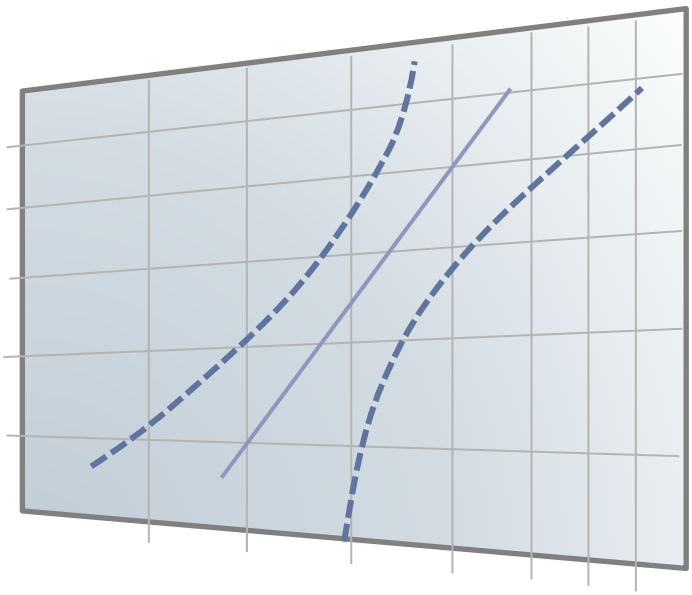
Weibull Analysis

Reliability methods



Contents

Requirement and related topics

Basics of statistics are beneficial for these descriptions. Further and related topics include: https://www.weibull.de/COM/Weibull_Analysis.pdf

Keywords:

Weibull, Weibull-distribution, density function, histogram, 3-parametric, reliability, unreliability, failure probability, failure frequency, censored data, suspensions, shape parameter, form parameter, characteristic lifetime, scale parameter, formulas, library, Arrhenius, software

Introduction

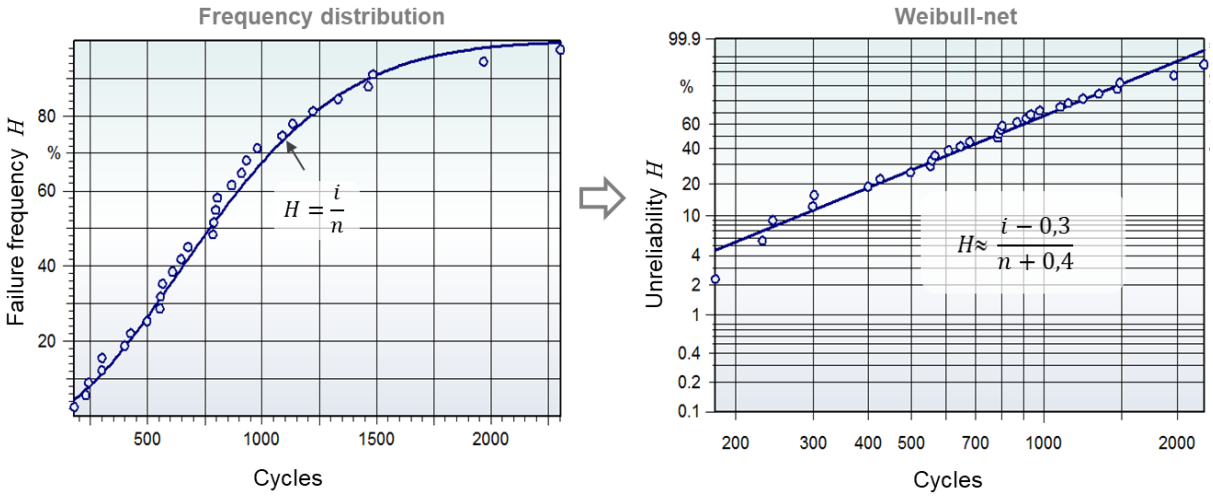
The distribution developed by the Swede Waloddi Weibull is a universal distribution that can be used to address a wide variety of problems. The Weibull distribution is the worldwide standard for service life and reliability. The so-called Weibull net shows the percentage of units that have failed or will fail after a service life (time) t.

Purpose and benefit

- Using the Weibull distribution, a statement can be made about the probability of failure at certain “running times” (operating hours, cycles, km, etc.)
- Time-dependent failure mechanisms appear as a straight line. Deviations from the straight line can be interpreted as different failure causes.
- With the help of Weibull analysis and its parameters, it can be checked whether the requirements of the specifications are met.
- The so-called acceleration factor can be determined by comparing lifetime tests with field failures
- From the gradient b of the failure line, the causes of failure can be deduced, even without analyzing the parts

