



1

... what is probability  
plotting?

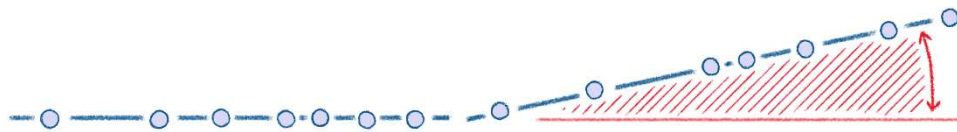
2

human beings are good at  
identifying straight lines in things ...

3



4

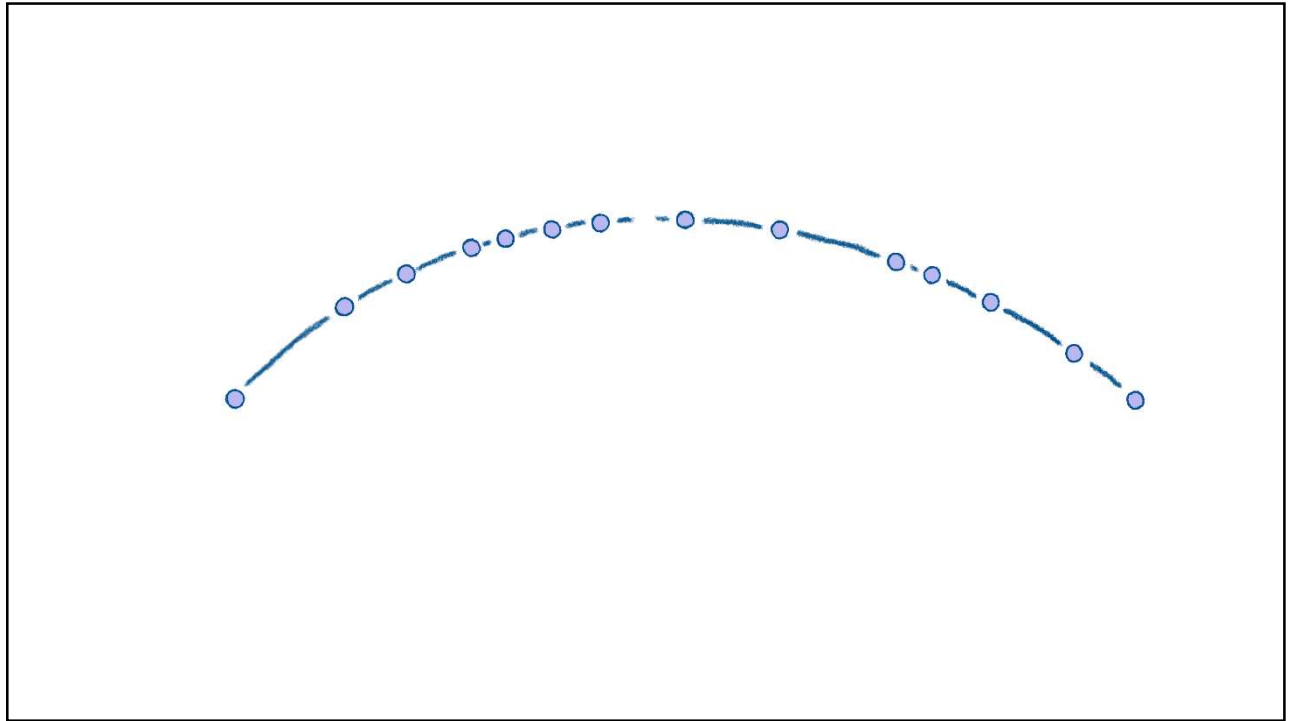


... some people might be able  
to judge this angle to be  
around  $12^\circ$

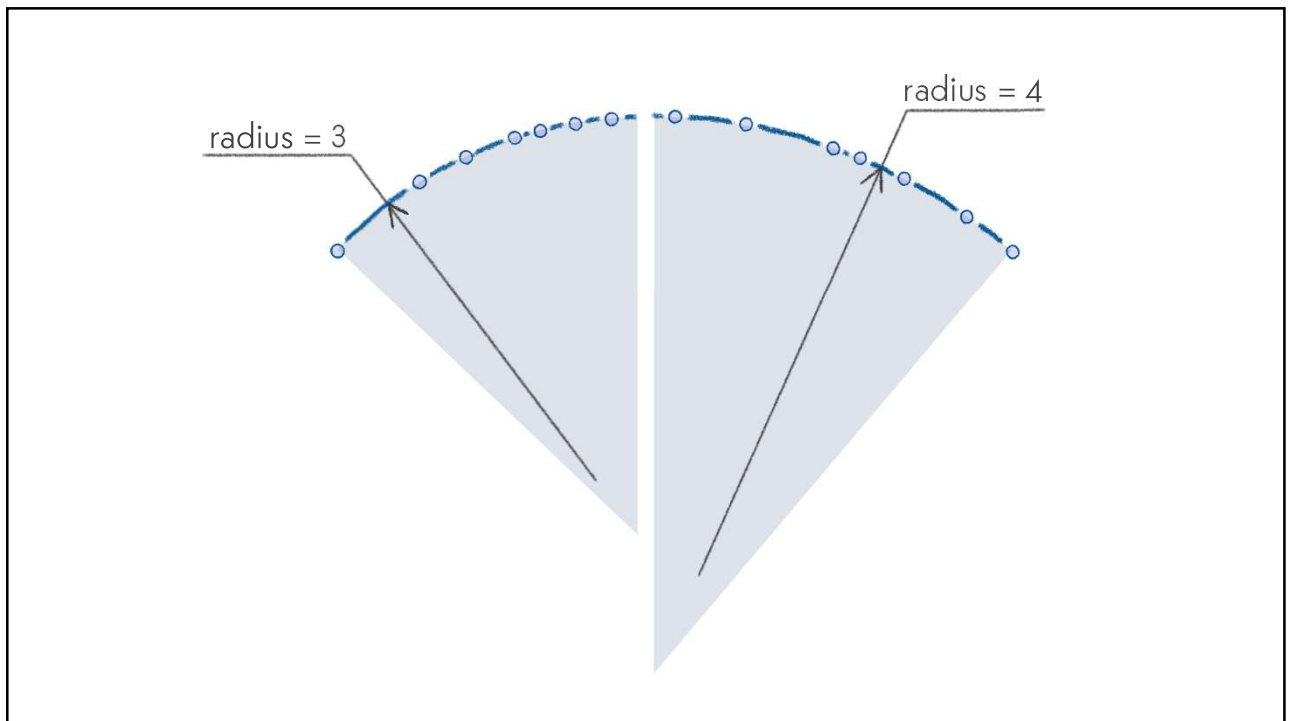
5

human beings are good at  
identifying straight lines in things ...  
... but not *different* curves

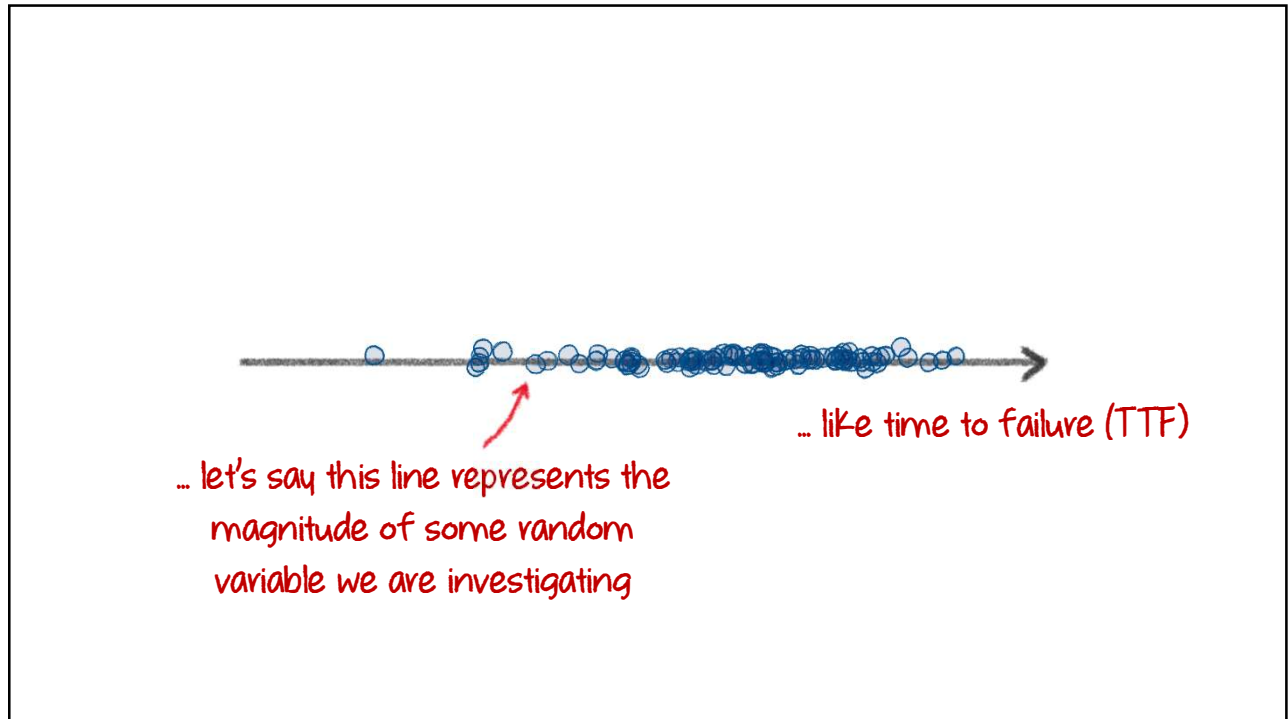
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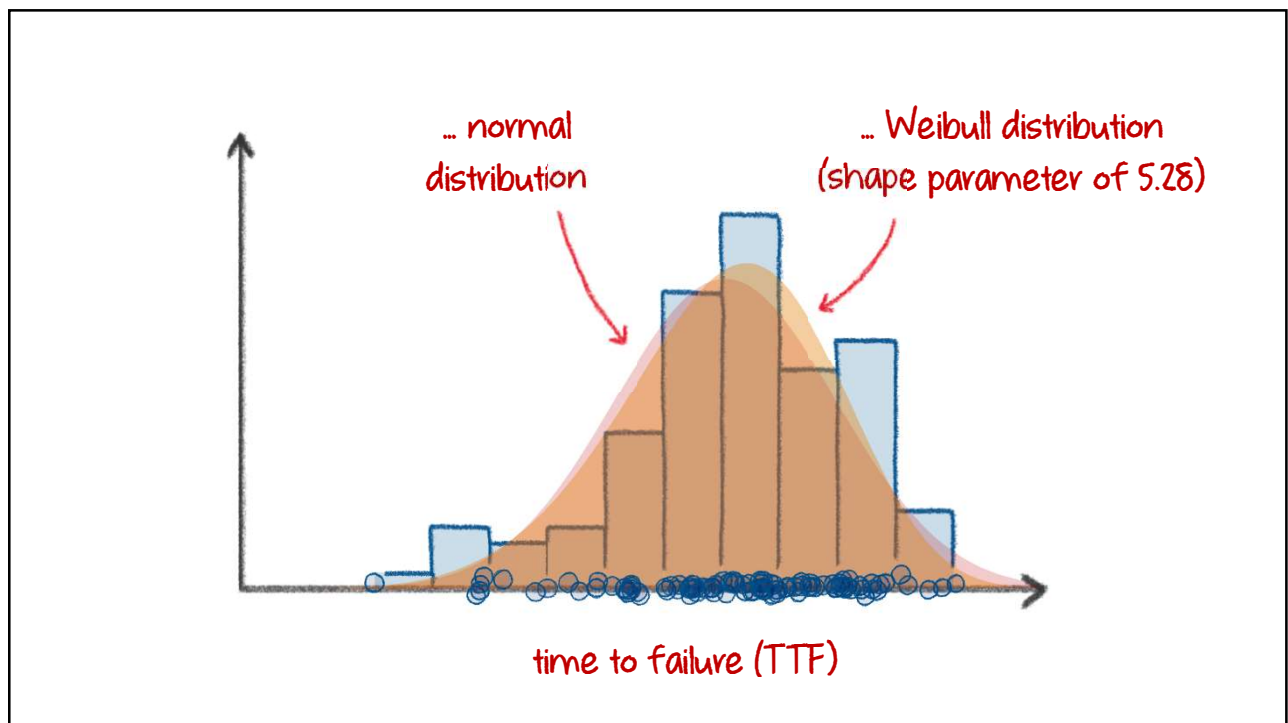
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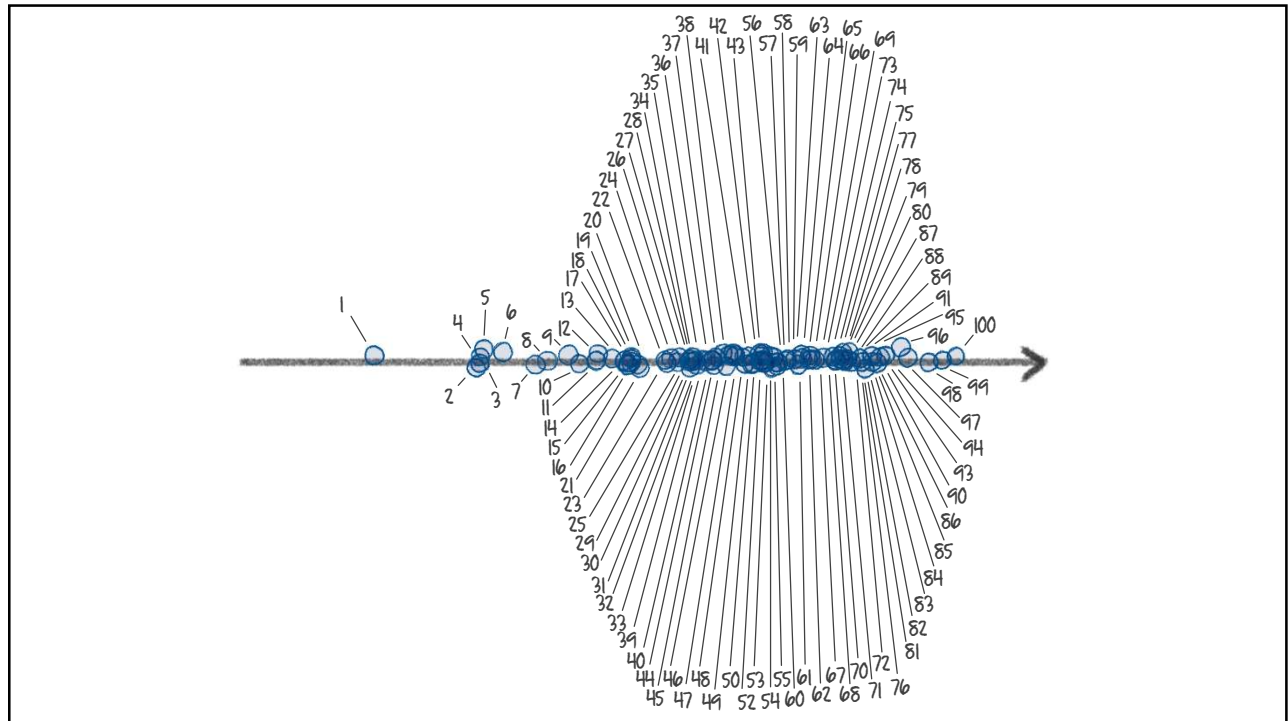
8



