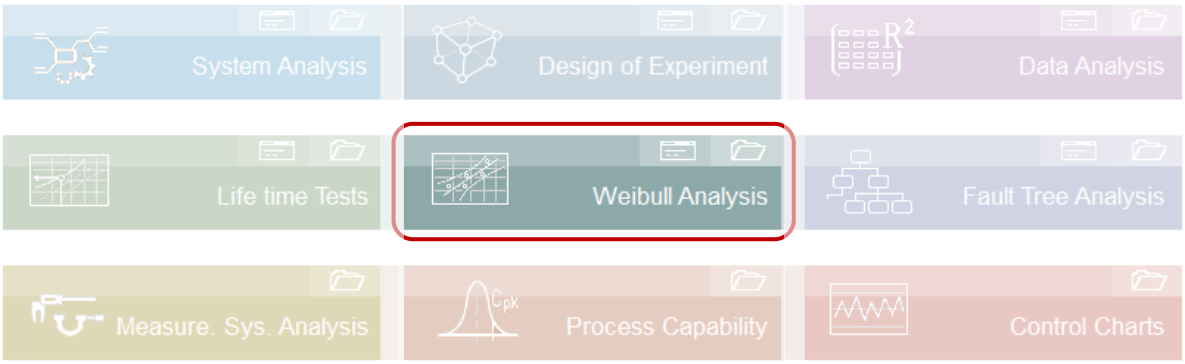
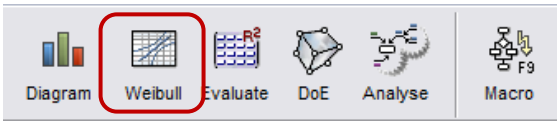
Visual-XSel Software-Guide for Weibull

The Weibull analysis shows the failure frequencies or the unreliability of parts and components in the Weibull-net and interprets them. Basics and more details can be found at www.weibull.de/COM/Weibull.pdf.

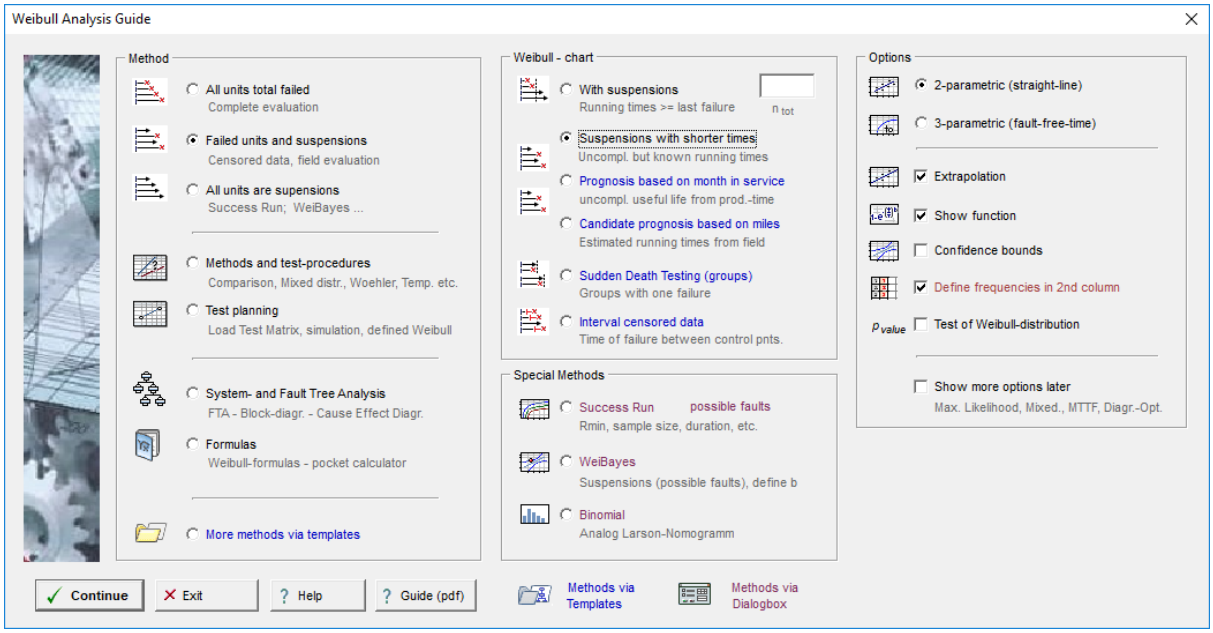
Here, the application of Weibull is shown in Visual-XSel by using the most important issues. When you first join the program, it is recommended to use always the main guide (select the menu item File / New if the guide is not visible):



..or use the icon Weibull above



At first time using Weibull a dialog appears for the most important methods:

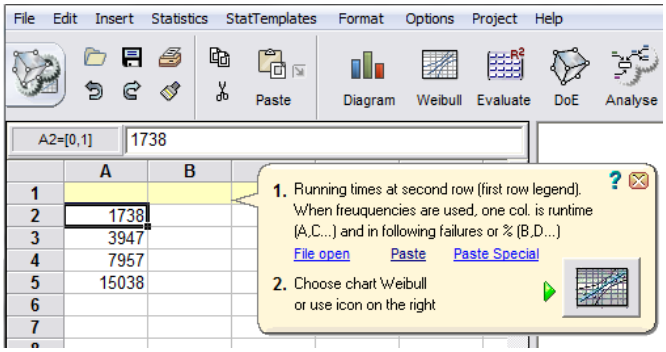


Select the analysis or method and consider the meaning of the icons.