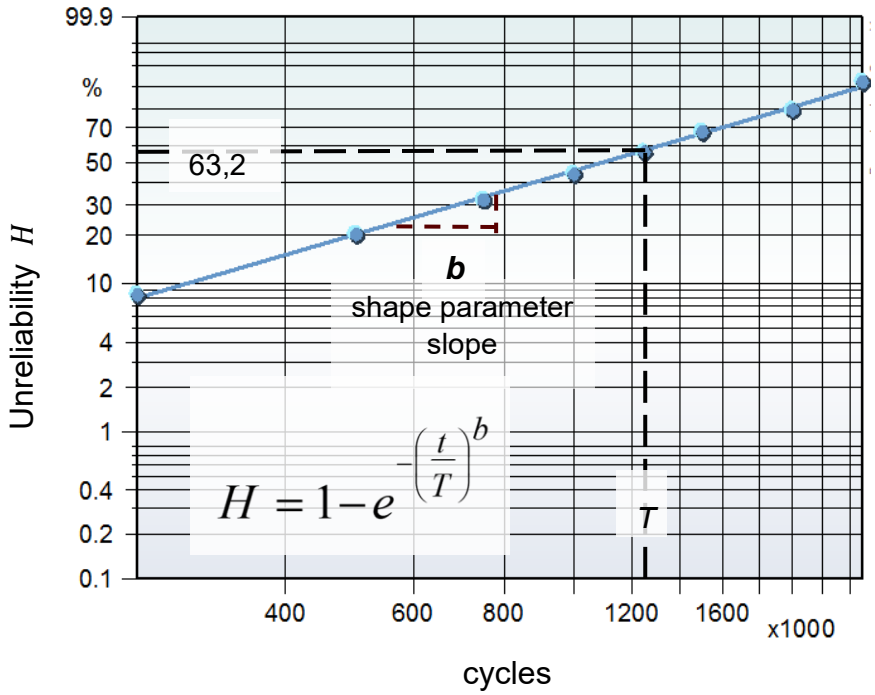
Basics

In general, the frequencies of "events" are represented in a graph by sorting them in ascending order and assigning them an order number i. In this case, this means the number of failures out of a total of n subjects. The frequency is then $H=i/n$. In the following example, the left image shows the result in a linear representation:



In the right-hand diagram, the axes are scaled according to the Weibull formula so that the curve is straight. For statistical reasons and the fact that this is always a sample, the frequency is calculated using here with $H=(i-0.3)/(n+0.4)$. The last point is then no longer at 100%, but lower. This indicates that, when observing the larger population, further failures can be expected further to the right.

Weibull net and function



H : Unreliability;
b : Form- or shape parameter (slope)
T : Characteristic lifetime (scale param.)

By scaling the x- and y-axes multiple logarithmic, a straight line in the Weibull net is ob-

tained, which is defined by the so-called characteristic lifetime T and the form parameter b (form factor).

The straight-line slope b in the logarithmic Weibull net can be interpreted as follows:

b < 1 **Early-type failures** (Premature failures)
e.g. due to production/assembly faults

b = 1 **Random failures** (Chance type failures)
there is a constant failure rate* and there is no connection to the actual life characteristic (stochastic fault) , e.g. electronic components

b > 1 **Wear-out type failures**
Failures within the design period
e.g. Ball bearings b ≈ 2, roller bearings b ≈ 1.5
corrosion, erosion b ≈ 3 – 4, rubber belt b ≈ 2.5

Different b in comparison signifies different causes of failure. The term early and late failure refers here only to the gradient regardless of the actual running times.

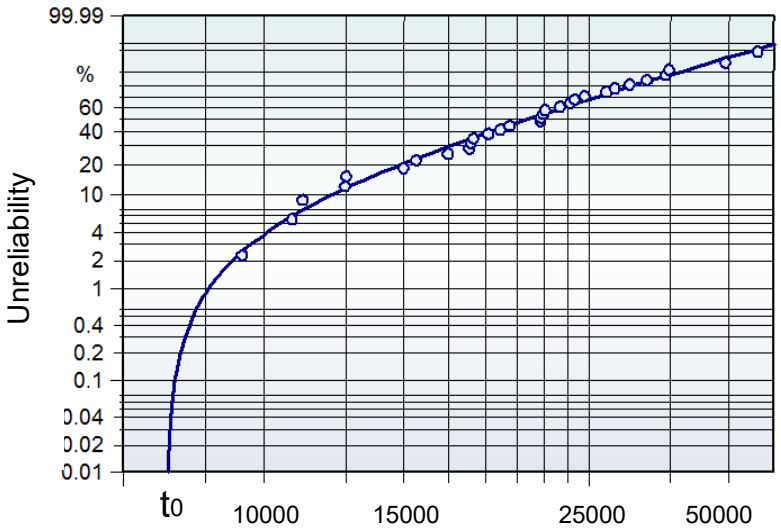
Failure-free period to

A component requires a certain period before the wear becomes so great that the function is no longer possible. This time is called a failure-free time.

There is no exact formula for determining t_o. The goal is to find via best fit the t_o iteratively.

In this case, t_o is changed as long as the best “coefficient of determination” = R^2 arises for the 3-parameter function.