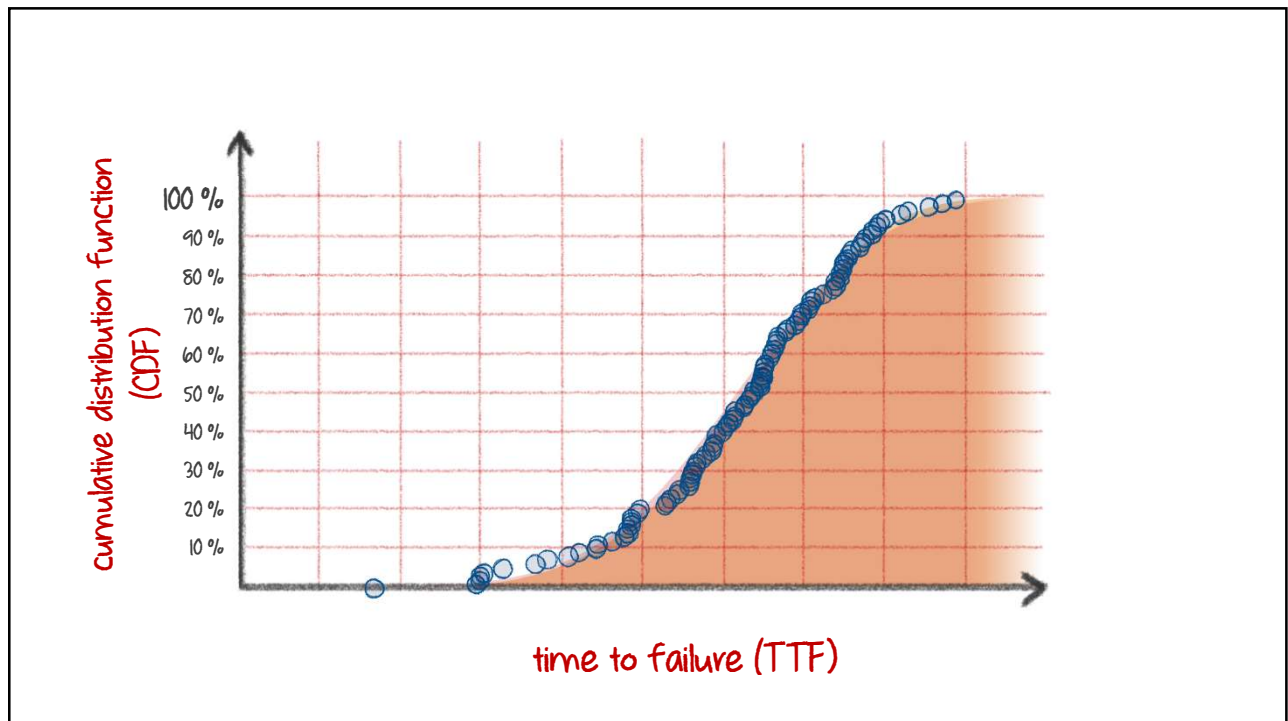
9



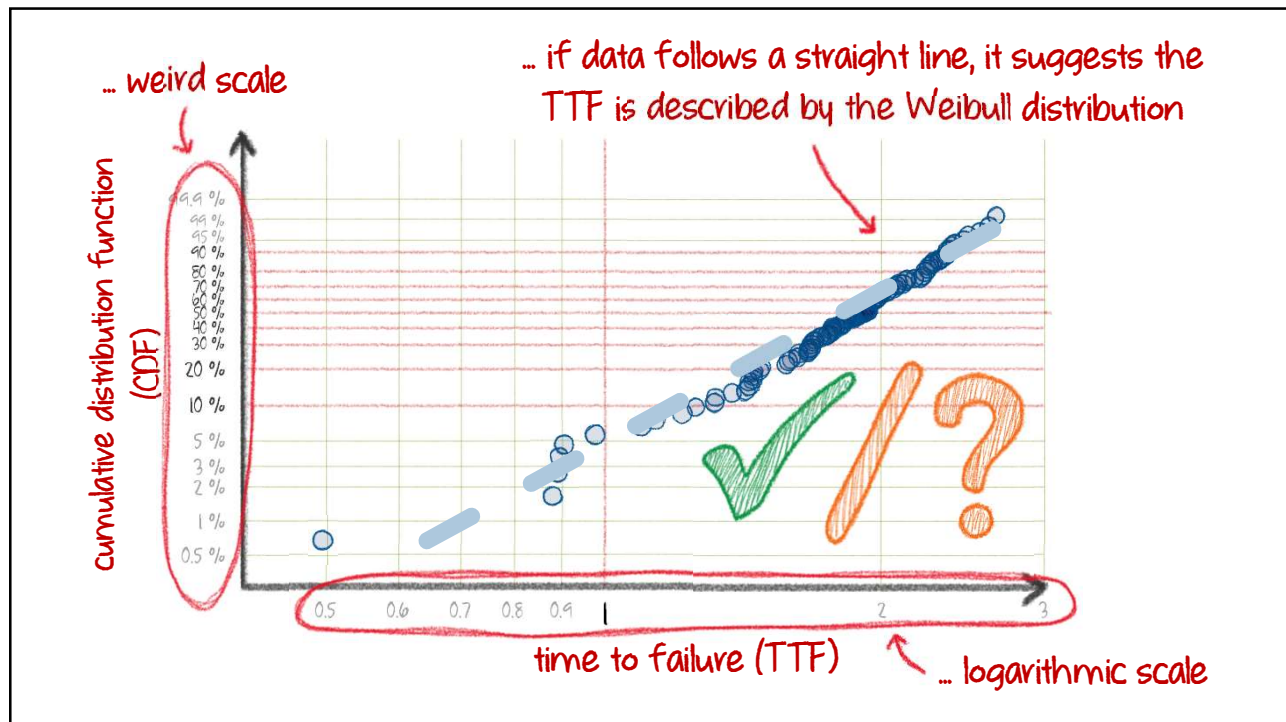
10



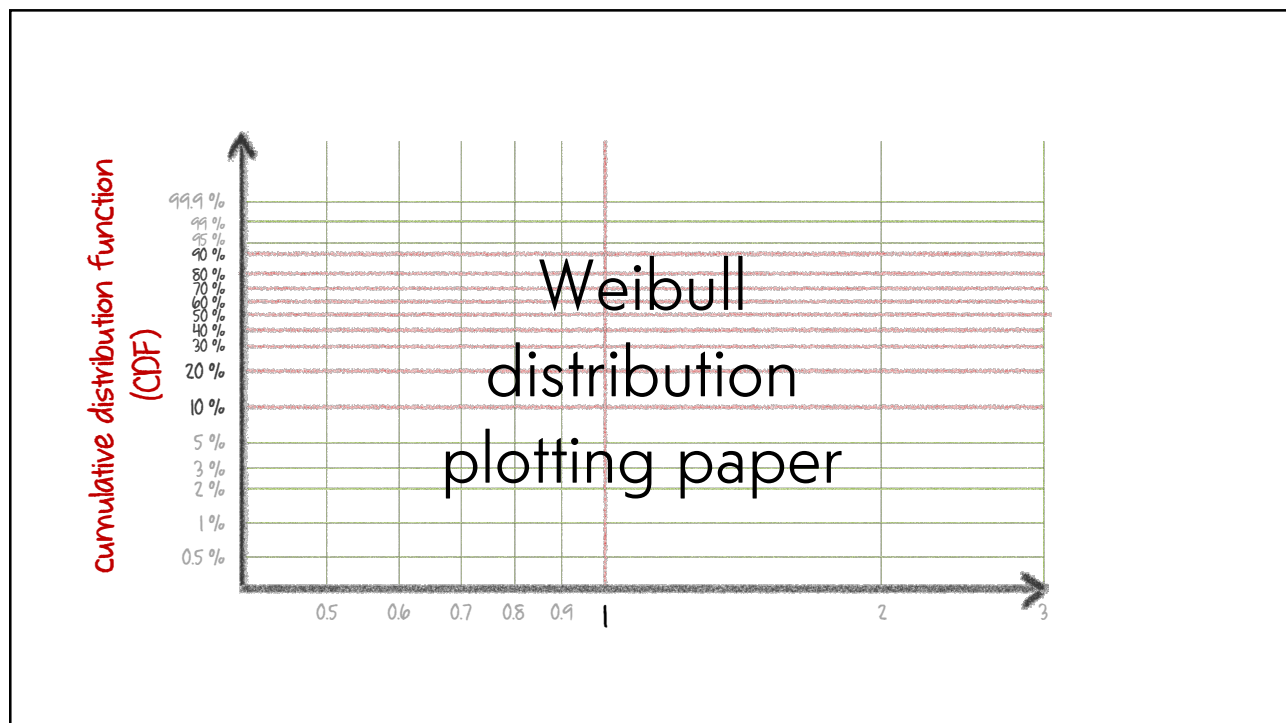
11



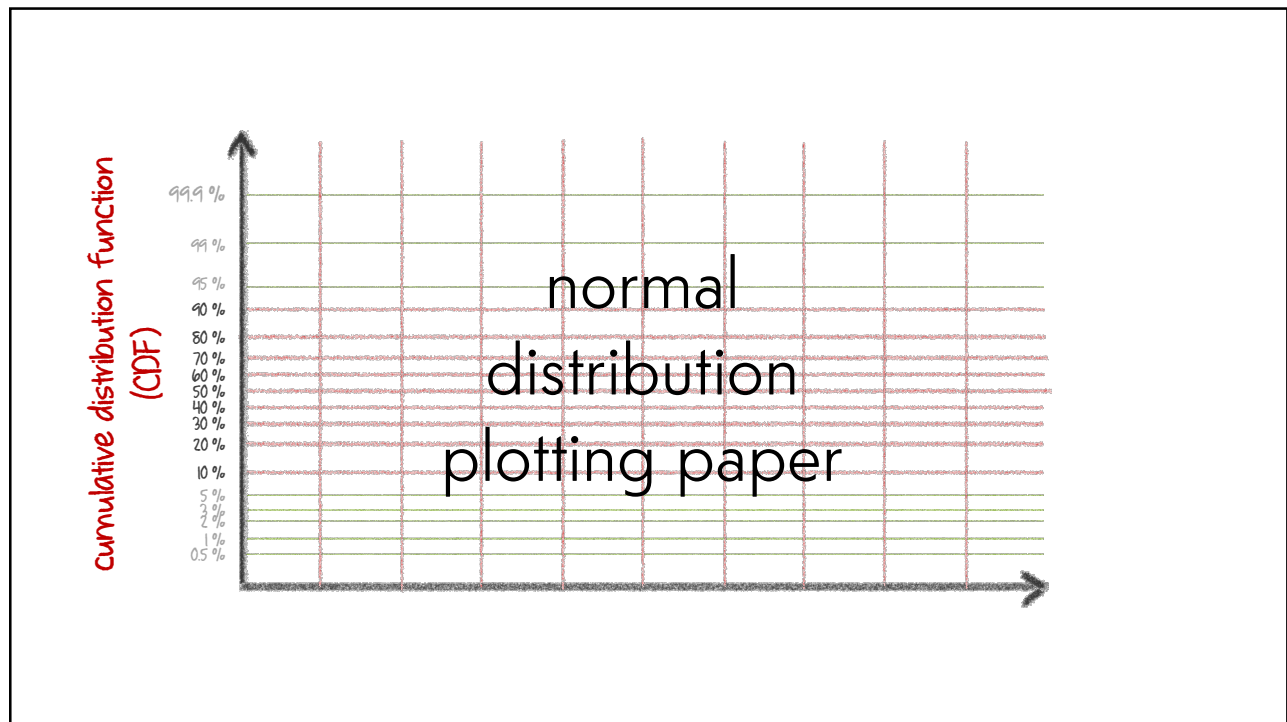
12



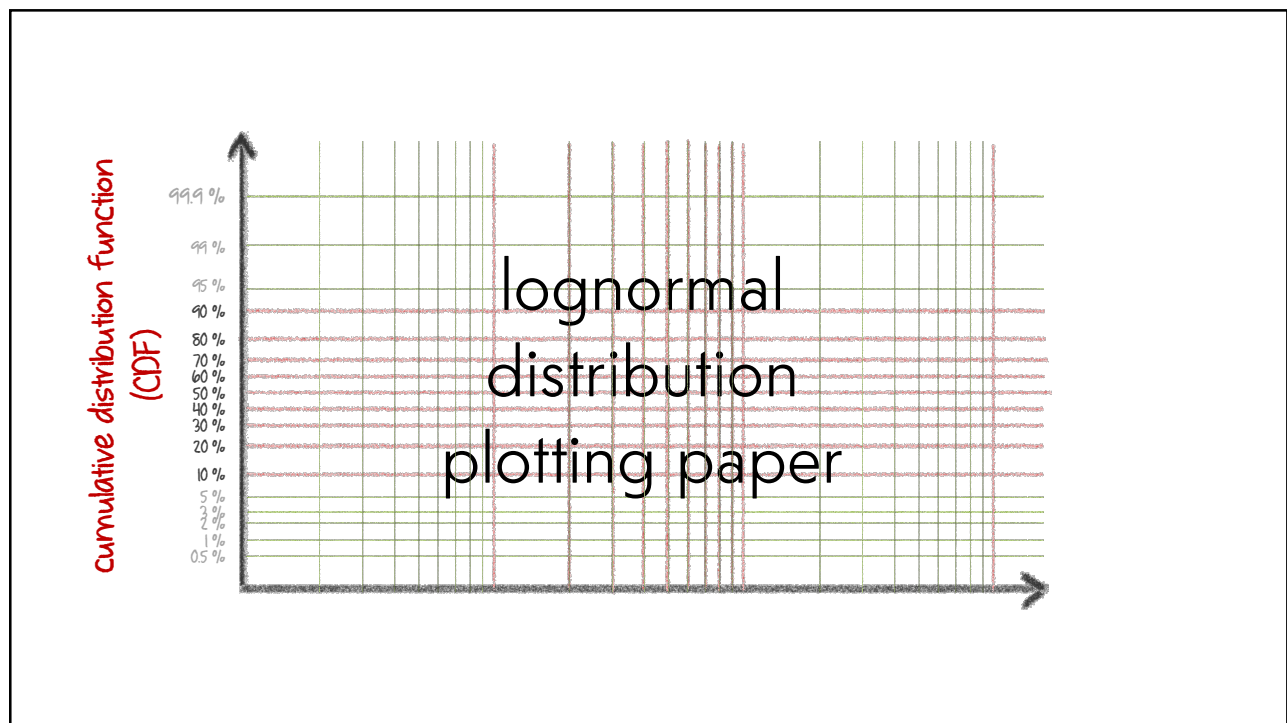
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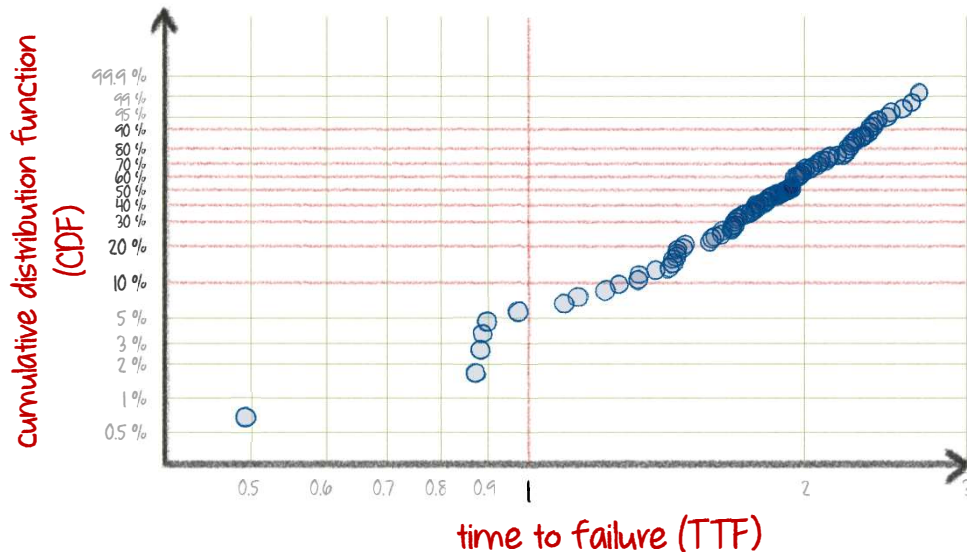
15