The Guide of Weibull allows a quick selection of charts and methods. Some of them are used as templates with examples. These are marked as blue text. The following sections are included in the Weibull-Guide:

Weibull-Net Data

Here different types of data and their associated methods can be chosen for the Weibull-net. Depending on the origin of the data und the meaning of the other columns, various options can be selected on the right.
After this selection it is recommended to follow the bubble-speeches step by step (see right example).



Weibull-Specification

To define a Weibull-Net without concrete data, this option needs to be selected. It is possible to define a straight-line or an empty net.

Methods

Under the section Methods templates can be used. These templates include examples and the algorithm is built via the flow-chart macro. One of the most important methods is the Mixed Distribution. In principle to use the templates it is advantageous to have data in the clipboard. Therefore copy your data before using the templates.

Life Time Tests

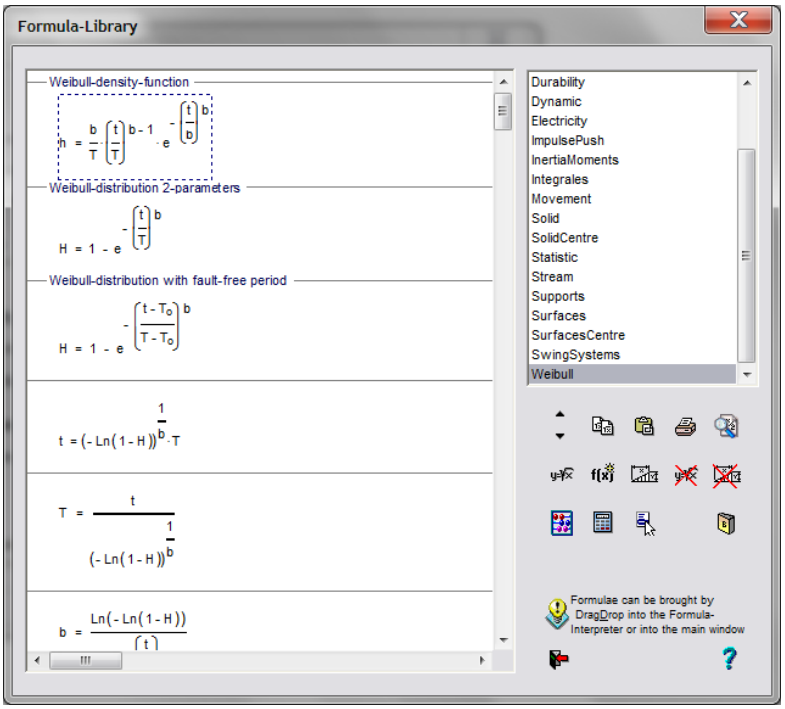
Here it is possible to plan experiments, in terms of reliability requirement, the test duration, or the required number of samples. Here various case studies can be calculated. This method is also well known under “Success Run”. Furthermore, unexpected failures during the test can be regarded also.
WeiBayes allows it to create a Weibull-slope with few data. And it is possible to have intact parts combined with failures.

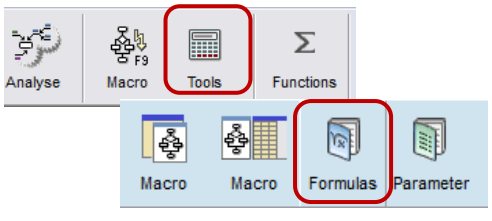
System Reliability

This allows a direct using of Reliability-Block diagrams to calculate a reliability for systems with a lot of components. Today more and more the Fault-Tree-Analysis is used to achieve the same task.