$$H = 1 - e^{-\left(\frac{t - t_o}{T - t_o}\right)^b}$$



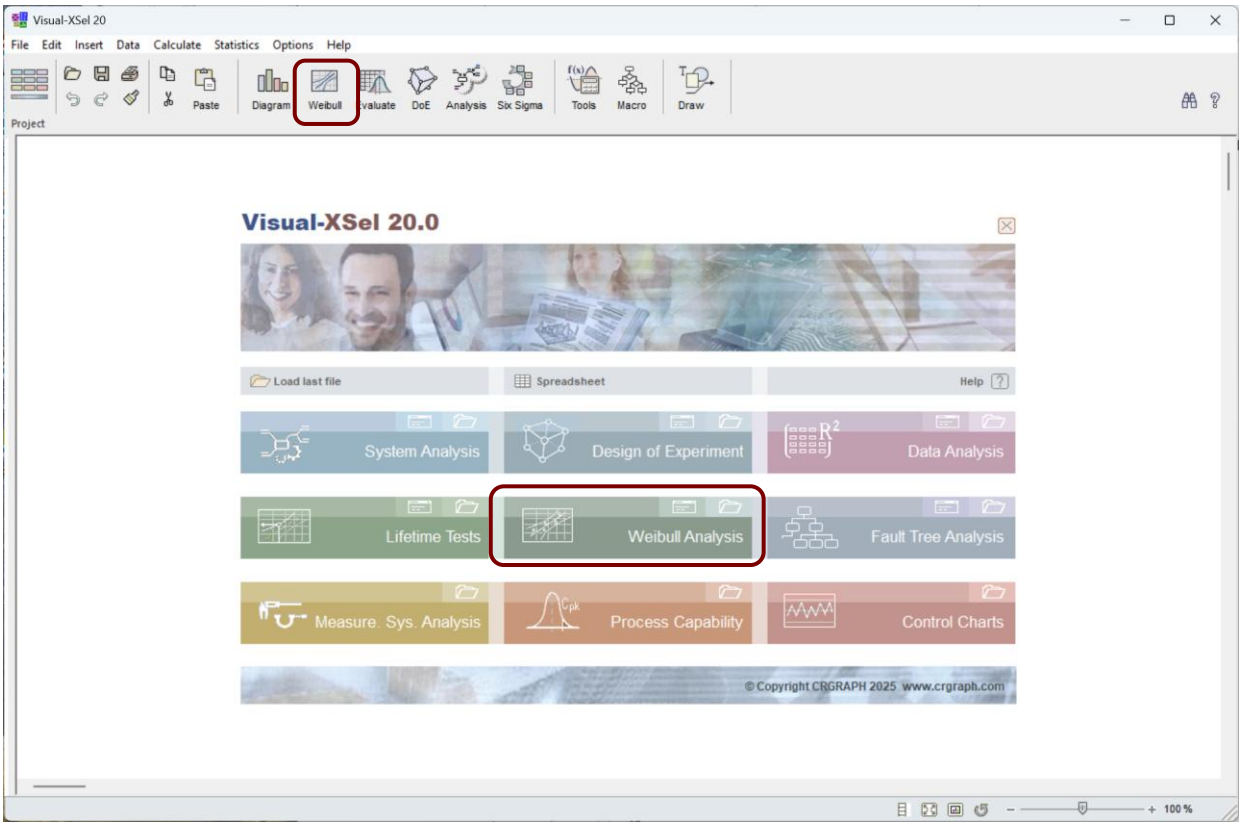
At least 10 - 15 points are needed for this method.

Note: A statistical test for a confirmation of t_o makes no sense really, but it is important if the technical context can expect a t_o

Application in Visual-XSel

www.crgraph.com

Our software Visual-XSel is a powerful tool for all important statistical quality and reliability methods. To get started, use the topic areas in the guide (see also crgraph.de/en/search-index), or the icon **Weibull**.



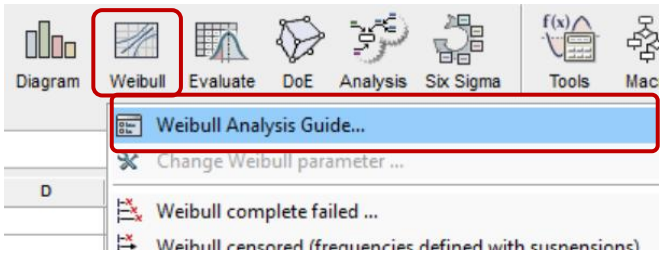
Here you can find an introduction and a short video:
crgraph.de/en/visual-xsel-software/

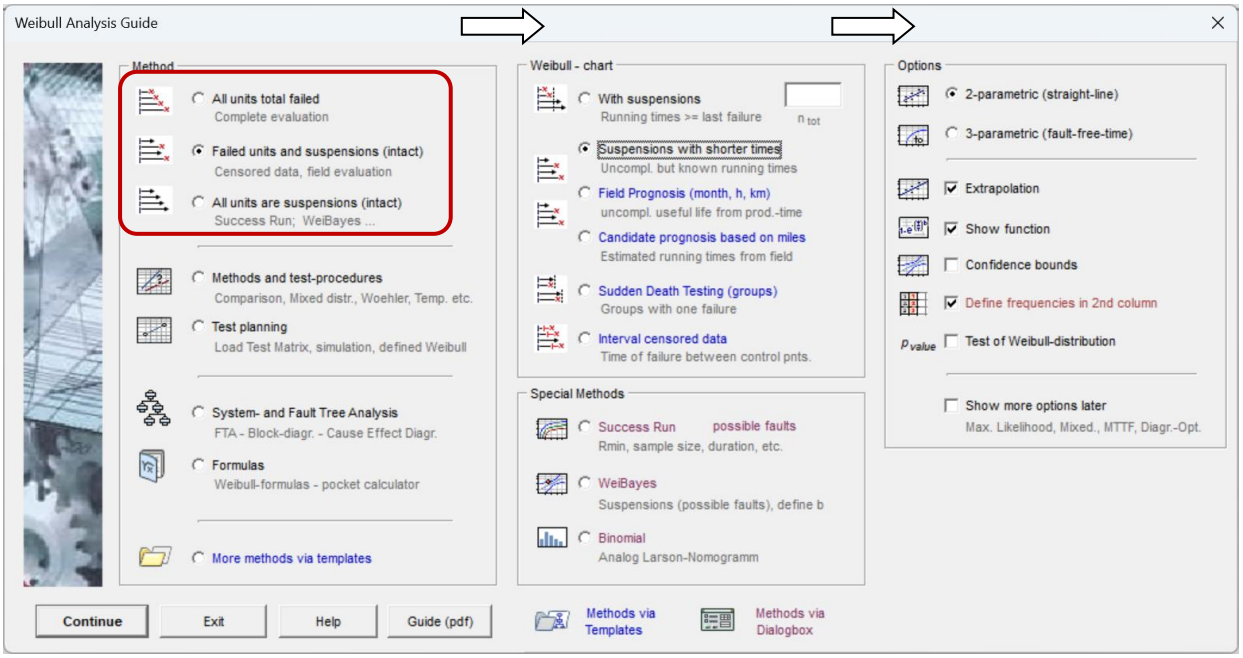
Here you can also find some introductory videos:
crgraph.de/downloads/software/Visual-XSel_Basis_Functions.mp4
crgraph.de/downloads/software/Visual-XSel_Methods.mp4

It is not for nothing that this software is used in many well-known companies:
References

The following description is a guide and introduction to the topic shown

The Weibull Analysis Guide allows for quick selection of graphs and methods.
Depending on the wanted selection, the dialog box expands to include additional columns.