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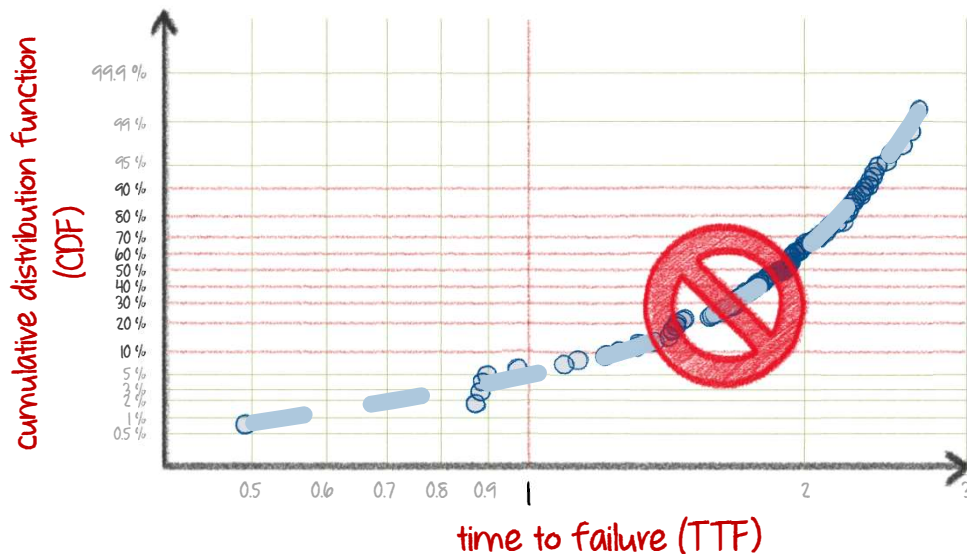


## Weibull distribution plotting paper

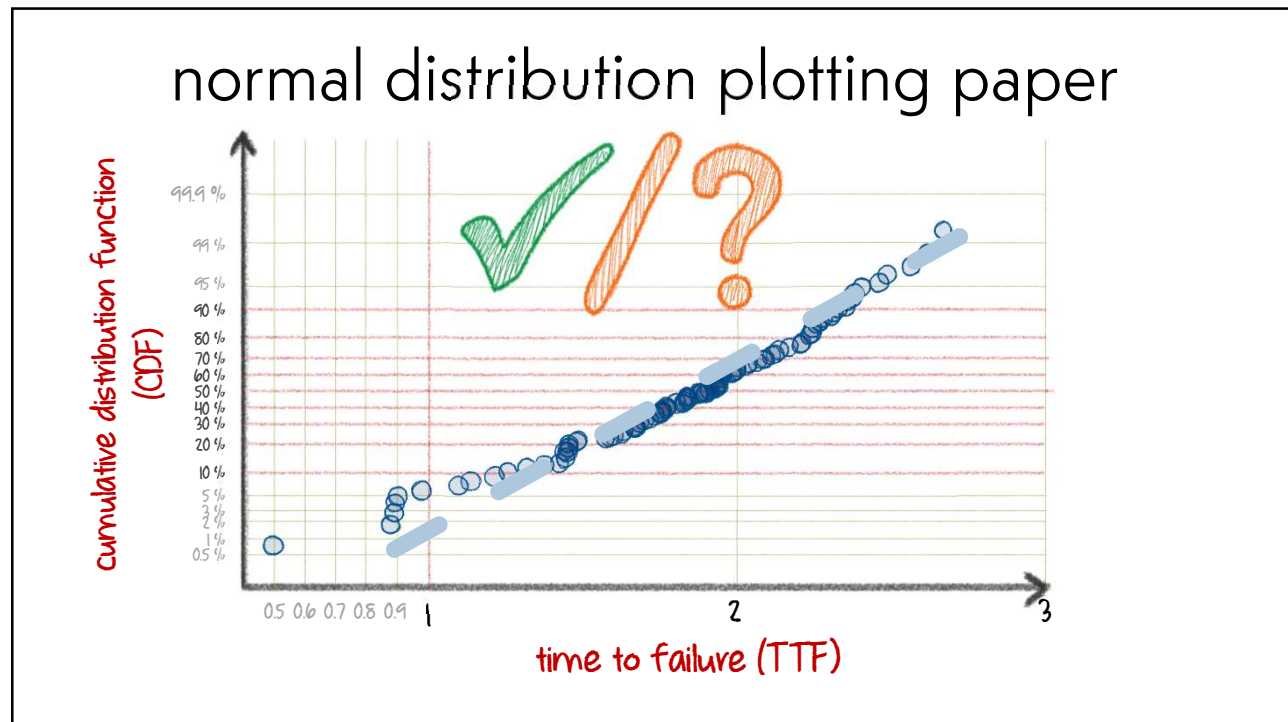


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## lognormal distribution plotting paper



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# probability plotting

... a graphical technique for comparing two data sets.

... typically one 'empirical' data set which could be the observed times to failure on a reliability demonstration test

... and one 'theoretical' set like a set of random variables described by a normal, lognormal, Weibull, ... distribution

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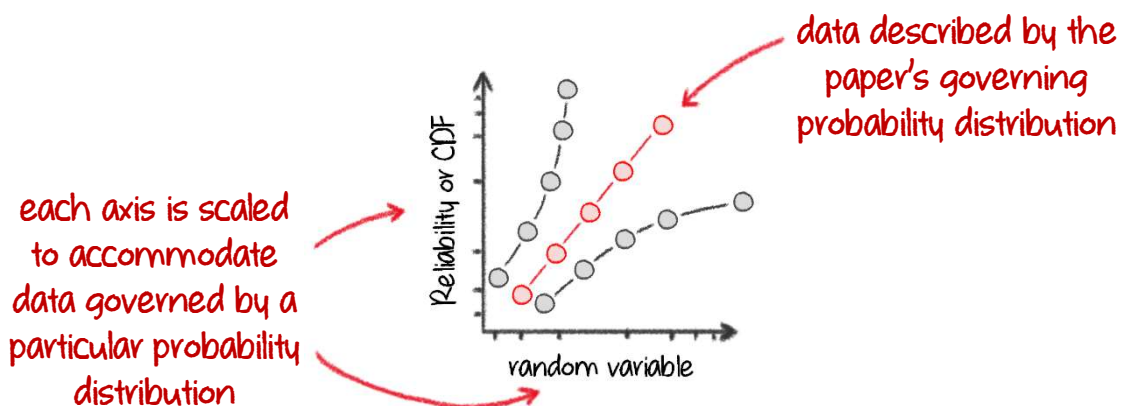
# probability plotting papers

... scaled and for a *specific probability distribution*

If plotted data creates a straight line, it suggests that the underlying random process is described by the *specific probability distribution*

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# probability plotting papers



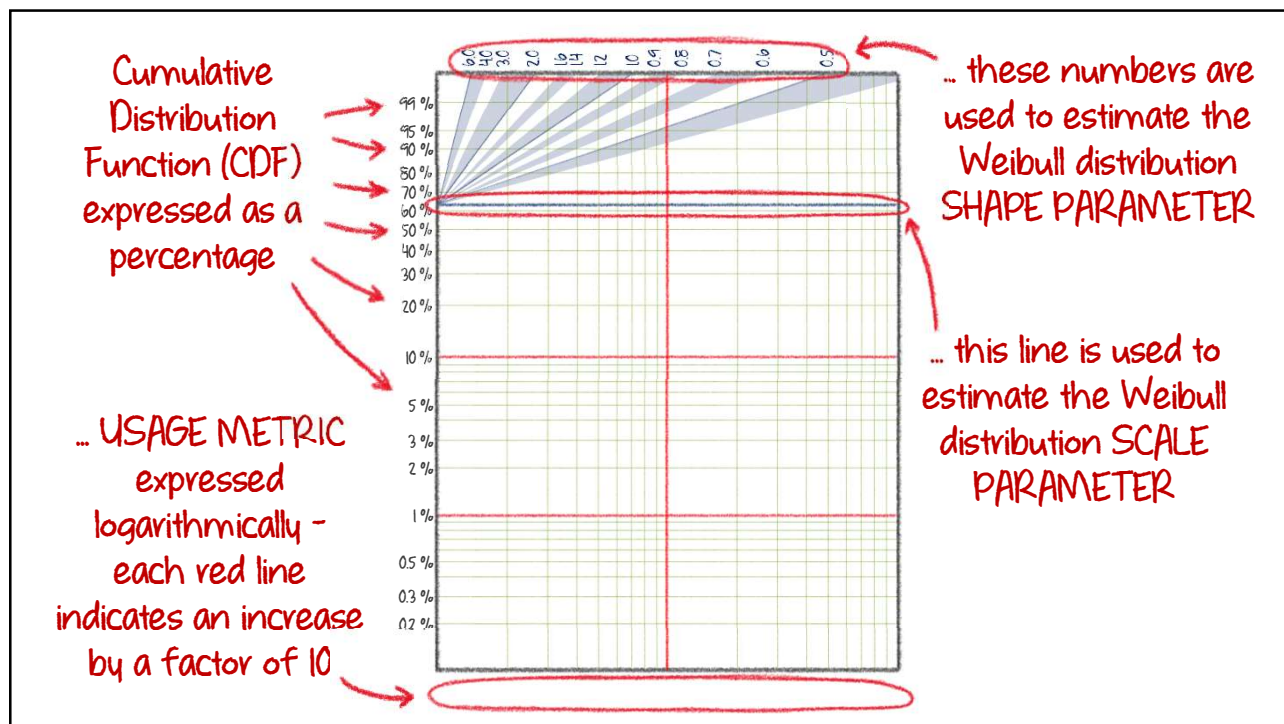
22

... and the most popular  
**probability plotting paper**  
is the one based on the  
Weibull distribution

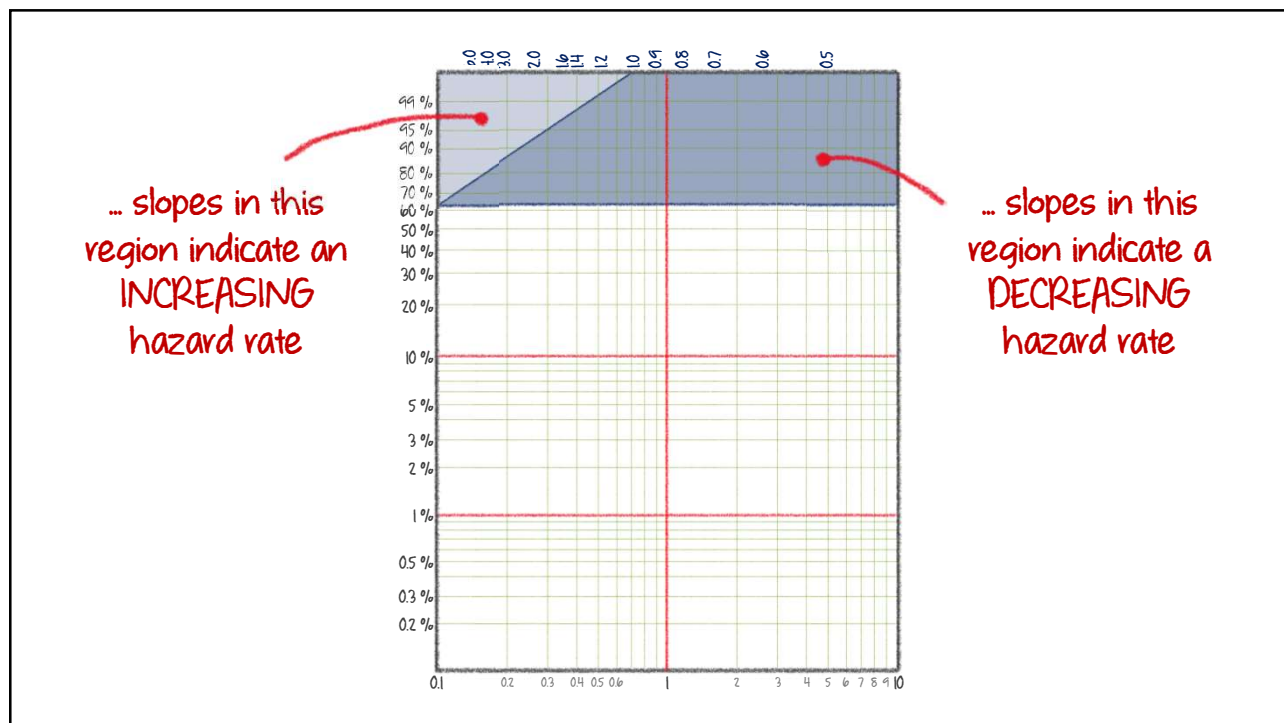
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... starting with being able  
to estimate distribution  
parameters directly from  
our probability plot