Weibull Formulas

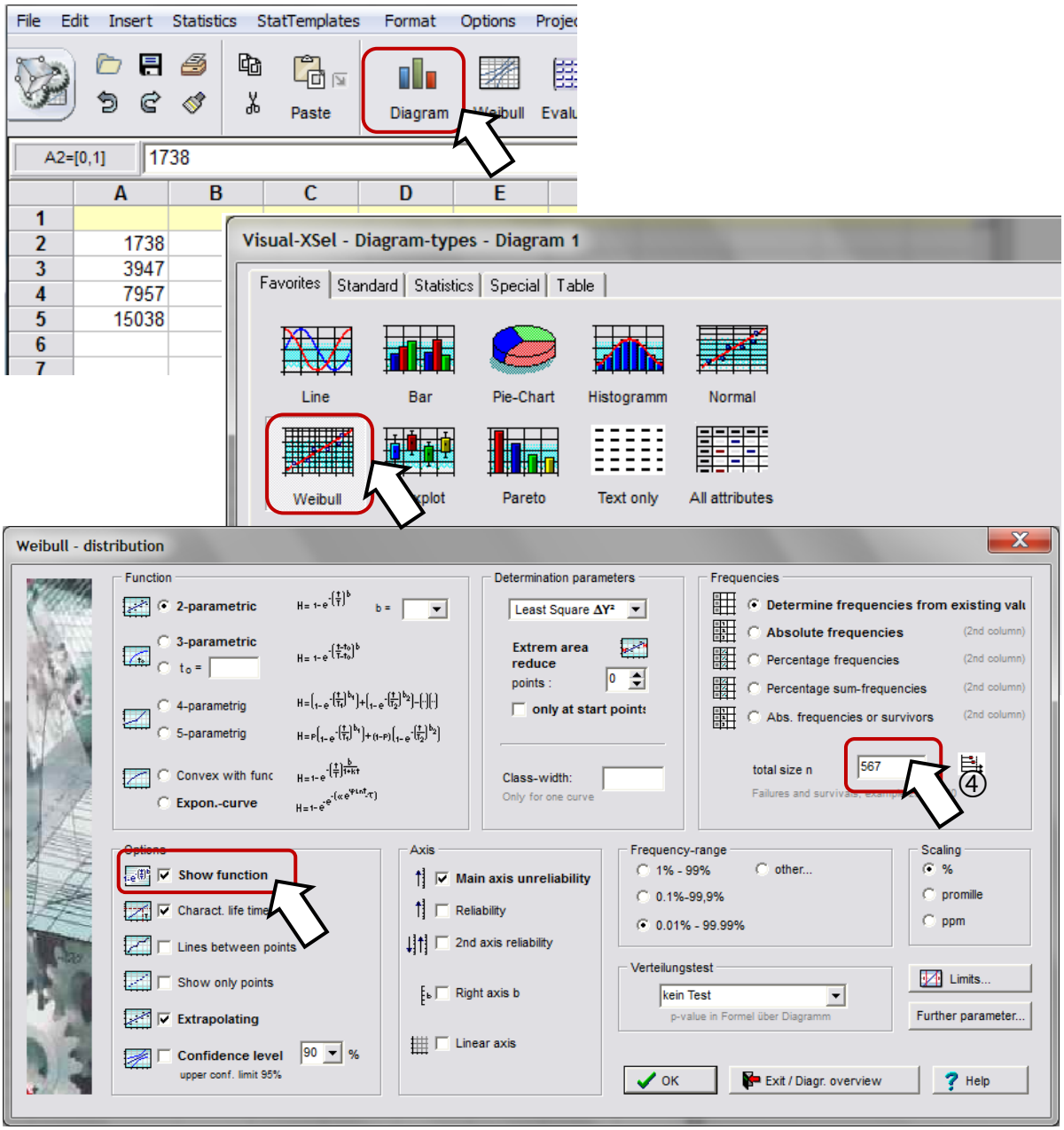
This opens the formula library. With these formulas one can calculate or via Drag & Drop one can use this in the main-window graphically. Click to the wanted formula and use the right mouse button.
The formula library can be opened also from the main-window.





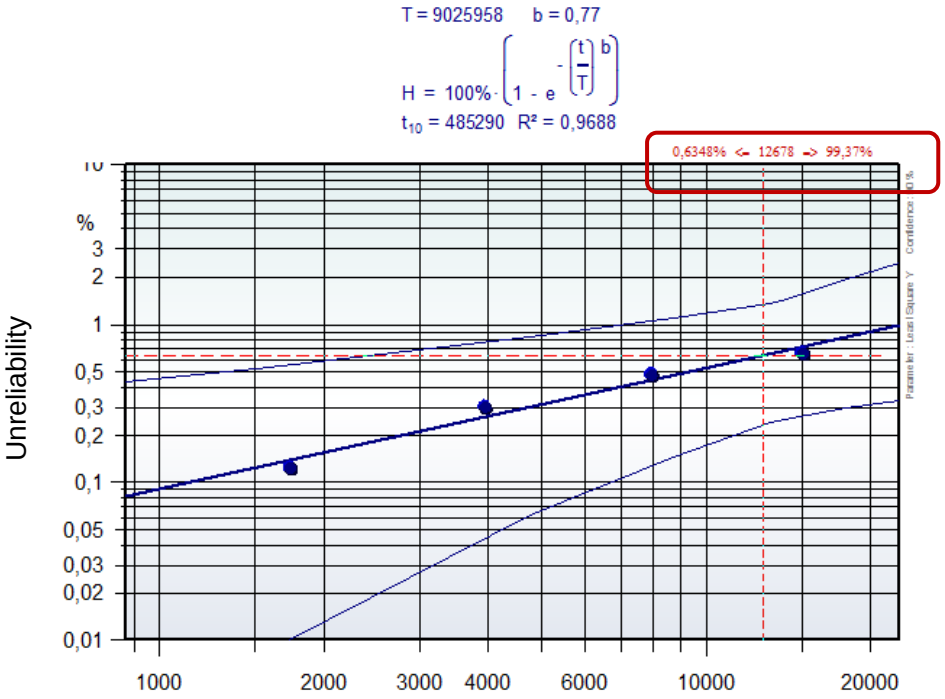
Creating a Weibull-chart

The Weibull-chart (Weibull-net), can also be created directly as a diagram-type from the spreadsheet. The spreadsheet is shown on the left.
The data entry must start at the second row. The first row is reserved for the legend. After the input of the data the column must be marked and the icon diagram has to be selected as well as the diagram-type Weibull



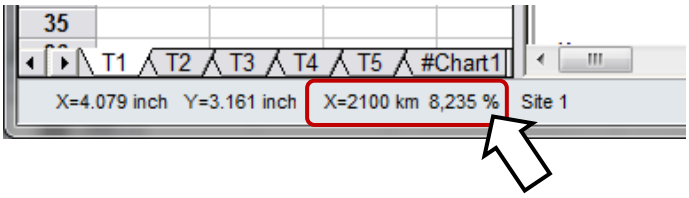
If there are survivors without failures, the amount of failures and survivors can be defined under “total size”. The assumption is here, however, that those have reached at least the running time of the last failure-time.
If the option “Show function” is chosen, the Weibull formula is represented above 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 (see also case study at the end).