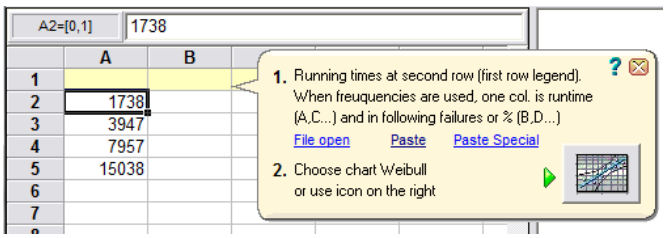




Methods marked in blue are provided via templates. Templates are example files with macros. These can also be customized and extended. Methods marked in purple open a separate dialog box. Data is entered here and not in the table.

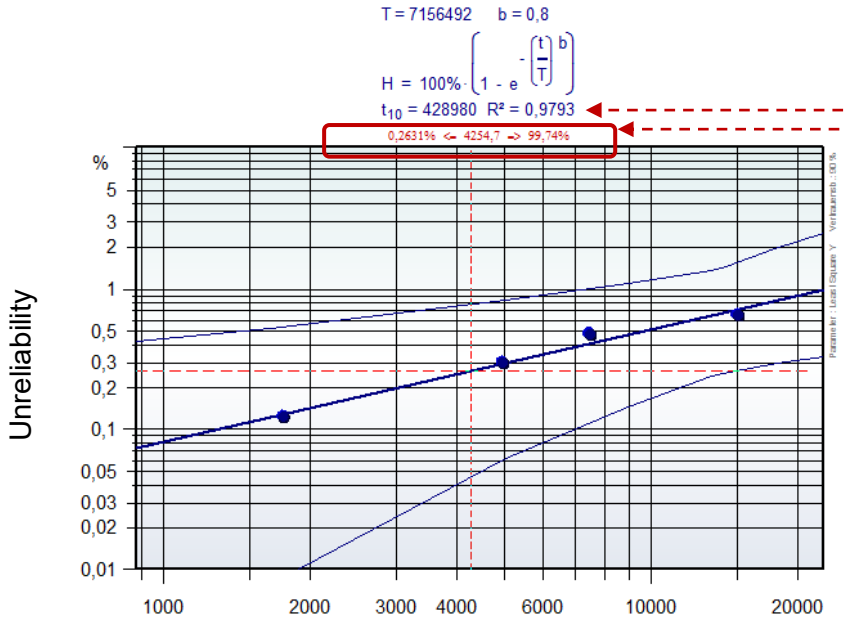
Weibull from data

In case of the first two options under Methods (failure data), the data must be defined in the table and can be insert via the link “Past” if data is available in the clipboard.



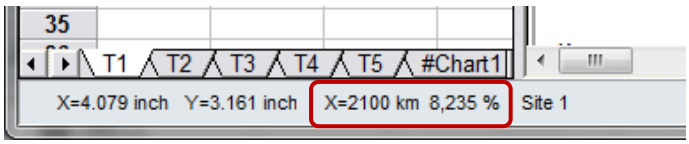
If there are failures and intact units (suspensions), the frequencies must be defined in the second column B.

After this selection it is recommended to follow the bubble-speeches step by step (see right example). After a click to the Weibull icon one can define titles and axis names.



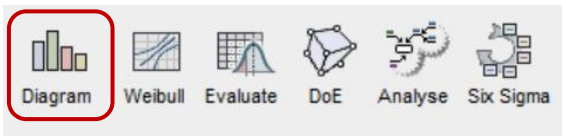
If one moves with the mouse over the chart a red-cross-line appears. The precondition for the cross-line is that no element is selected. In the middle (the red text on the top of the diagram) the running time is shown. For this time the unreliability (failed units) on the left is the result of the Weibull-function. The complementary value of this, the reliability (survivors), is represented on the right.

Another possibility to get the unreliability is to have a look where the mouse point is positioned. The exact value is shown in the status bar on the left bottom.