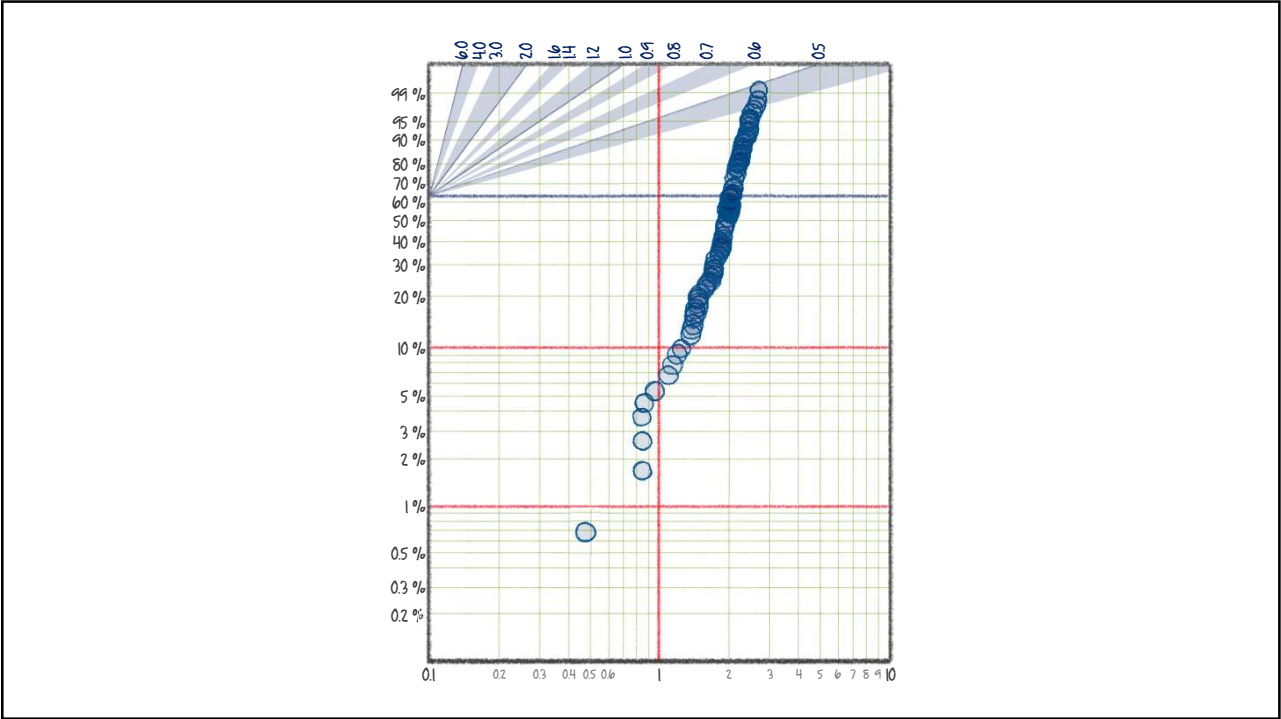
24



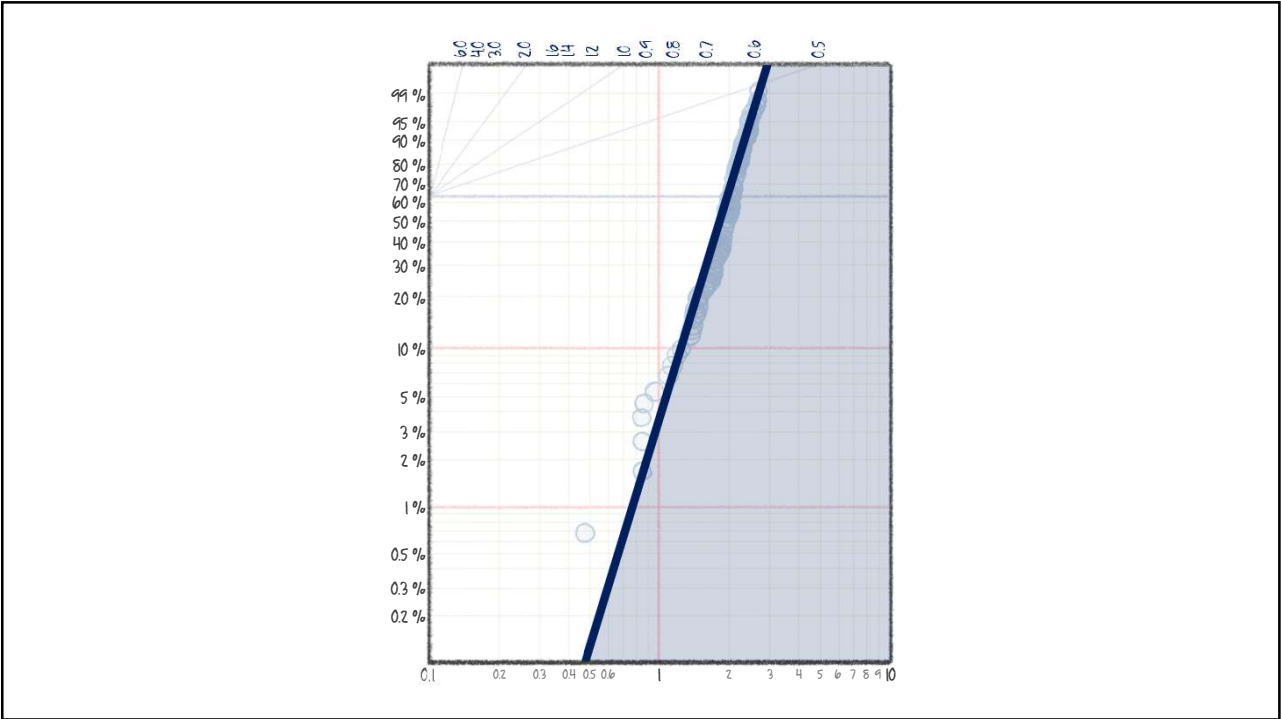
25



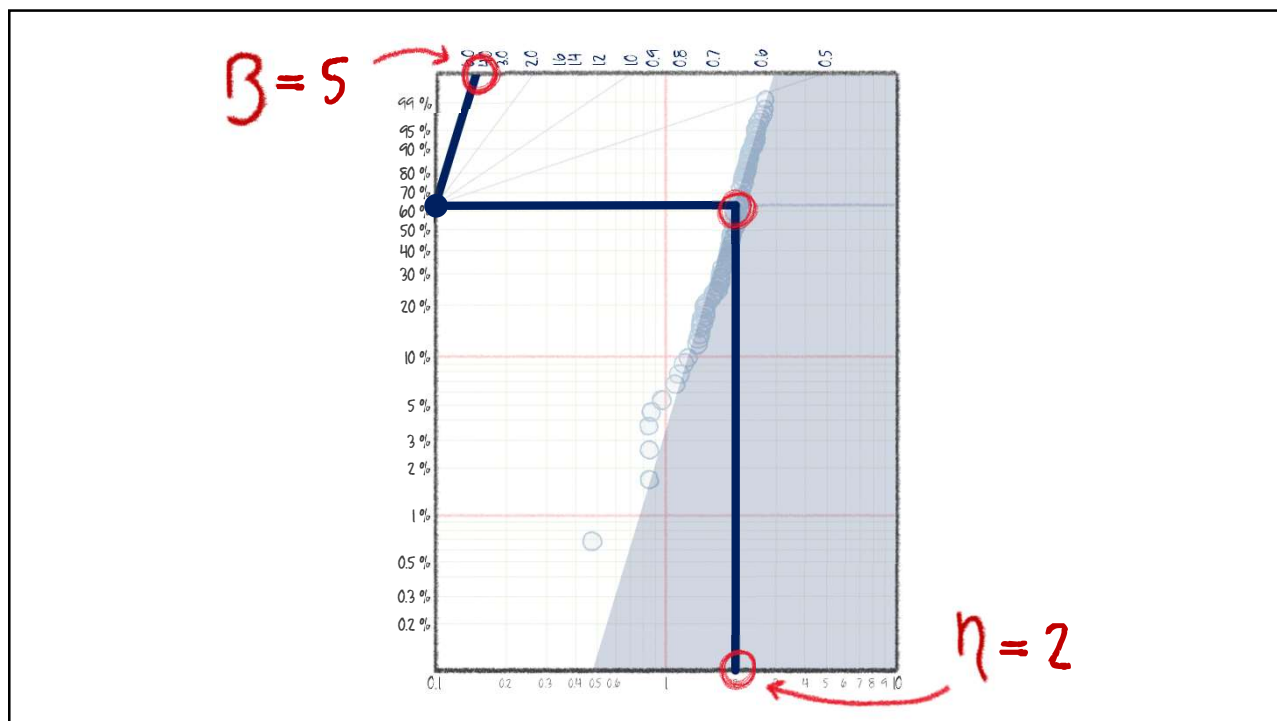
26



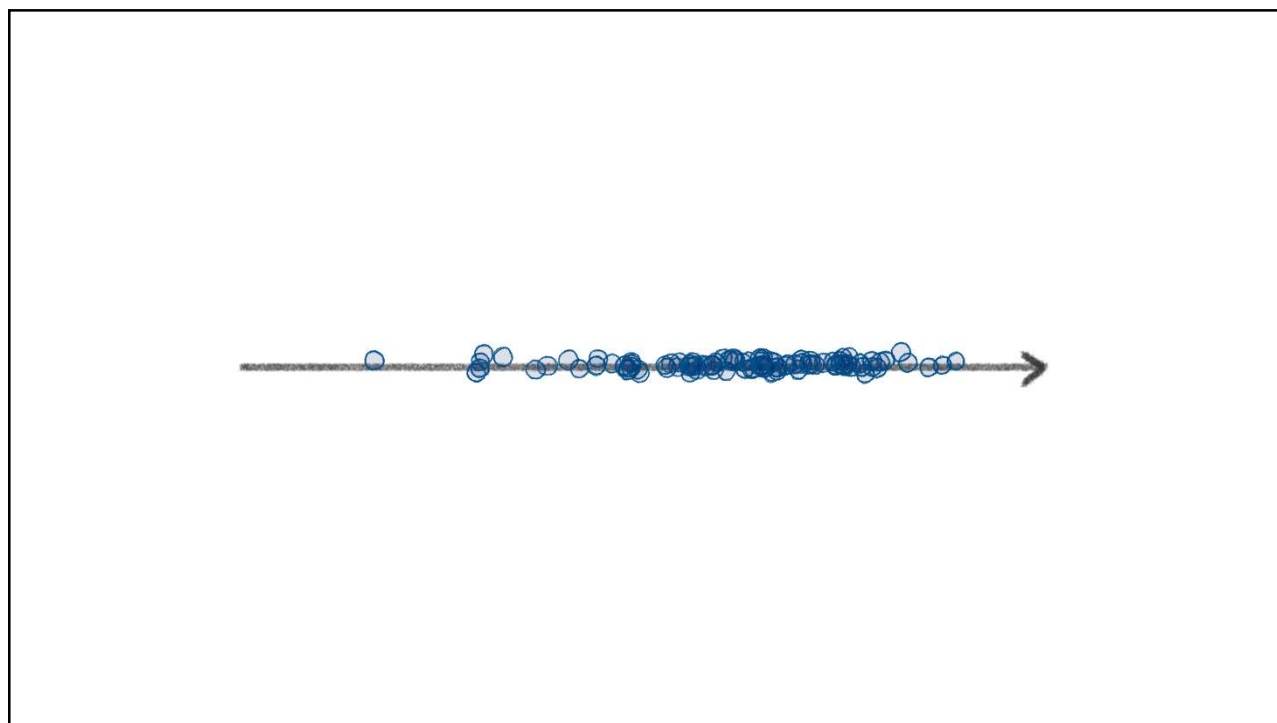
27



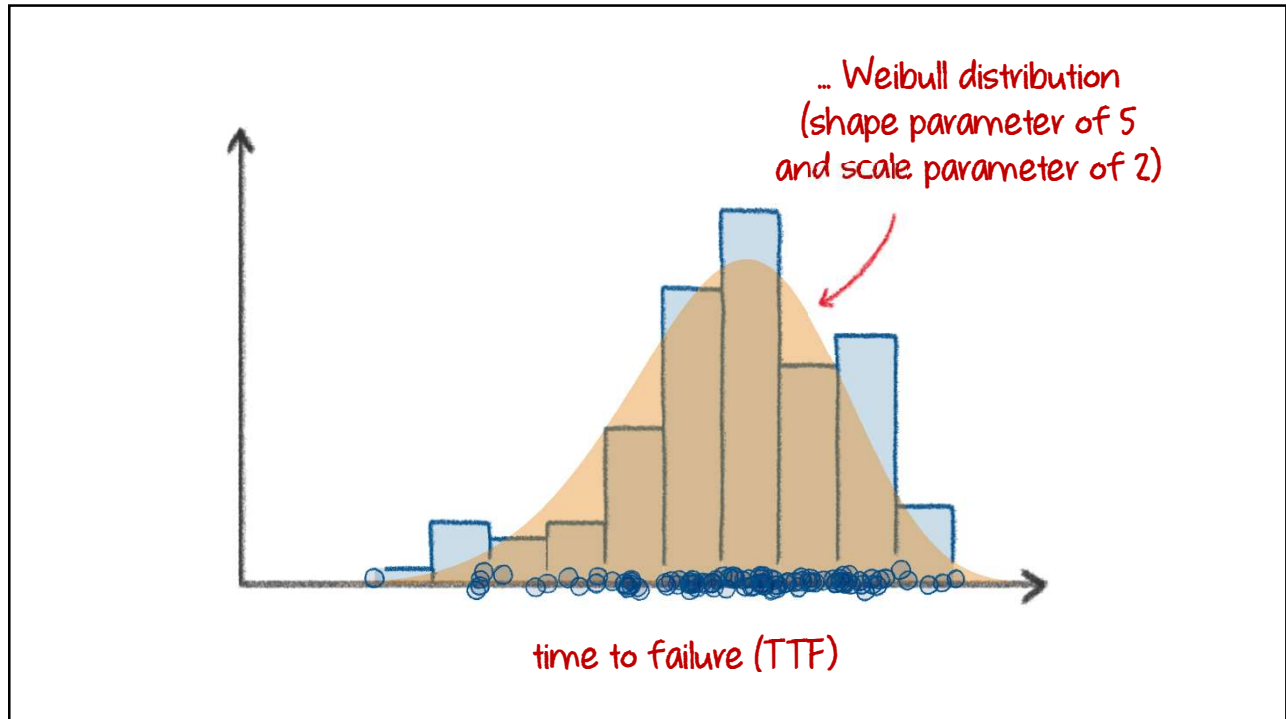
28



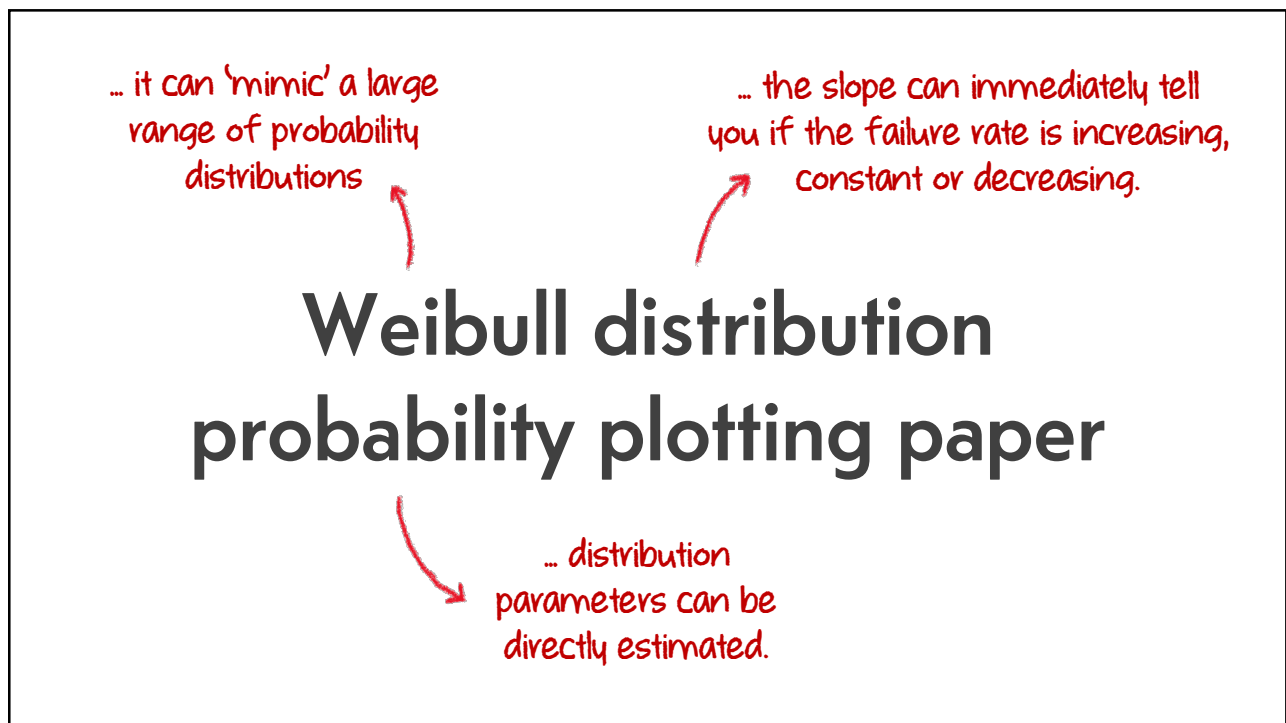
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30



31



32

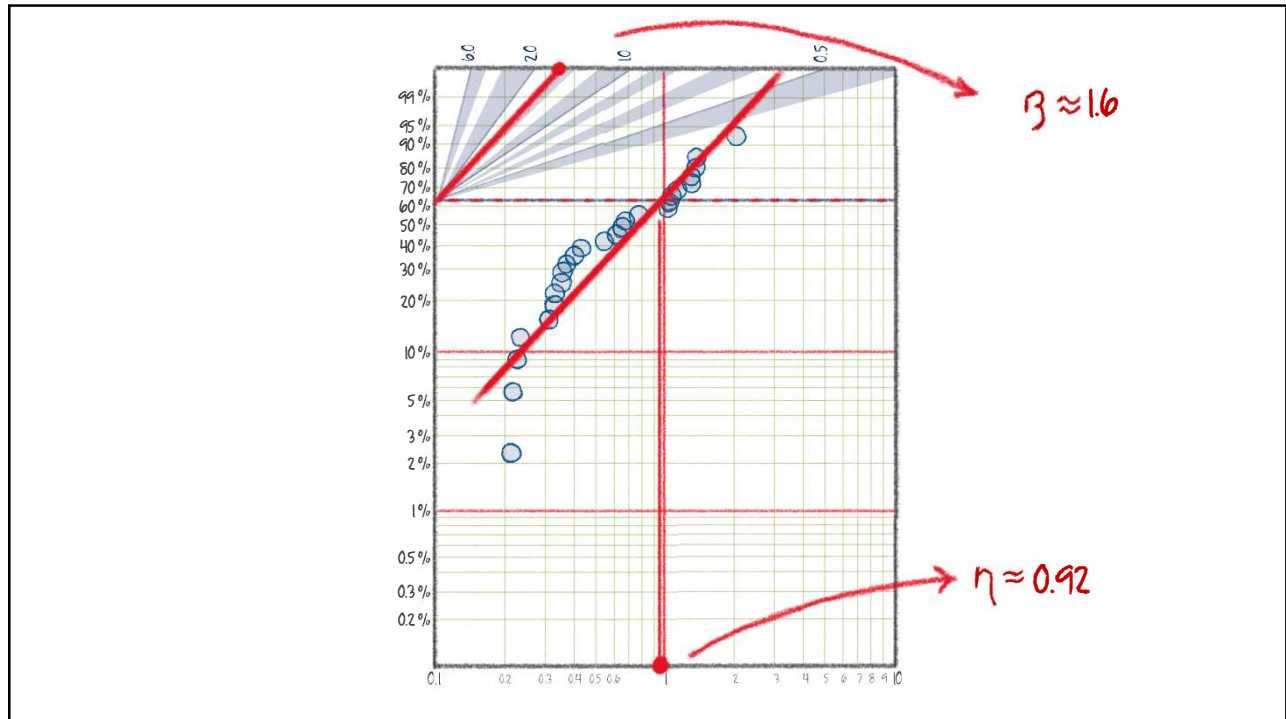


the 8 steps for  
probability  
plotting

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... are the  
subject of a  
specific lesson