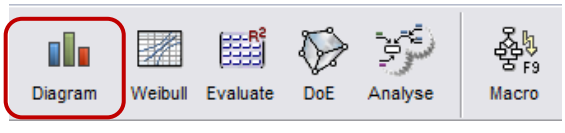


If one moves with the mouse over the chart a red-cross-line appears. The precondition for the cross-line is that no element is selected. In the middle (the red text on the top of the diagram) the running time is shown. For this time the unreliability (failed units) on the left is the result of the Weibull-function.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

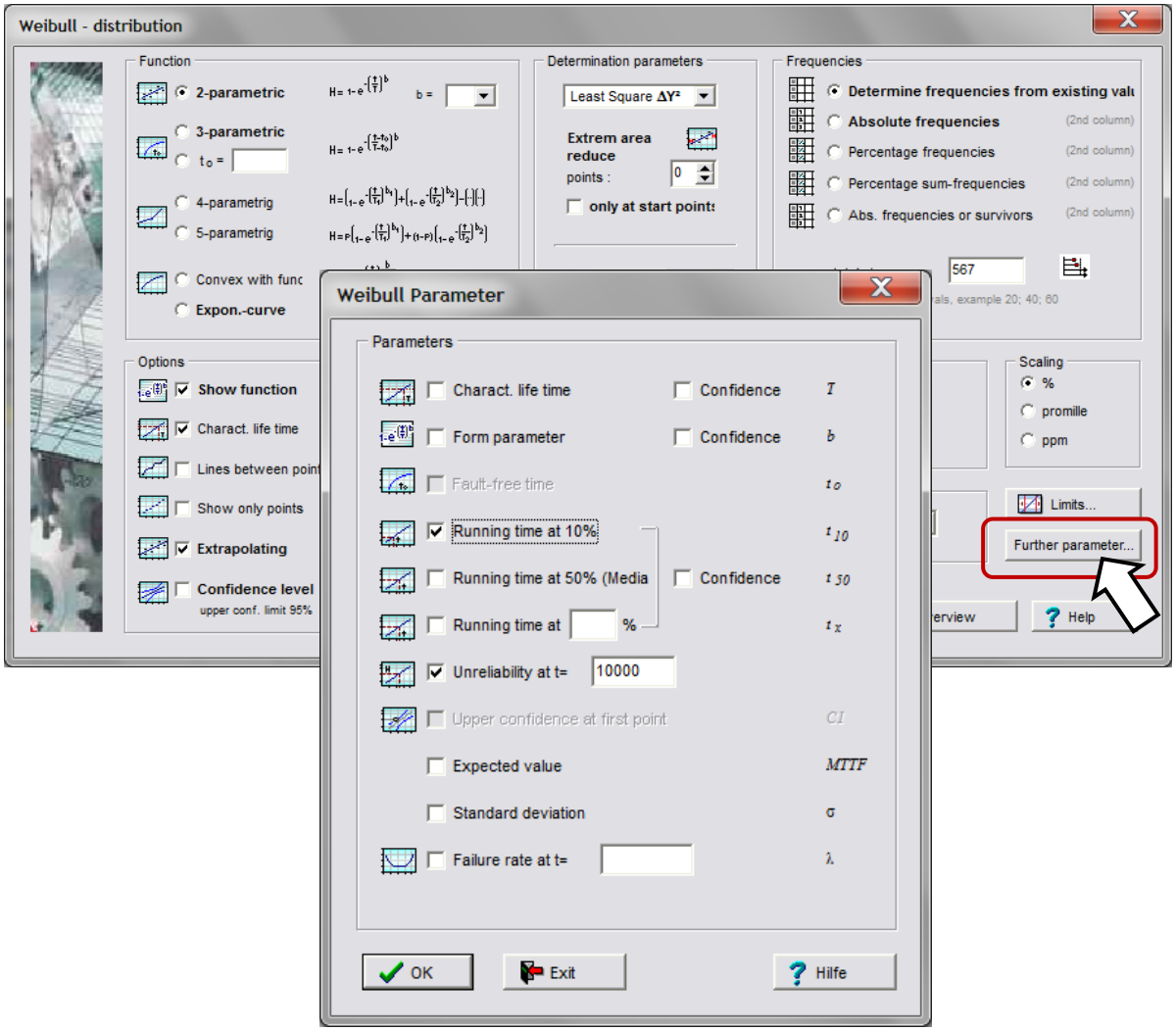


For using other Weibull-parameters, click to the diagram icon. For new input of data or changing data use the Spread-sheet icon.