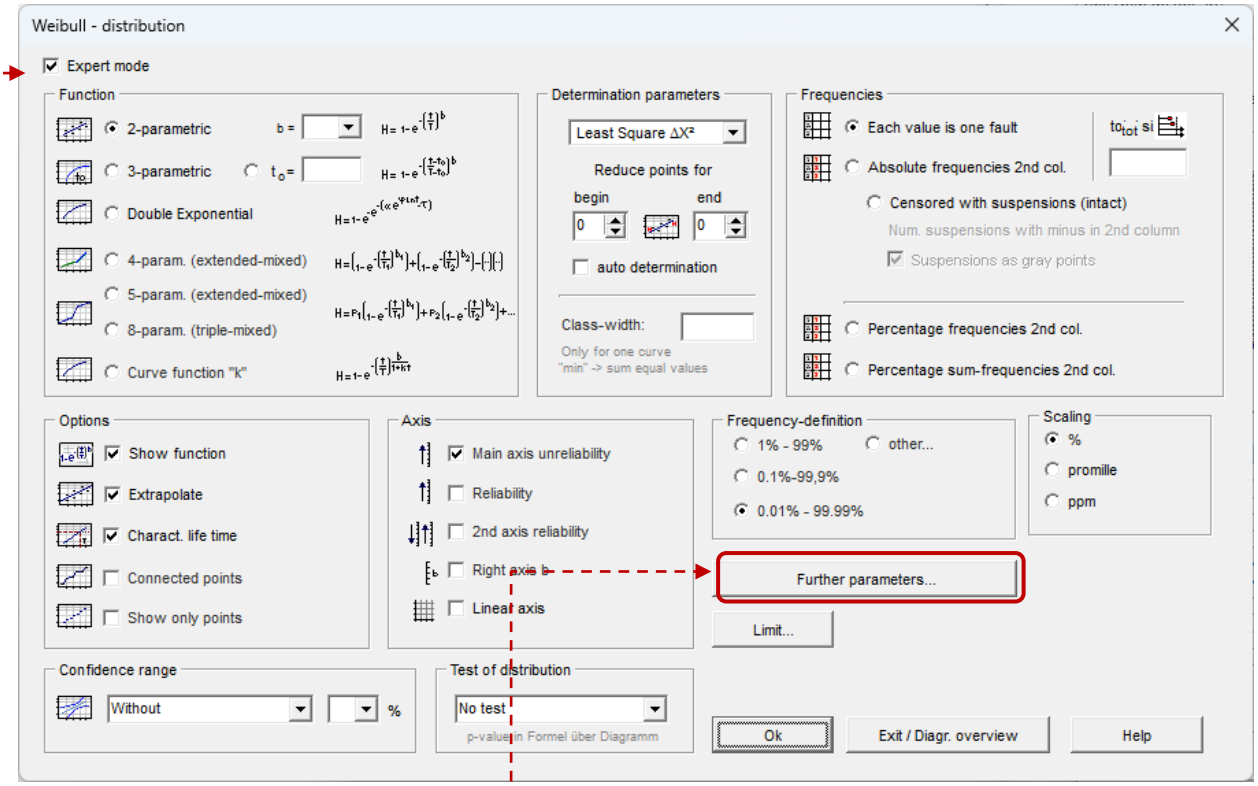


If the option “Show function” is chosen, the Weibull formula is represented above the diagram. In this formula the Weibull-Parameter can be interpreted. Furthermore, the often used t_{10} (B_{10}) – value is available. This value represents the running time, when 10% of the total size have failed. Beside this the so-called R^2 (coefficient of determination) shows the goodness of fit. Normally it is recommended to have at least R^2=0,95. If R^2 < 95, it is recommended to use another Weibull-functions, for example the 3-paramtric Weibull. But for that function more than 4 points are needed.

For using other Weibull-parameters, click to the diagram icon. For new input of data or changing data use the Spreadsheet icon.



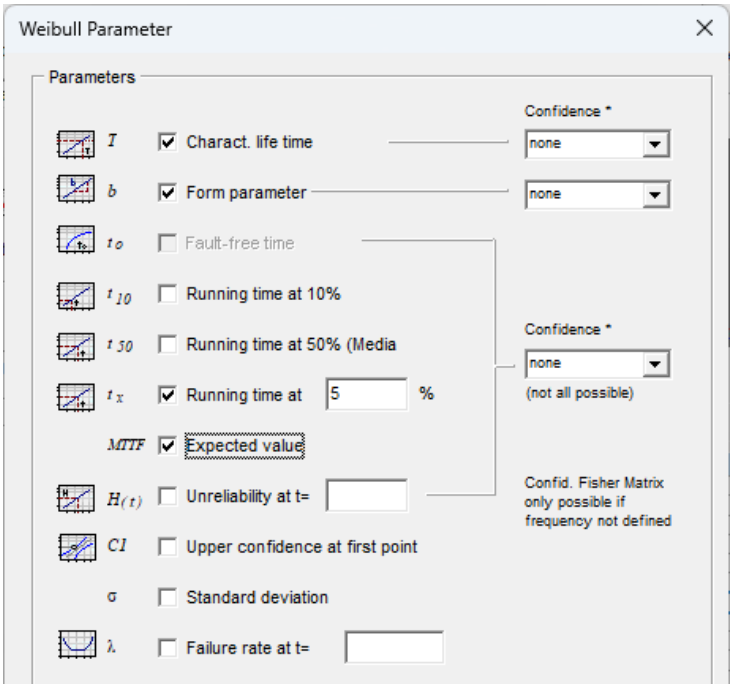
Beside the standard options of the Weibull characteristics, it is possible to define some additional parameters. For this use the button “Further parameter”.



To reduce the area of full options, deactivate the Expert mode.

Beside the standard options of the Weibull characteristics, it is possible to define some additional parameters. For this use the button “Further parameter”.

The results will be shown right beside the Weibull chart

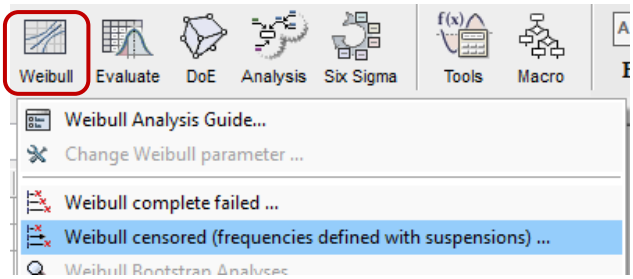


Censored data

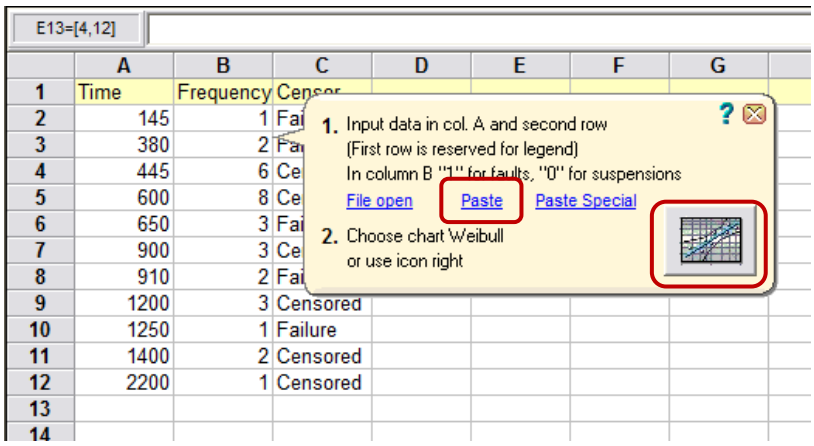
In a life-time test it is often the case that only some samples fail. The other samples are not tested to the end, may be because of prematurely removing from the test or because of other reasons (defect of the test-rig, etc.). The table on the right shows a typical situation.