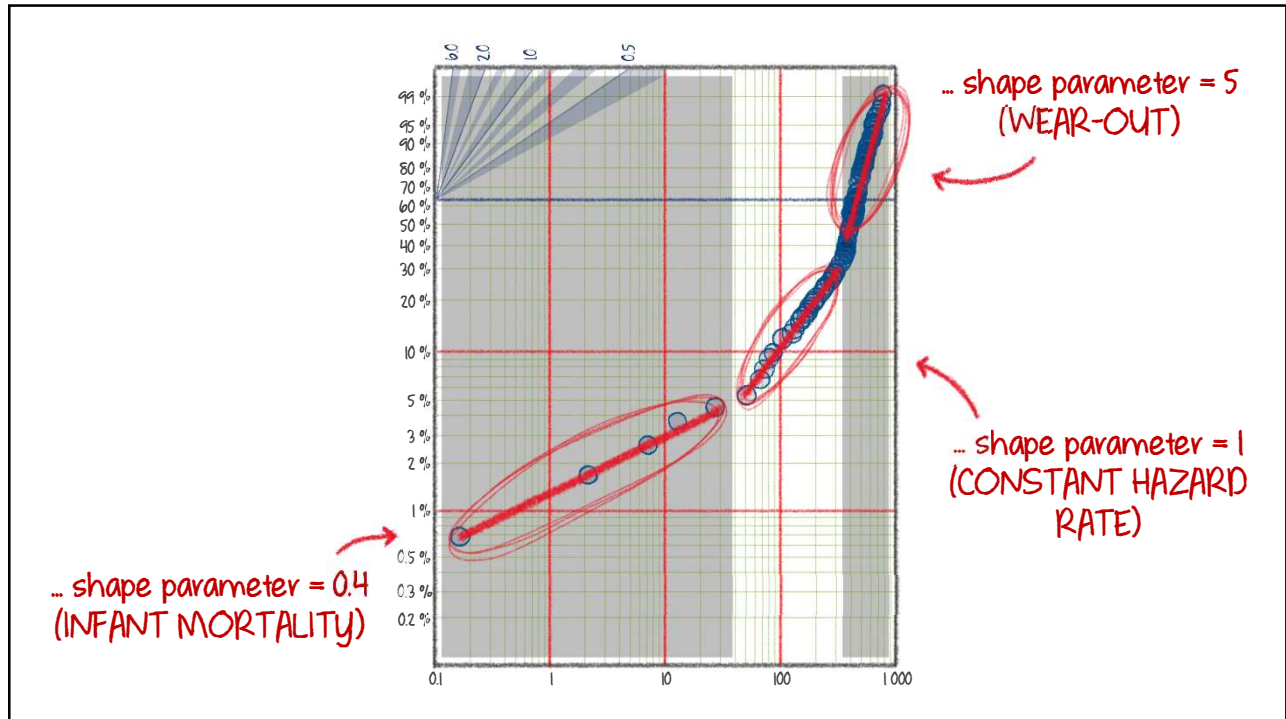
34



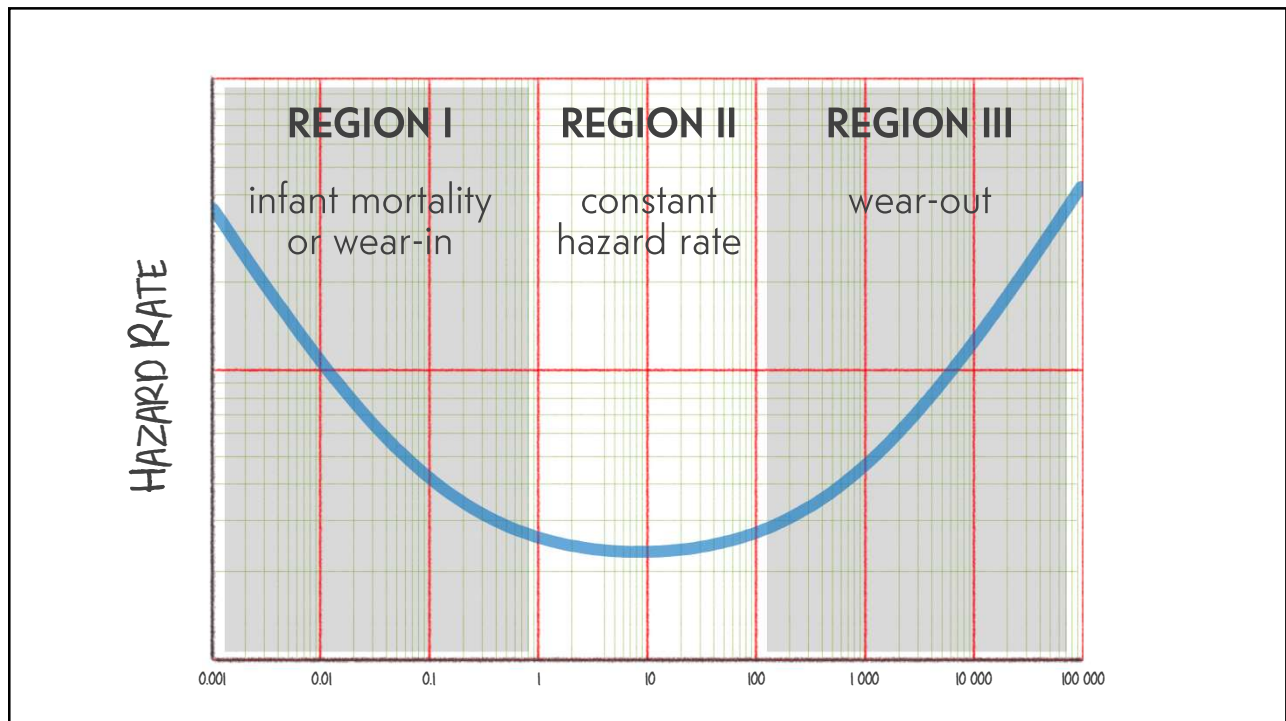
35

... and we can find  
different failure  
modes on one chart!

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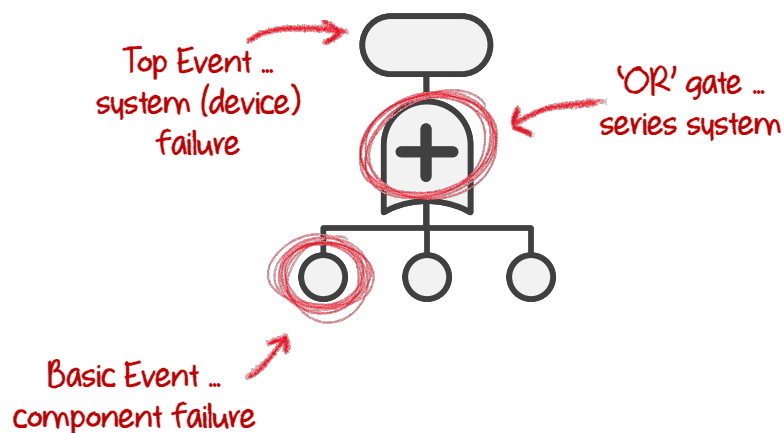


38

... but don't try  
and see things  
that aren't there ...

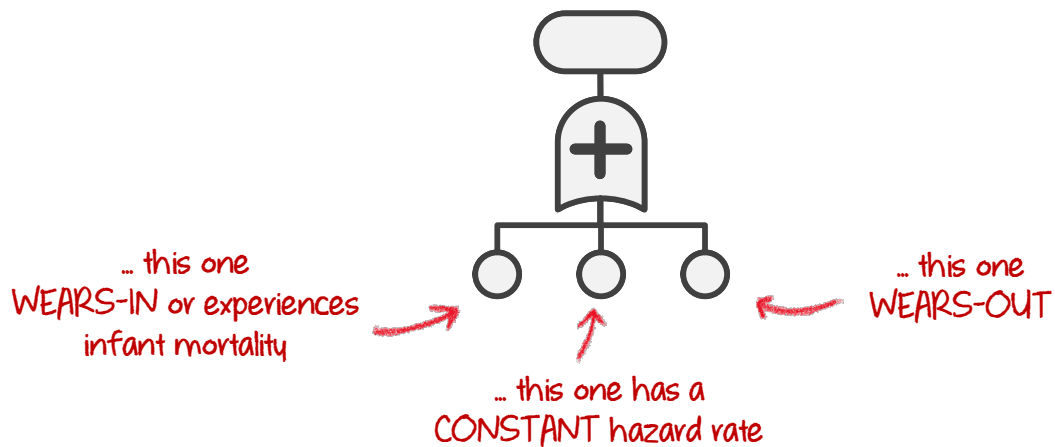
39

... let's say our system has three components



40

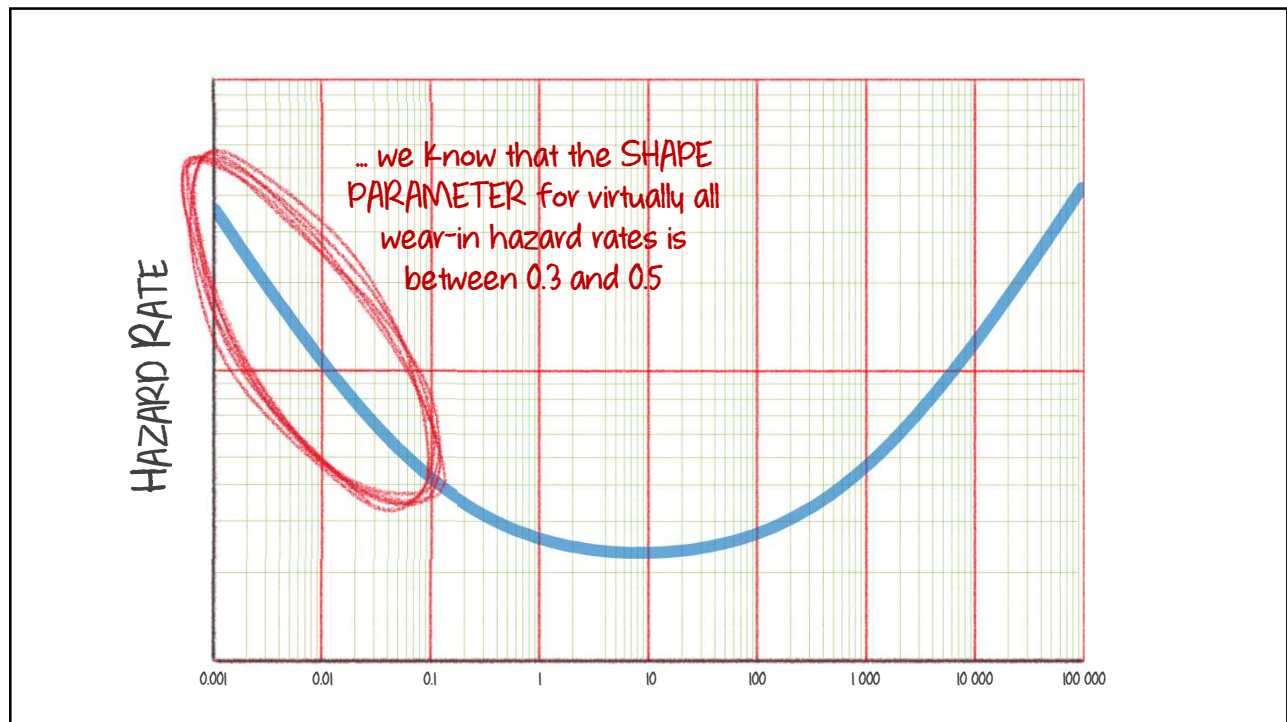
... let's say our system has three components