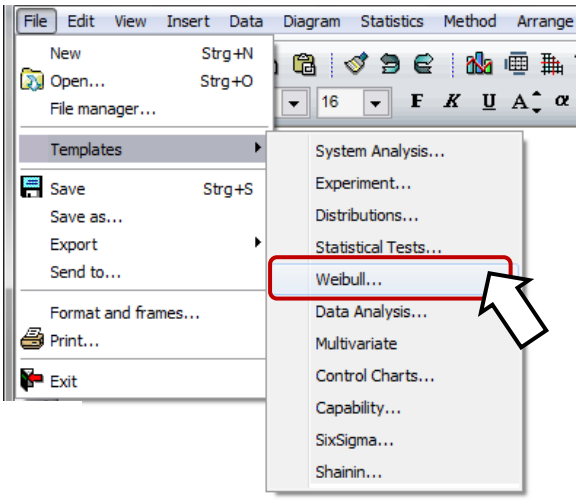


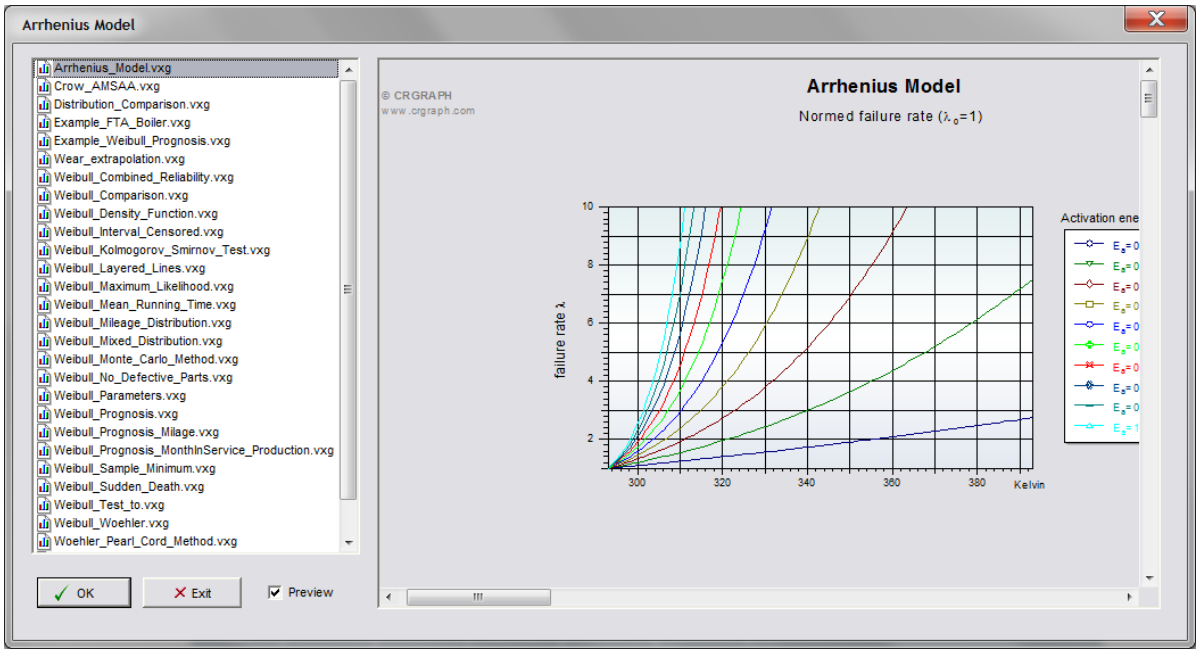
Beside the standard options of the Weibull characteristics, it is possible to define some additional parameters. For this use the button “Further parameter”.

Weibull – Reliability Analyses



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.
For the next steps follow the speech bubbles.



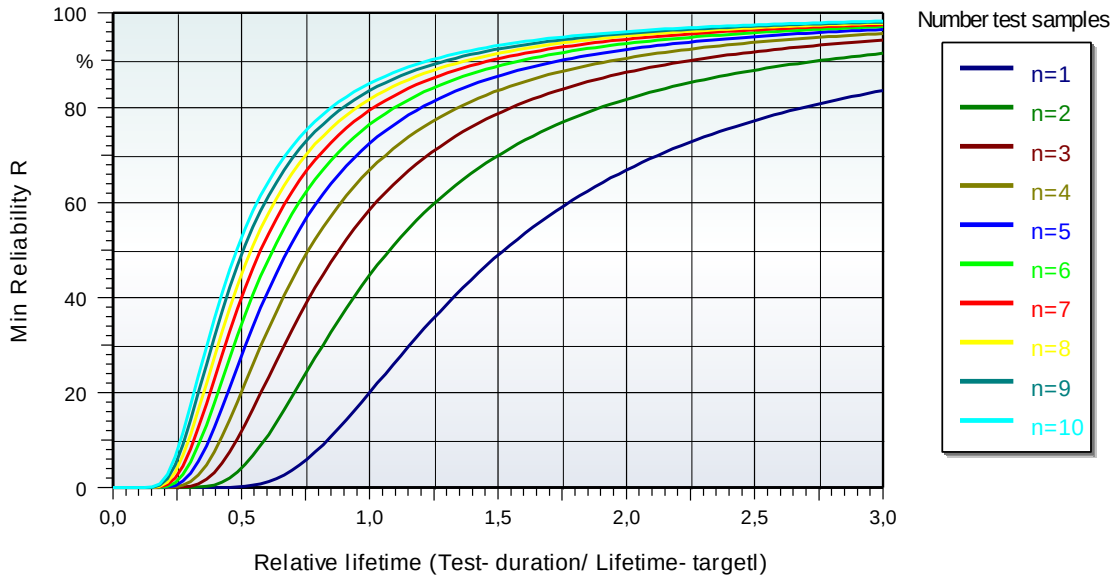


In some templates no data is needed. For example in the template *LvRb20.vxg* only a formula is represented (see ..\Templates\04_Test_Planning). This is about the determination of a minimum guaranteed reliability in testing with no failures (success run).

