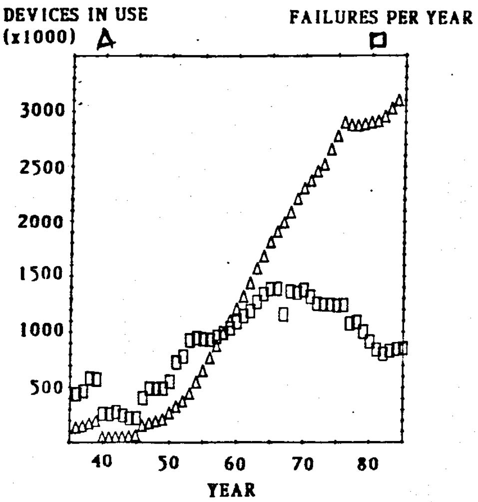

Figure 6
Number of registered cars in Sweden and the annual number of people killed in the traffic.

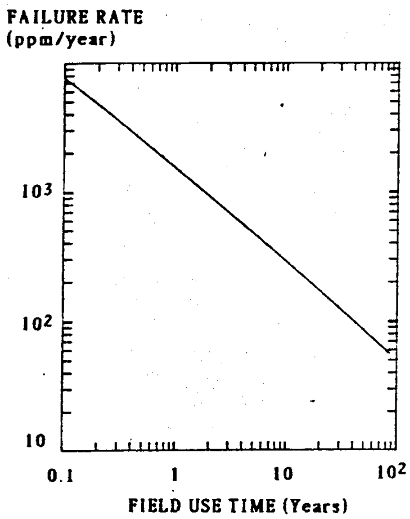

Figure 7
Time dependent risk of getting involved in a mortal traffic accident.

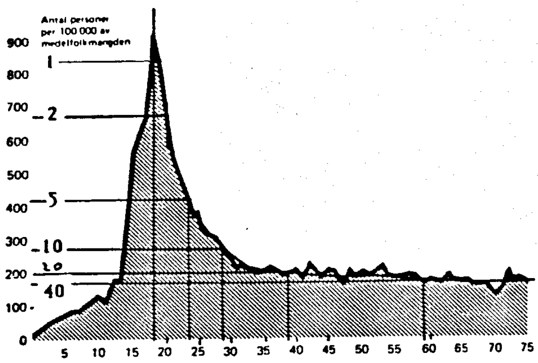

Figure 8
Persons killed and injured in road accidents reported to the police, per 100 000 mean population within each age group 1983 /3/

Indicates a strongly time dependent failure rate where time counts from the drivers licence (appr 18 years)

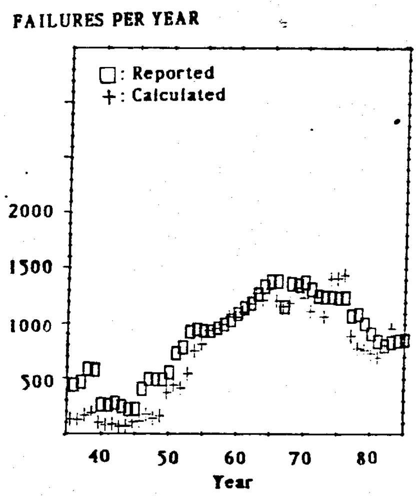

Figure 9
Calculated and reported annual death rates in the traffic.

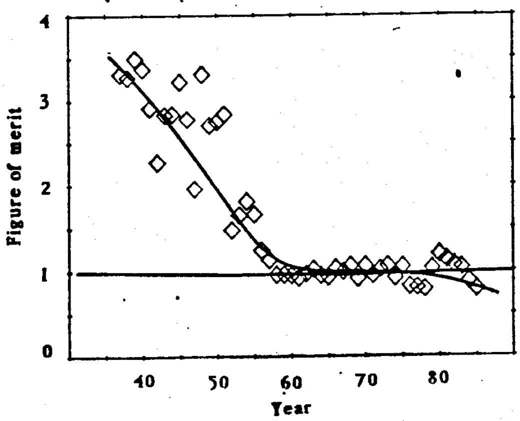

Figure 10
Reported failure rate divided by calculated failure rate used as a figure of merit of the traffic system realibility. An improvement is indicated also for the last few years despite the increase in death rate.