41

... so let's simulate failures  
of this system

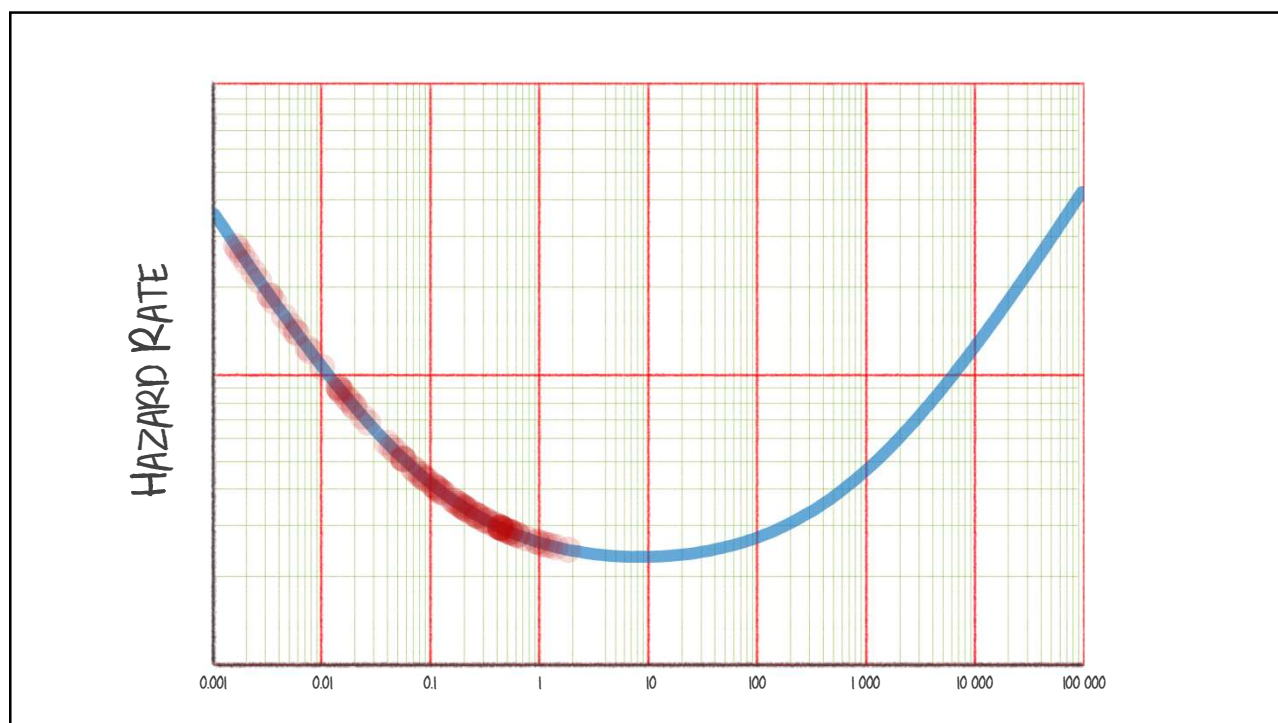
42



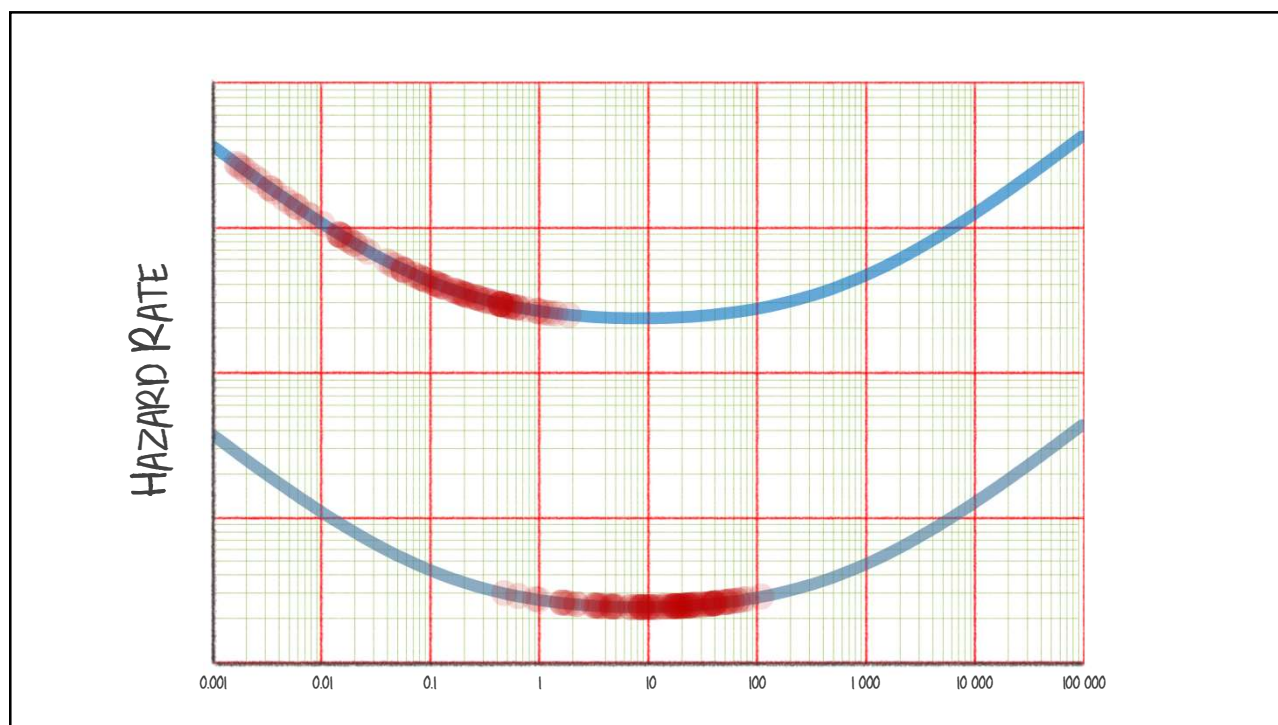
43

... so let's compare this to a bathtub curve with a lower hazard rate

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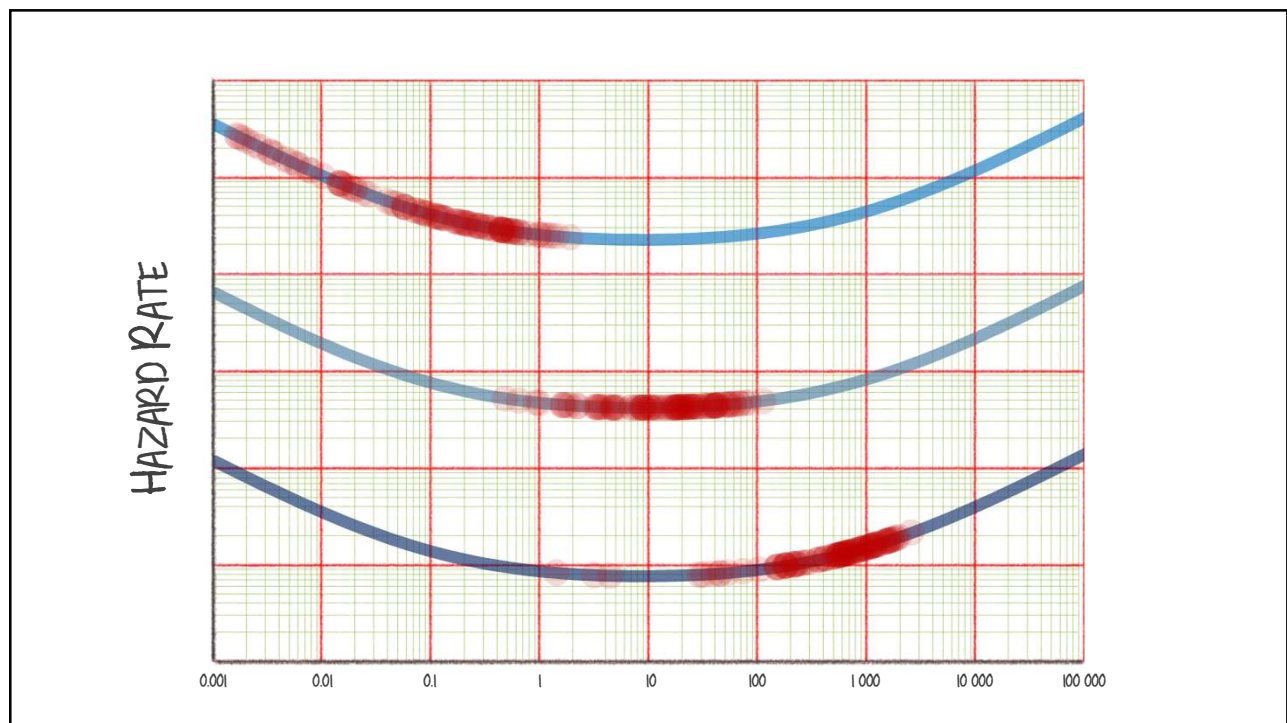
45



46

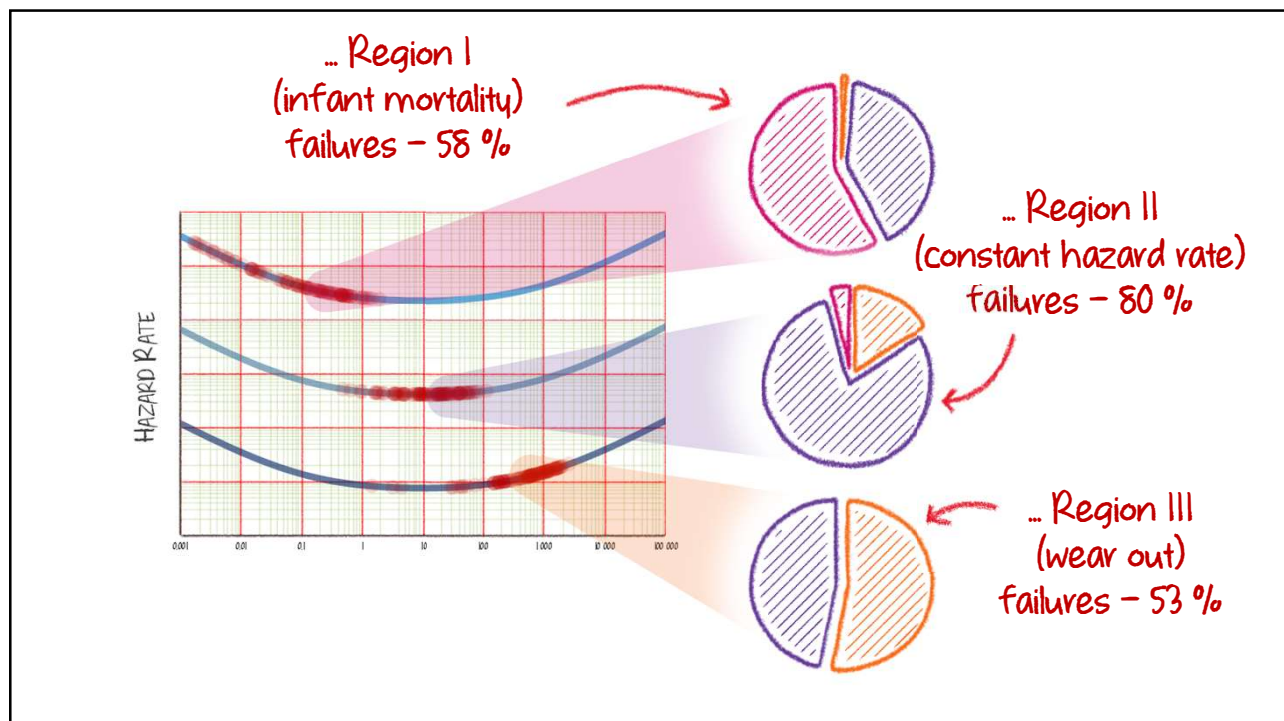
... and again

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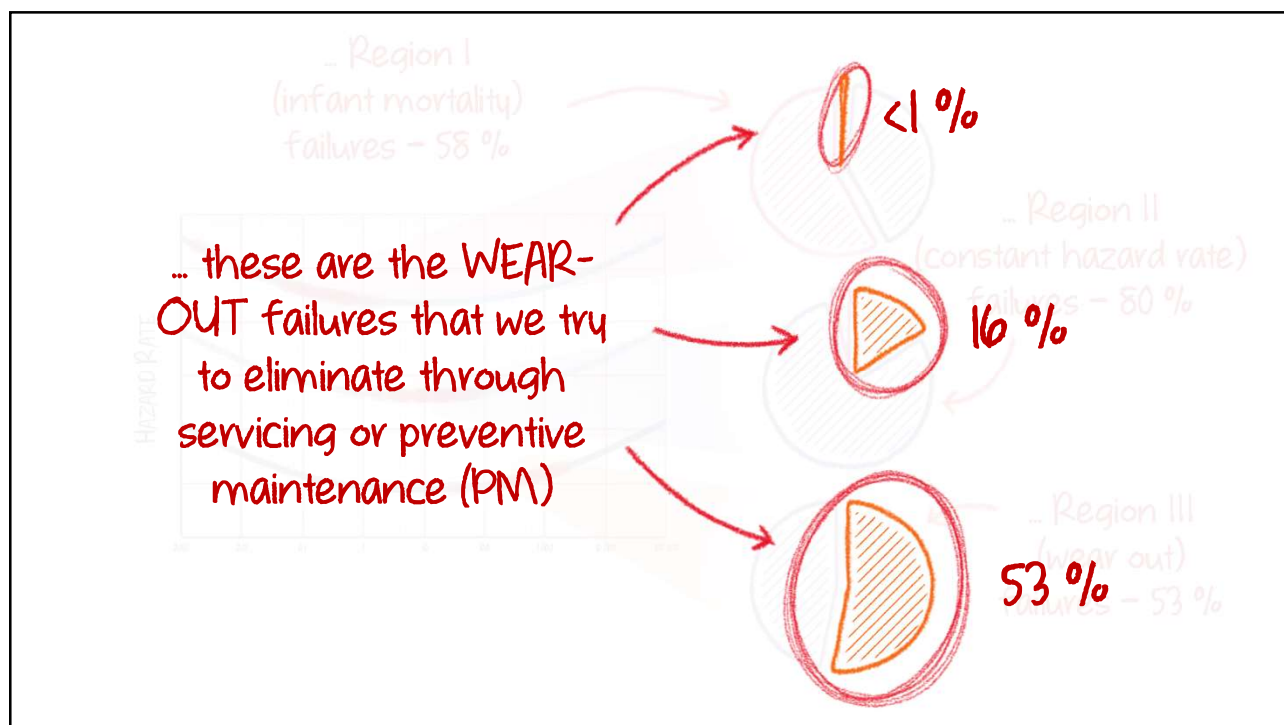


48

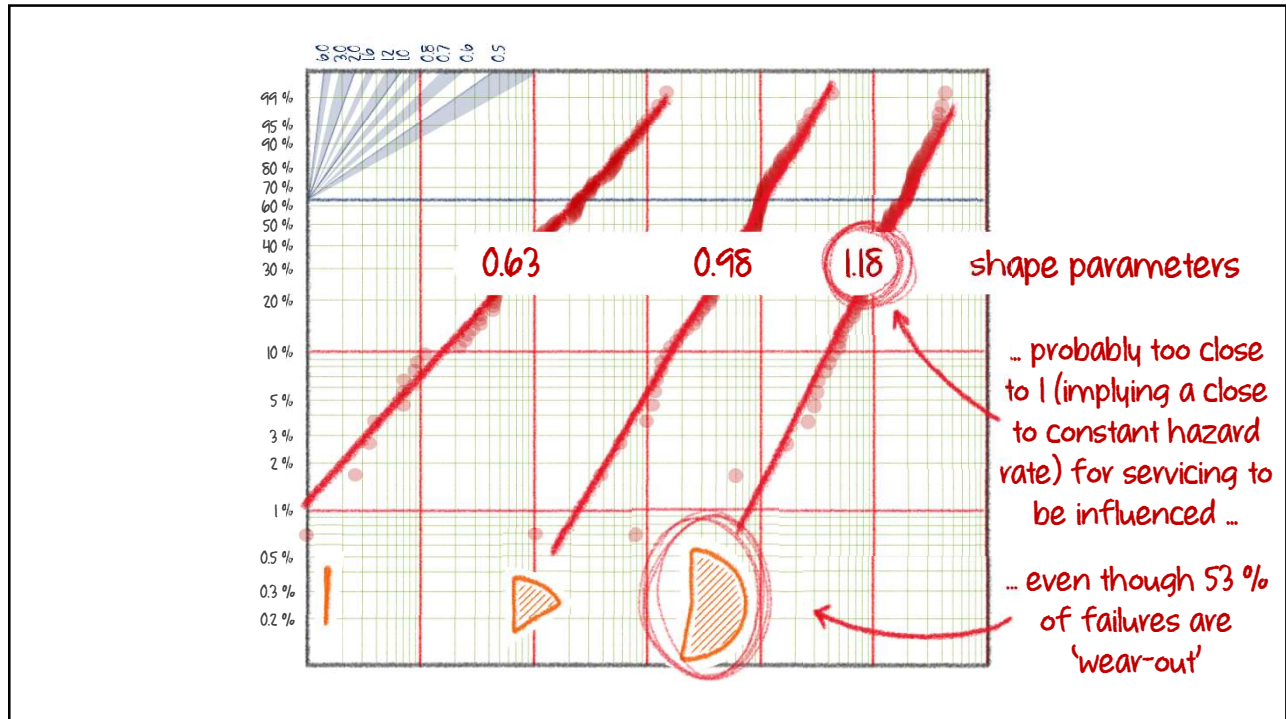




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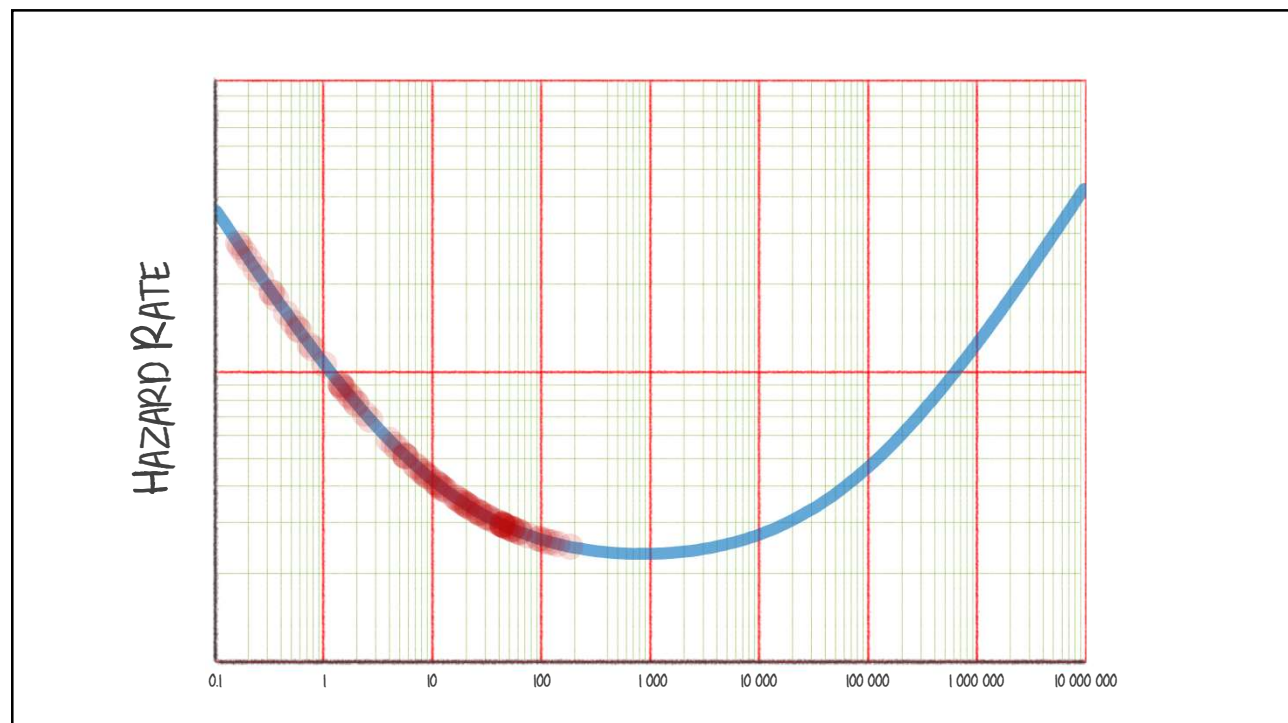
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... Weibull analysis just  
the beginning – you need  
to understand *why*  
failures are occurring