	A	B	C
1	Time	Frequency	Censor
2	145	1	Failure
3	380	2	Failure
4	445	6	Censored
5	600	8	Censored
6	650	3	Failure
7	900	3	Censored
8	910	2	Failure
9	1200	3	Censored
10	1250	1	Failure
11	1400	2	Censored
12	2200	1	Censored
13			

In a new file select icon Weibull and Weibull censored, or the Weibull guide as descripted before.



Add the appropriate data from the Clipboard, or load a file. In the case that the data start not in the first row use the dialog Paste special and use the option “Row higher”. Column C must include the word “censored” or “suspension”, to define the parts, which are not failed. If the column B – Frequency is not available, one sample for each Time is expected.

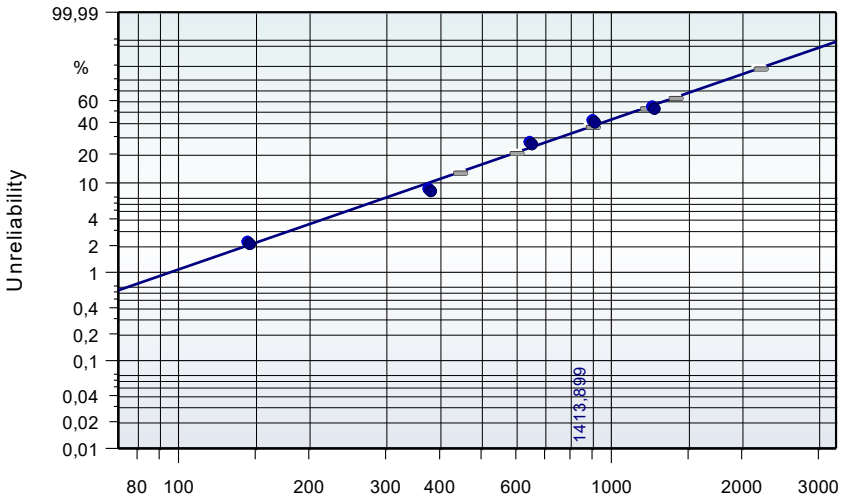


After that, the icon Weibull must be selected.

In the Weibull-diagram the failed samples are shown with thick blue points, the suspensions with a gray point. Thus, is shown where are the last running times of the non-defective parts.

Those suspensions reduce the unreliability either by the Least-Square- or the Maximum-Likelihood method. The first method is the default option.

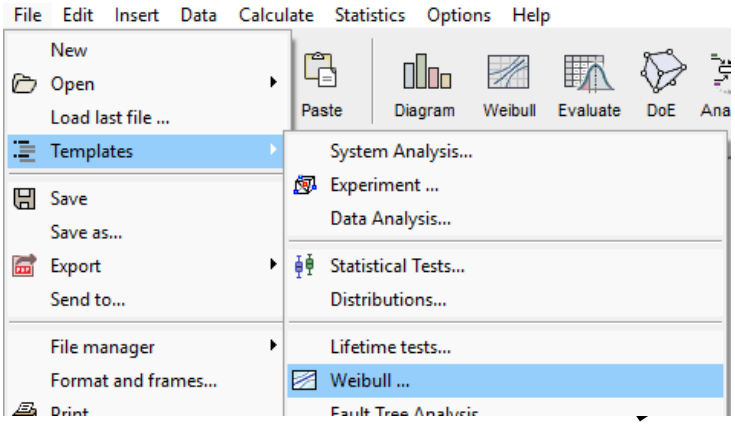
To change this, use the menu Diagram/ Diagram-type… and then “Determination parameters”