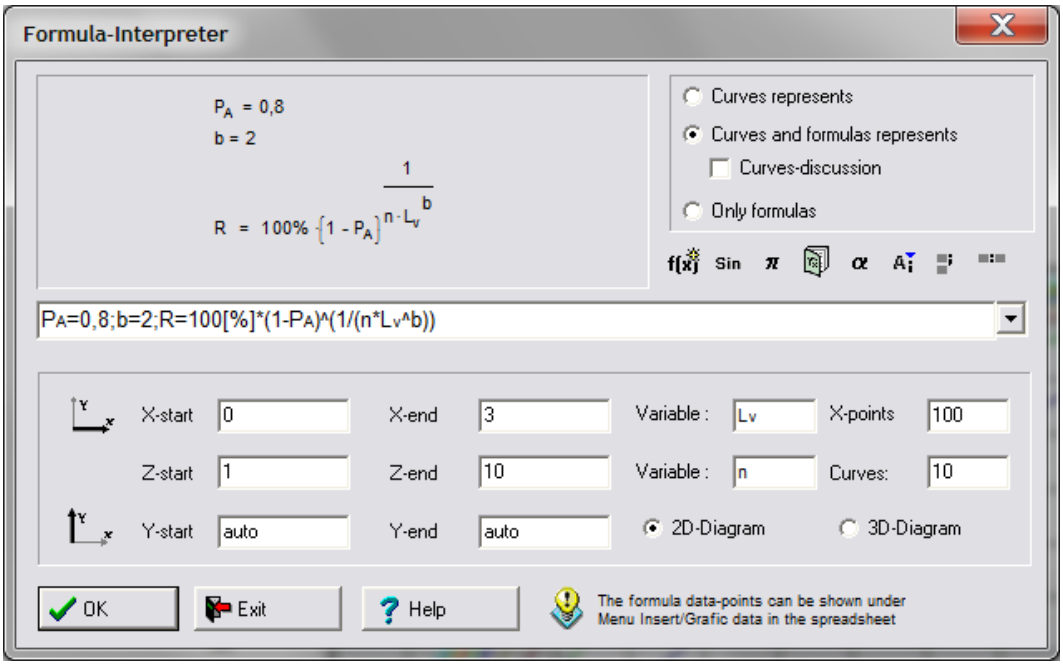
$$P_A = 0{,}8$$

$$b = 2$$

$$R = 100\% \cdot \left[1 - P_A\right]^{\frac{1}{n \cdot L_v^{\,b}}}$$



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*

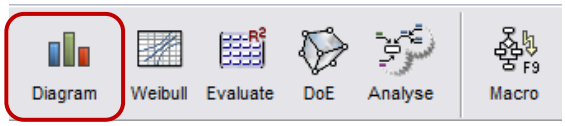


The templates *Weibull_Density_Function.vxg* or *Arrhenius_Model.vxg* are also simple formula charts.

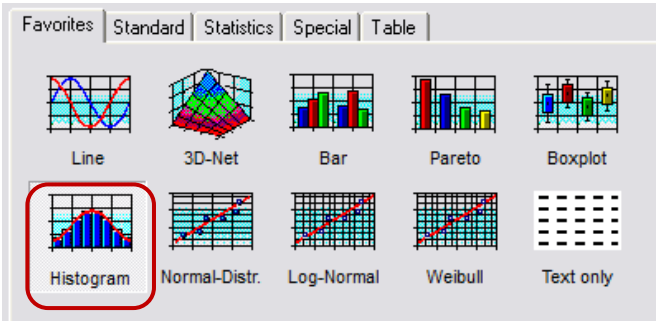
New templates can be created or existing can be modified. Of course, new or modified templates must be saved under a different name, otherwise later updates of Visual-XSel overwrite this possibly again.

Weibull density function (Histogram)

By default, the Weibull distribution is used as the probability net. In some cases one want 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 Spread-sheet (left area). Enter the running-times, shown on the right, begin-ning from the second row.