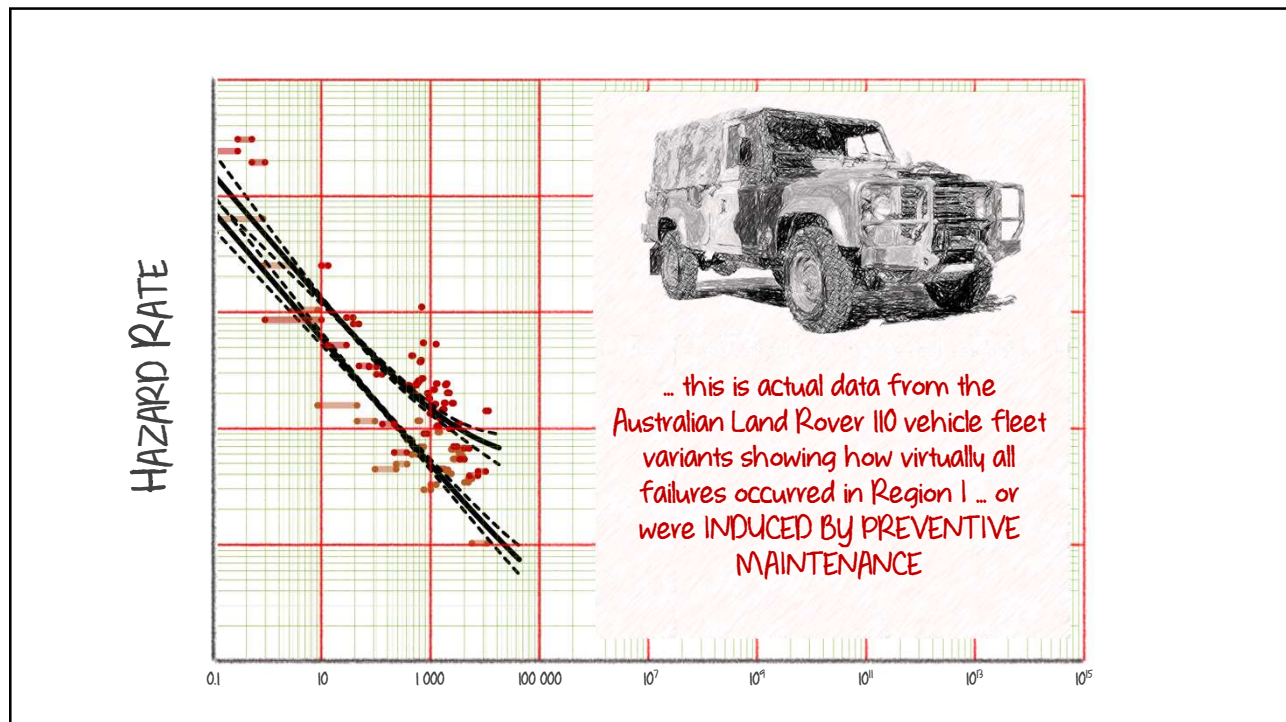
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... this is a problem if we  
are using the Weibull  
distribution for servicing or  
preventive maintenance  
(PM) intervals...

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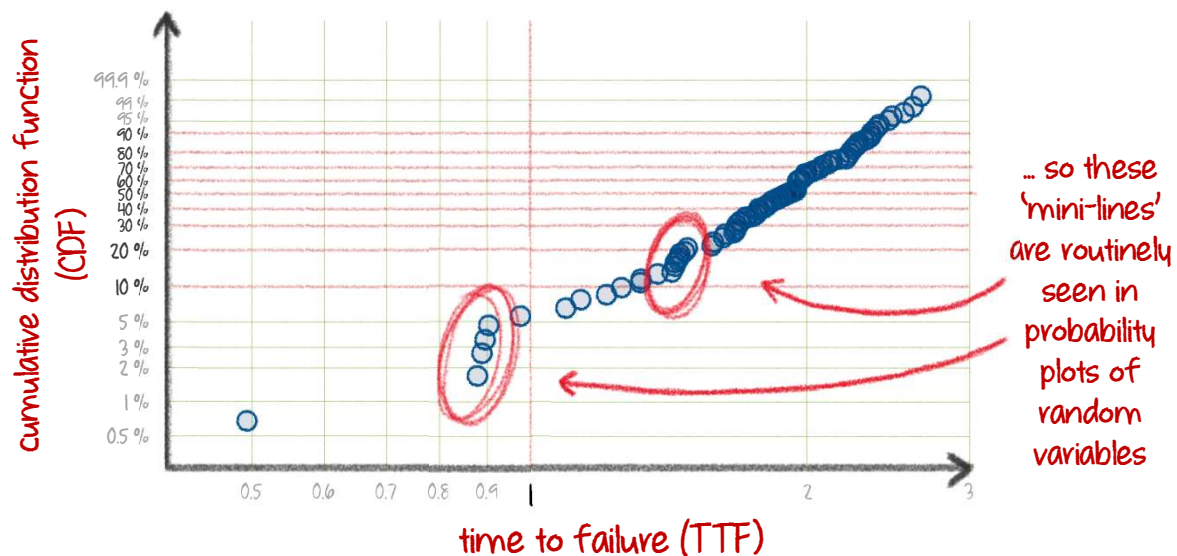
... so by doing less preventive maintenance (PM) we improved reliability by 23 %.

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... but don't try  
and see things  
that aren't there ...

57

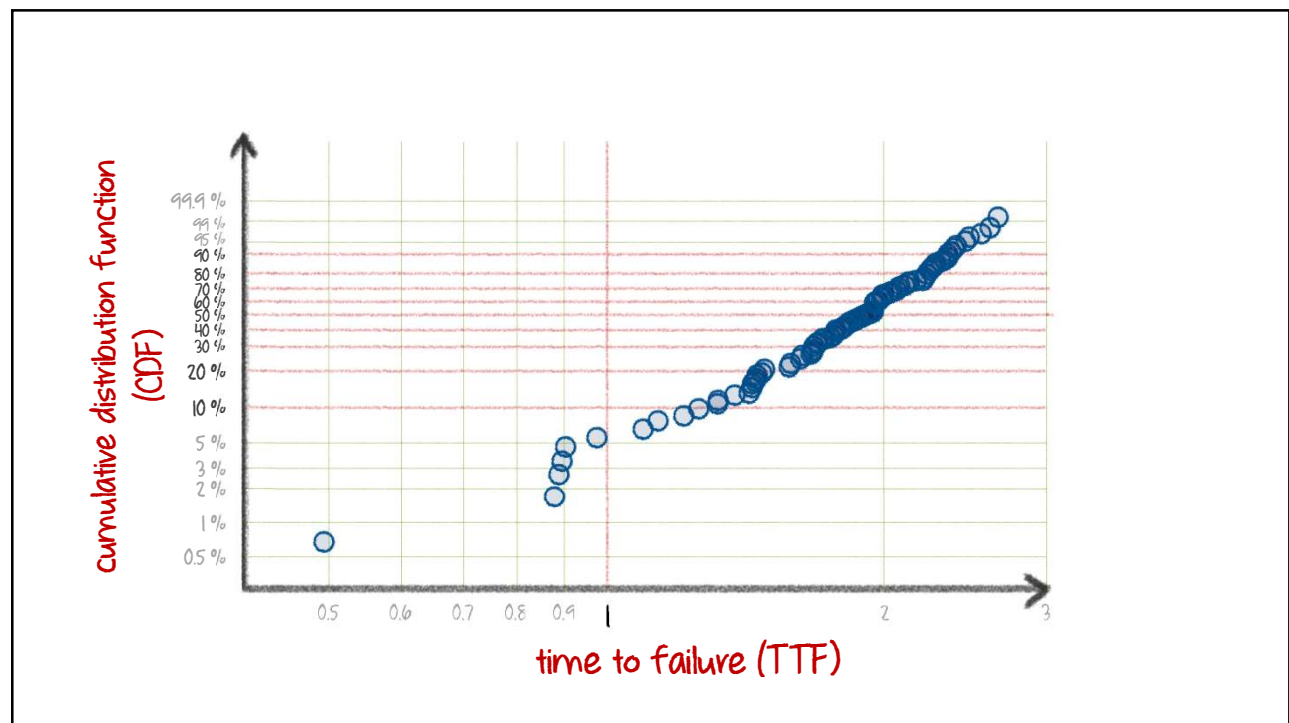
this data was generated using a Weibull distribution



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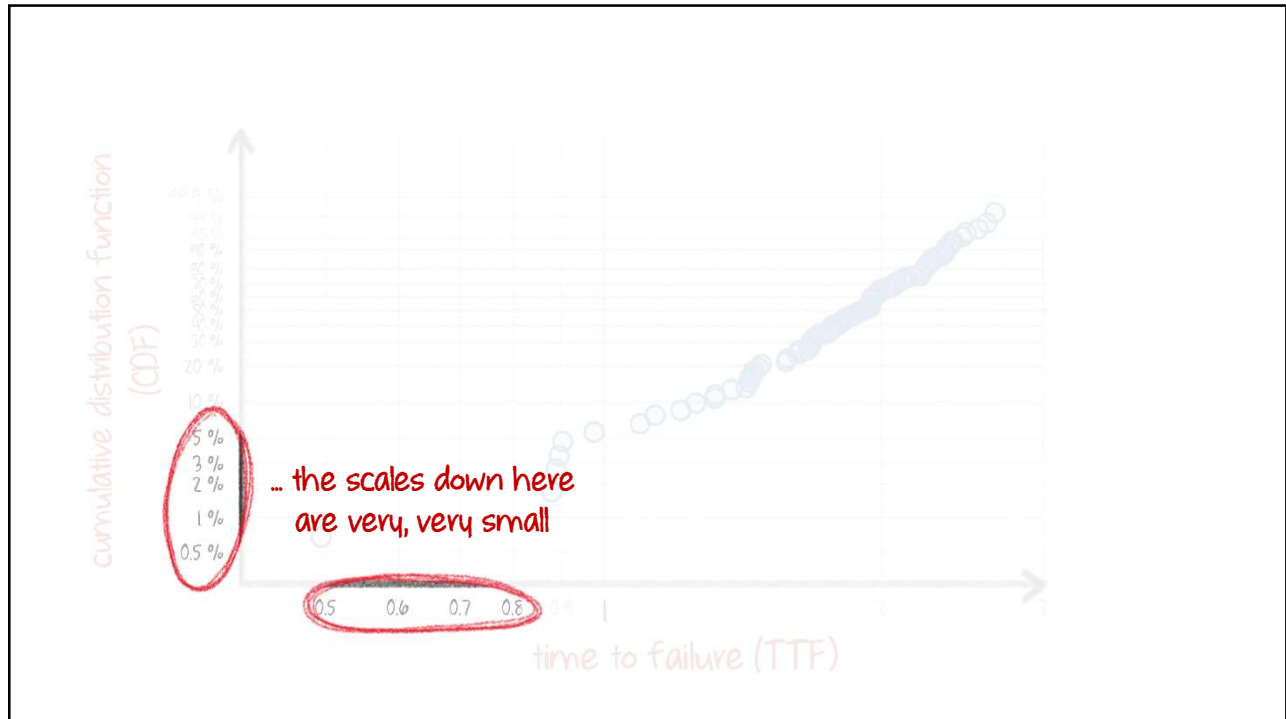
... but don't try and  
see things that aren't  
there ...  
... especially at small  
CDF values

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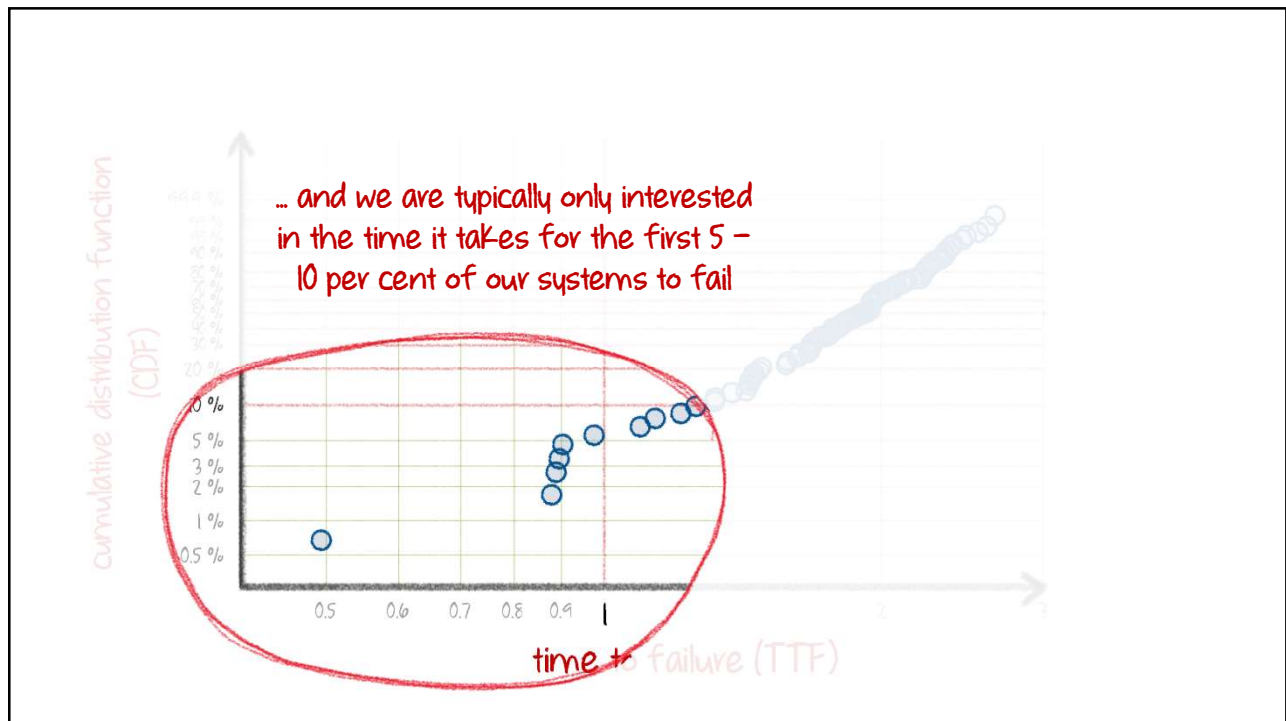