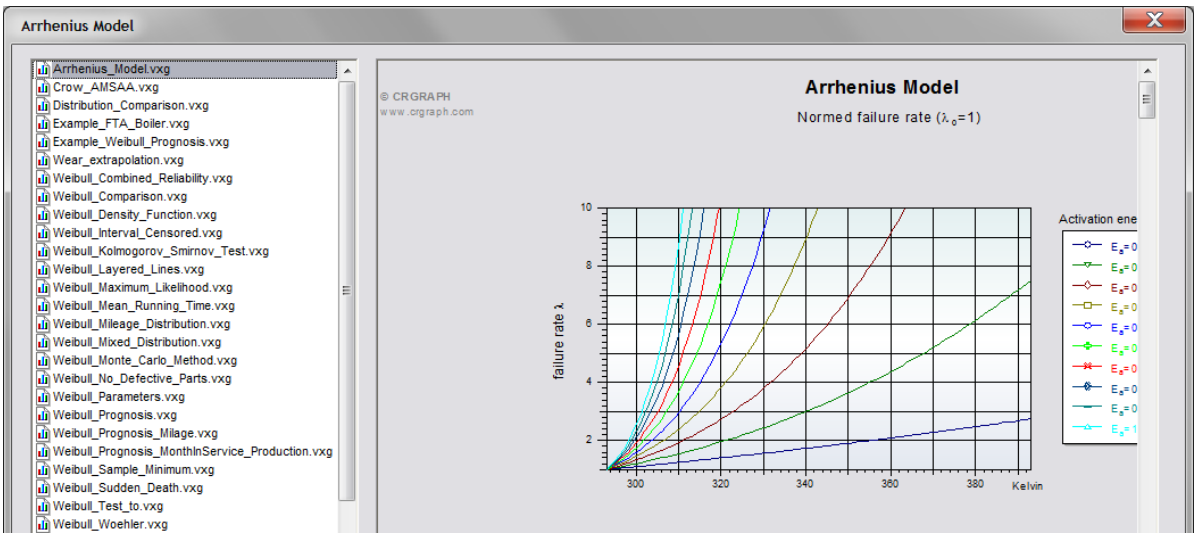


Templates

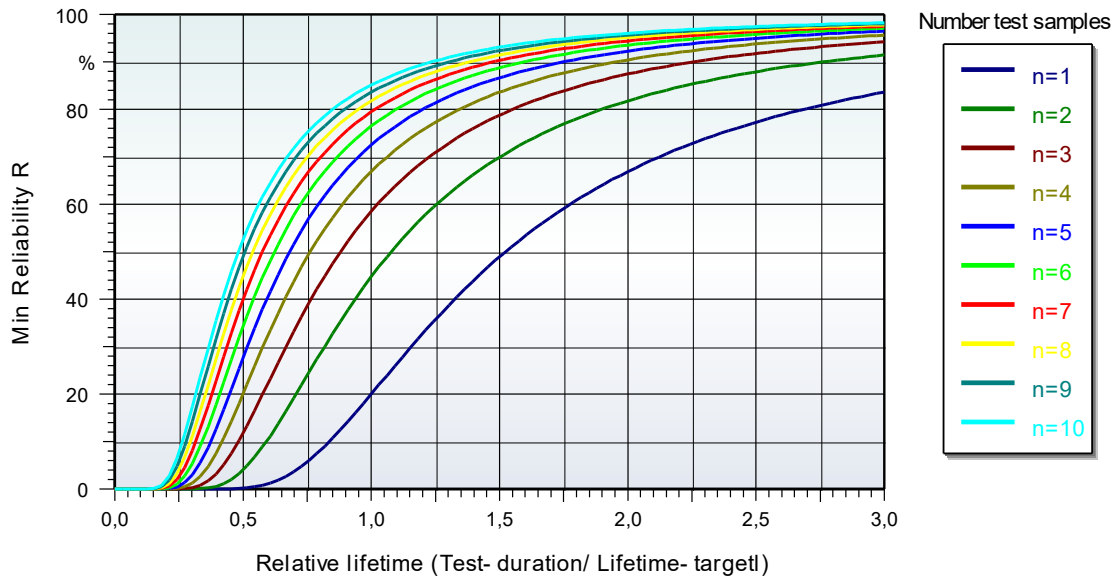
Besides the direct representation of the Weibull chart, there are some more methods, that are available as templates including examples.

Alternatively, to access via the main guide the templates can be opened through the menu *File/Templates/05_Weibull*.
Some of these are available only in this way.





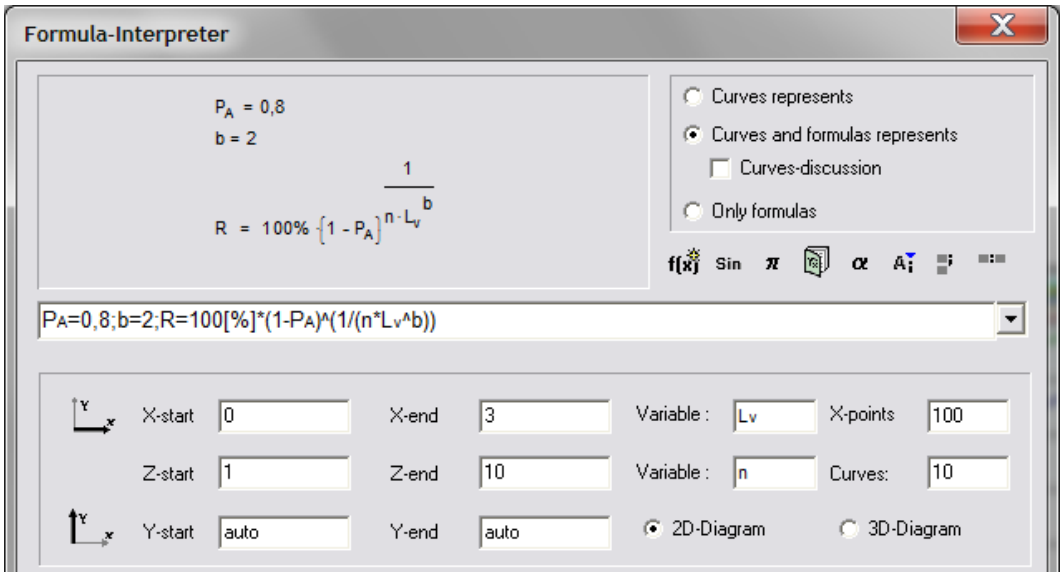
In some templates no data is needed. For example, in the template *LvRb20.vxgn* only a formula is represented (see ..\Templates\04_Test_Planning). This is about the determination of a minimum guaranteed reliability in testing with no failures (success run).



Formula interpreter

The parameters of the formula can be changed by a double click to the formula in the top of the diagram.

Alternatively, the formula can be opened through the menu point *Tools/Formula*



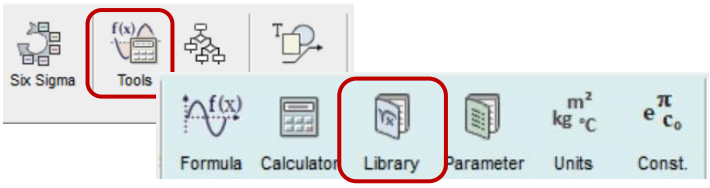
The templates *Weibull_Density_Function.vxgn* or *Arrhenius_Model.vxgn* are also simple formula charts.