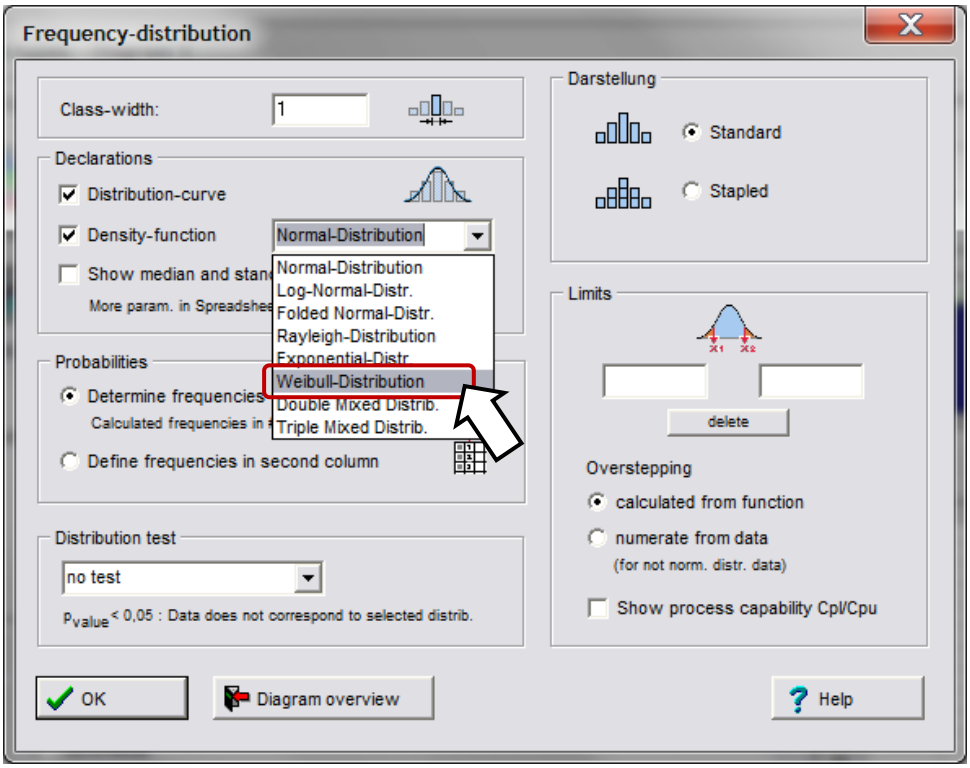


	A	B
1		
2	1,1	
3	1,4	
4	1,8	
5	2,2	
6	2,3	
7	2,5	
8	3,3	
9	3,7	
10	5,2	
11	7,2	
12		

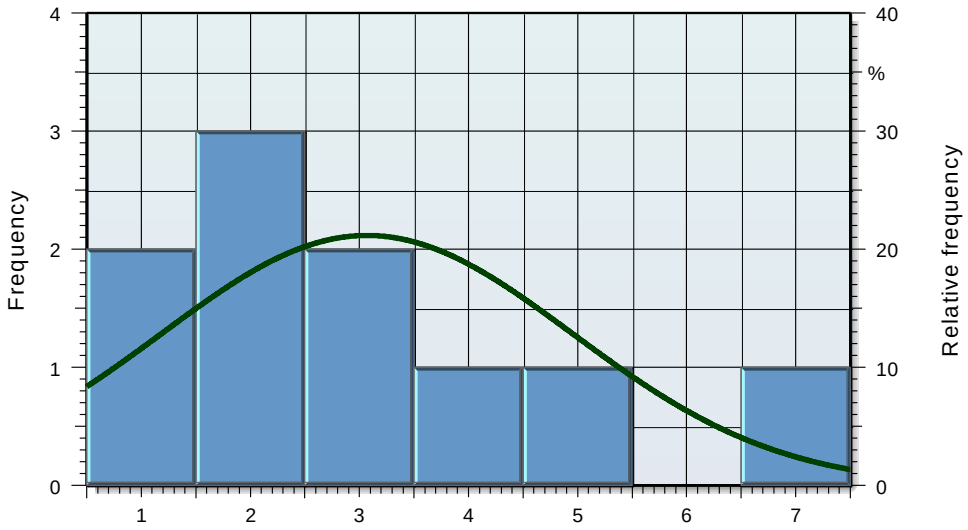


Select the entire column A and the icon *Diagram* and then select *Histogram* (hint: do not use the icon *Weibull* in this case).

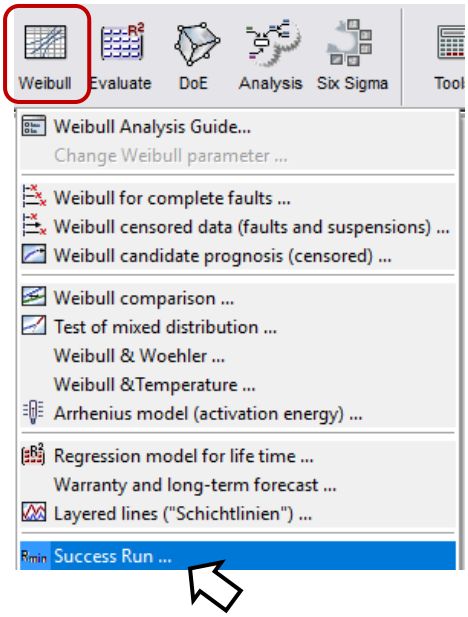
Use Weibull-Distribution. Other parameters can be