60

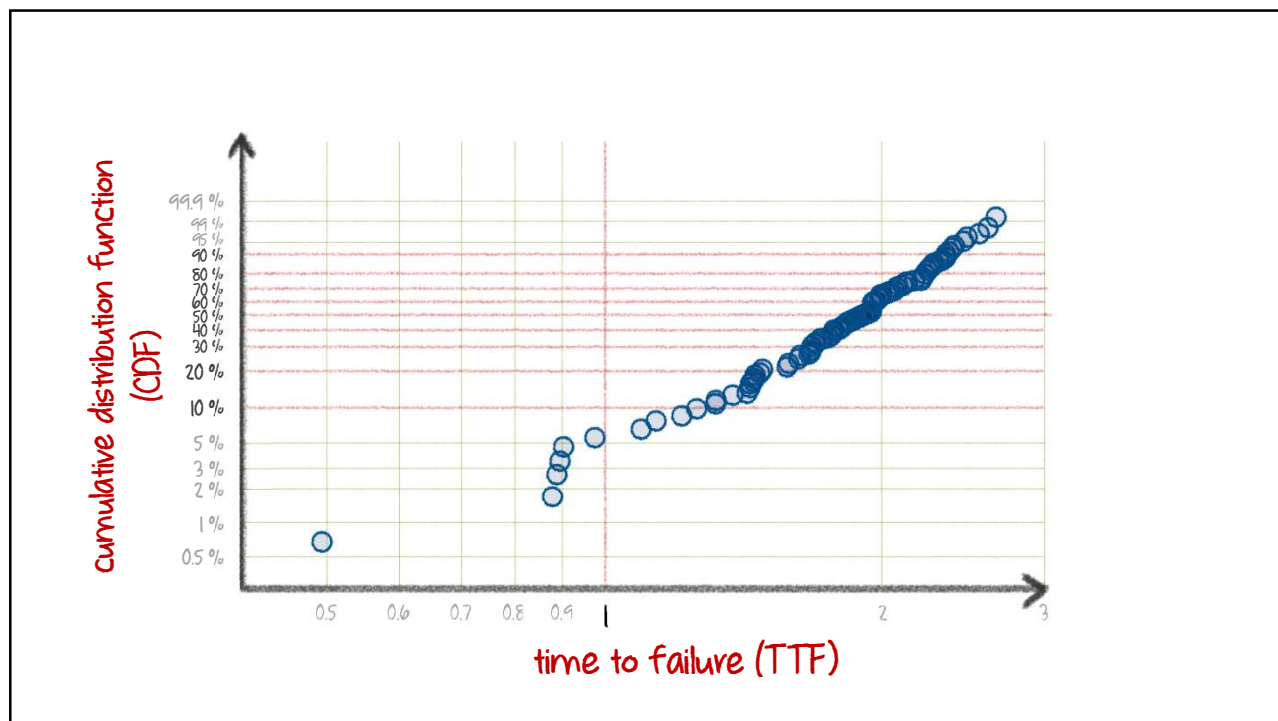




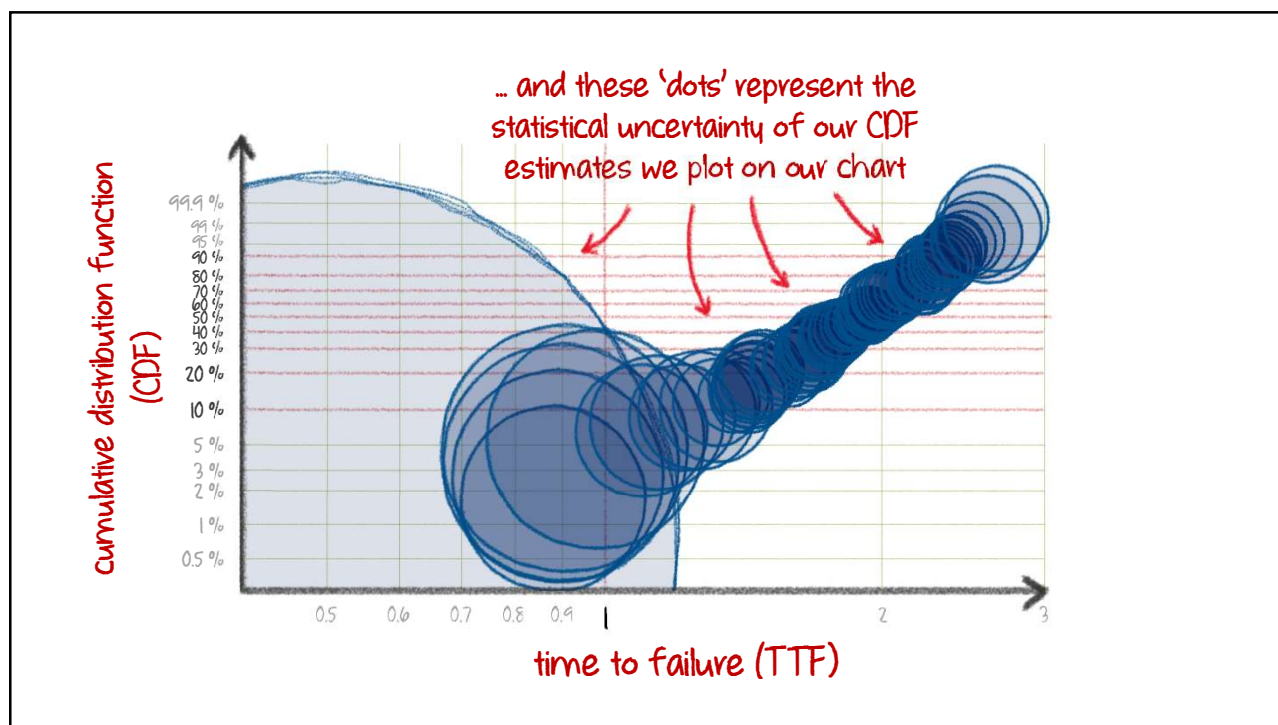
61



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64



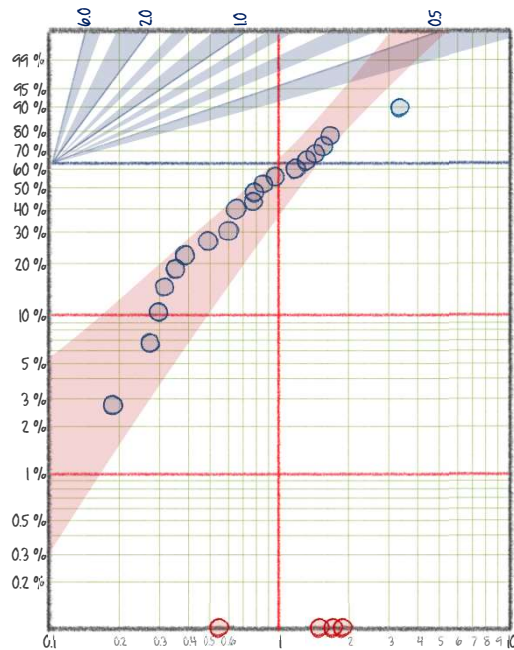
... always understand the  
uncertainty or the  
'confidence' we have on  
our results

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**... and the confidence  
on the results?**

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... software can  
calculate  
confidence  
intervals - like  
this 90 %  
confidence  
interval region



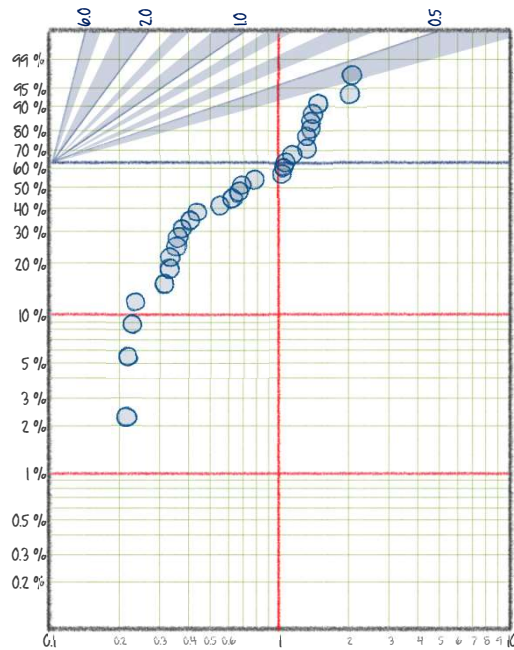
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... your confidence  
increases as you have  
more data or information

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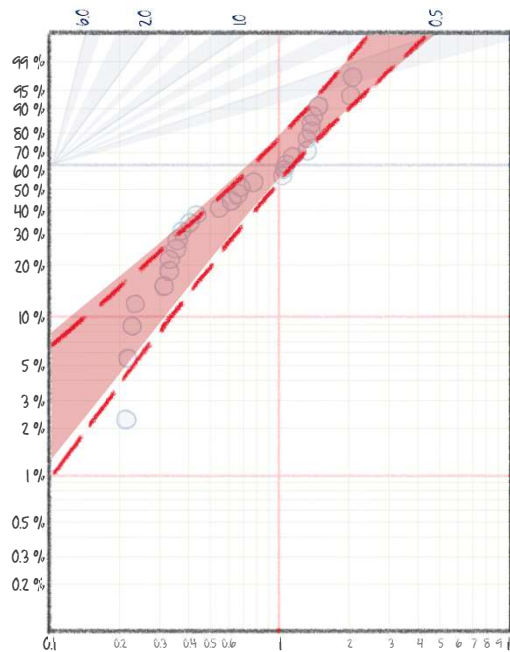
... but most  
commercial software  
makes a tonne of  
assumptions

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... red area  
represents 90 %  
confidence  
bounds based on  
the algorithms  
virtually all  
commercial  
software uses ...  
... using the 'Fisher  
Information' matrix  
approach

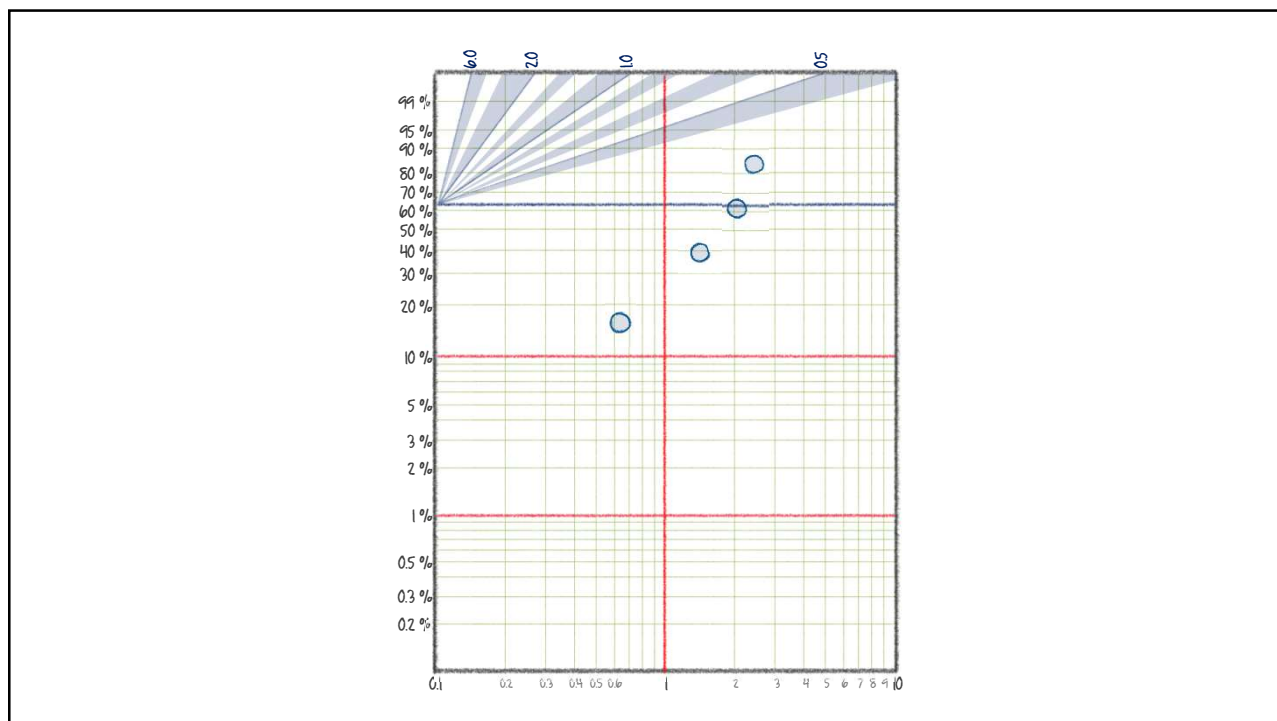


... dotted lines  
represent  
**ACTUAL**  
confidence  
bounds ...  
... based on 10 million  
Markov Chain  
Monte-Carlo  
simulations of the  
underlying likelihood  
function

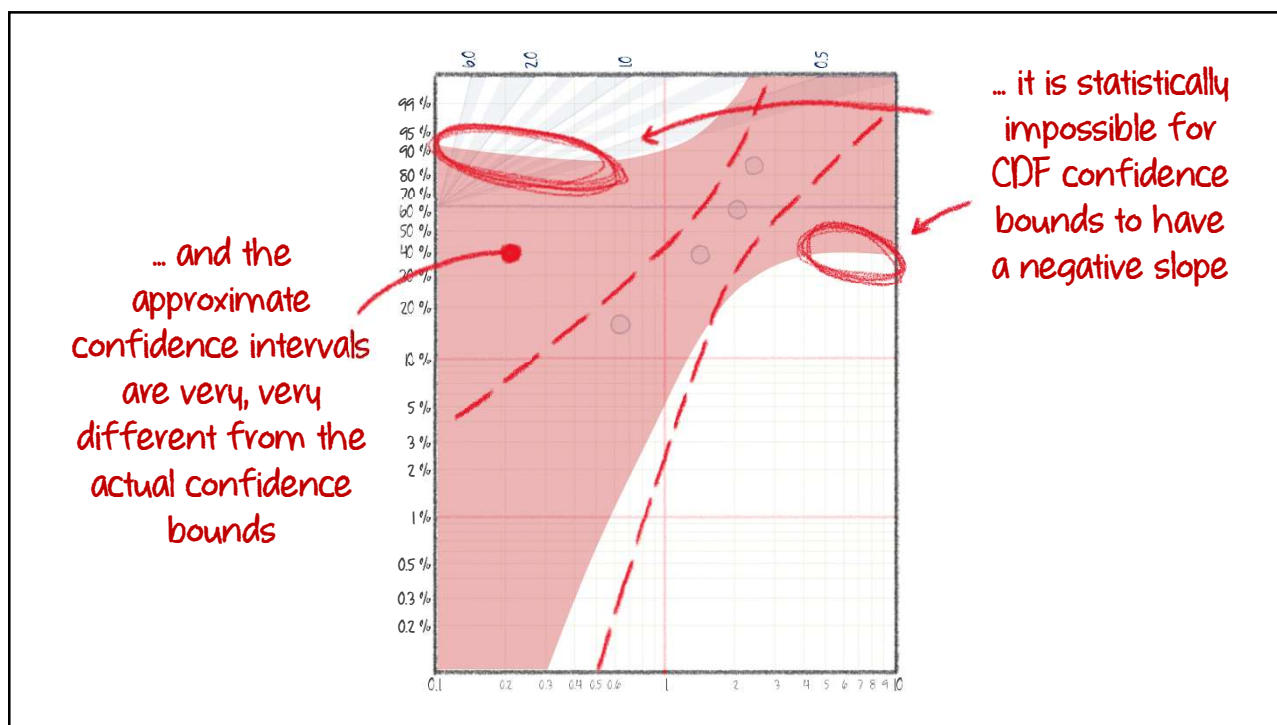
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... it gets worse for the  
less information you have

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... do you know what  
assumptions *your*  
probability plotting  
software makes?

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