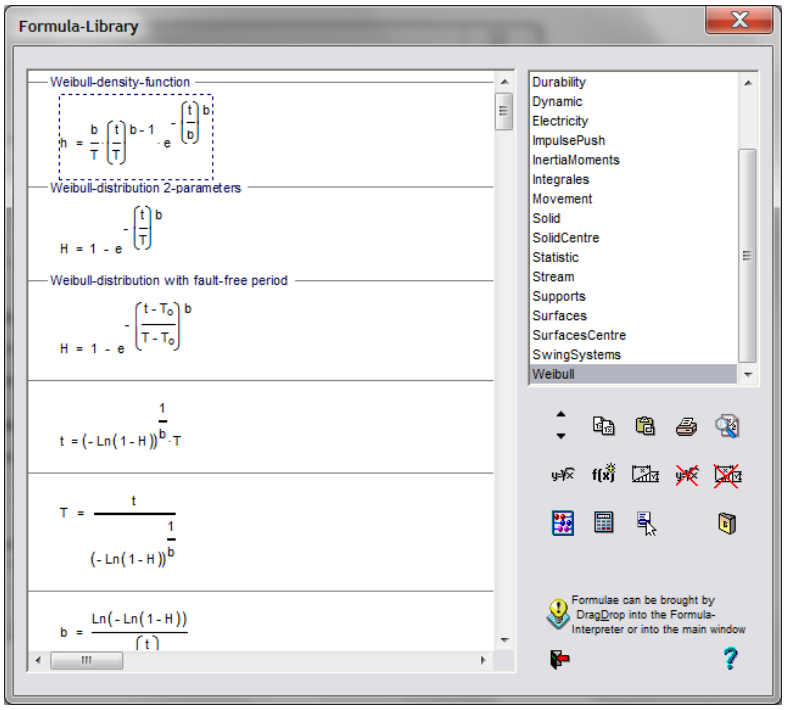
New templates can be created or existing can be modified. Of course, new or modified templates must be saved under a different name, otherwise later updates of Visual-XSel overwrite this possibly again.

Weibull Formulas Library

This opens the formula library. With these formulas one can calculate or via Drag & Drop one can use this in the main-window graphically. Click to the wanted formula and use the right mouse button.

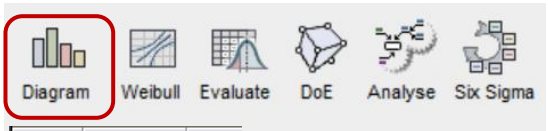
The formula library can be opened also from the main-window.



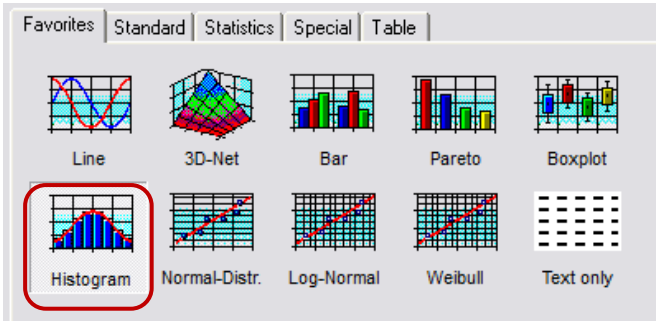


Weibull density function (Histogram)

By default, the Weibull distribution is used as the probability net. In some cases one wants to show, however, where is the center of failures. In the previous section, it was mentioned that there is a template for the density function. This is purely a functional representation (formula) with known parameters. From the data, one can also create a density-diagram, in this case a histogram. For an example, start Visual-XSel again, or select the menu item *File / New*. Go to the Spreadsheet (left area). Enter the running-times, shown on the right, beginning from the second row.

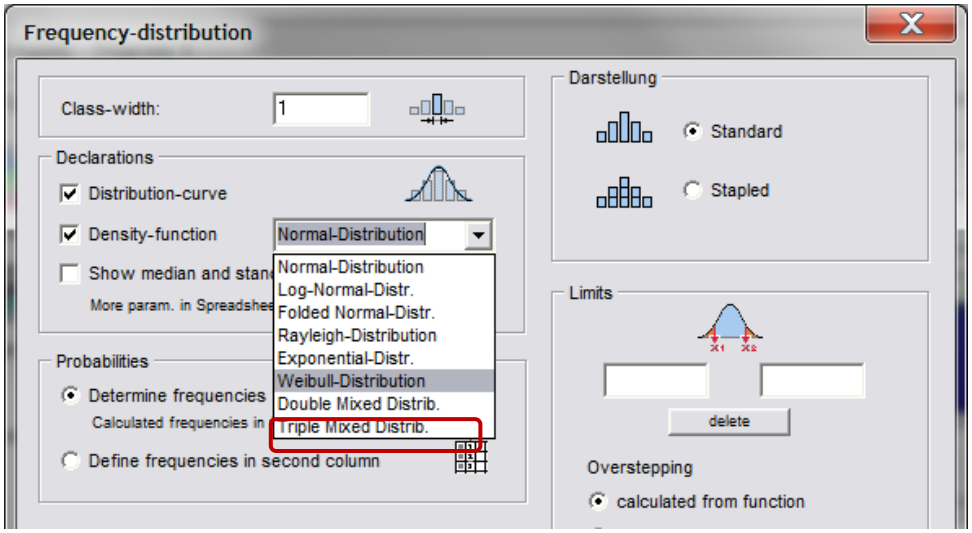


	A
1	
2	1,1
3	1,4
4	1,8
5	2,2
6	2,3
7	2,5
8	3,3
9	3,7
10	5,2
11	7,2
12	



Select the entire column A and the icon *Diagram* and then select *Histogram* (hint: do not use the icon *Weibull* in this case).

Use Weibull-Distribution. Other parameters can be



Optionally select *Distribution test*