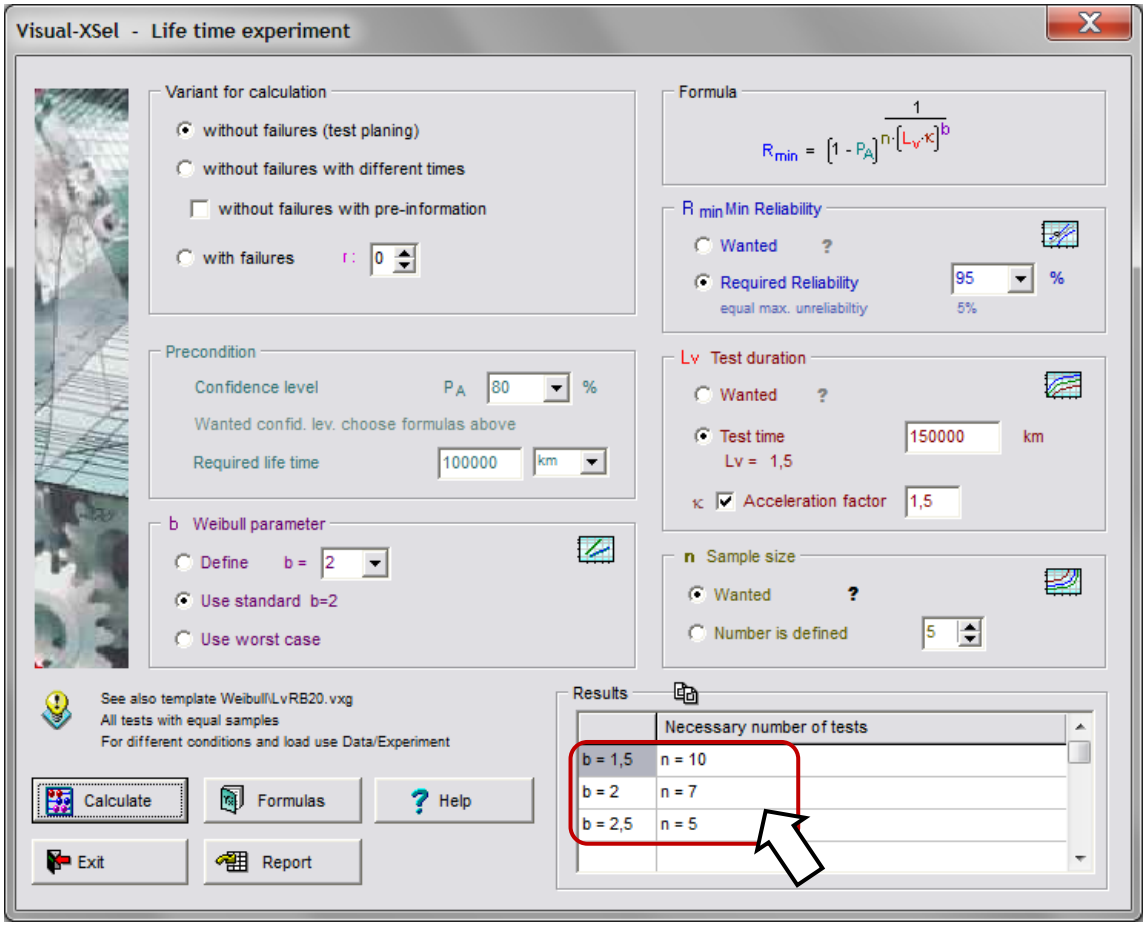
Optionally select *Distribution test*



Life time tests – required sample size



Via the main guide or the menu point Statistics in the main window, the required reliability, the necessary test duration or the sampling size can be calculated. For this a default information is the confidence level.
This method is also well known as „Success Run“. Here, however, it is also possible to make calculations with unexpected failures. In the dialog it is recommended to go step by step from the top left to the right bottom.
In the dialog below there is shown an example to determine the necessary number of sampling for a required reliability of 95%. The Weibull-parameter b was estimated by b=2. It is shown what was needed if instead b=1.5 or b=2.5 would have been.

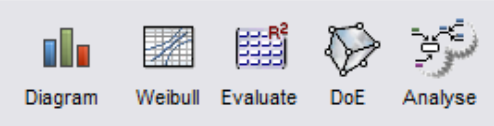


This method assumes that a required life time is given. If there is no reference, then the method WeiBayes is an alternative.

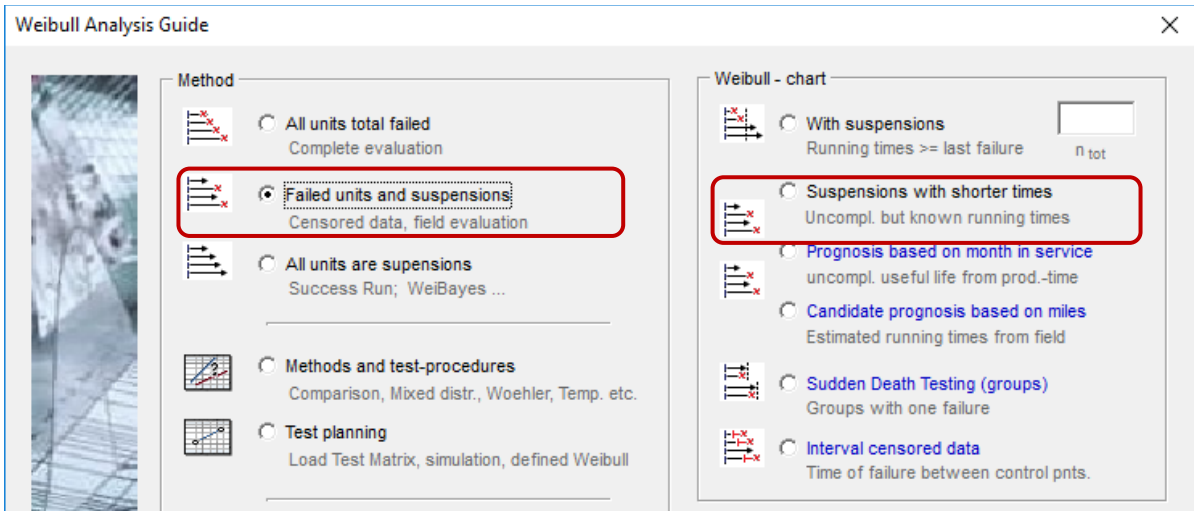
Censored data

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 following table shows a typical situation. Select File/New and the icon Weibull:

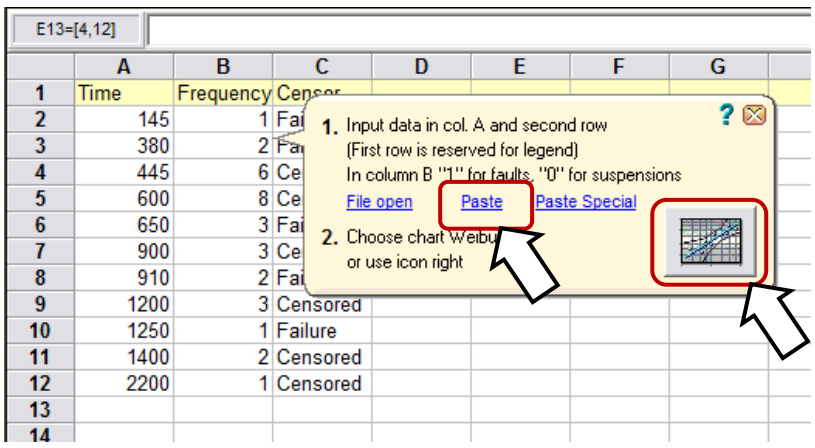
	A	B	C
1	Time	Frequency	Censor
2	145	1	Failure
3	380	2	Failure
4	445	6	Censored
5	600	8	Censored
6	650	3	Failure
7	900	3	Censored
8	910	2	Failure
9	1200	3	Censored
10	1250	1	Failure
11	1400	2	Censored
12	2200	1	Censored
13			



Use in the Weibull Guide the marked options



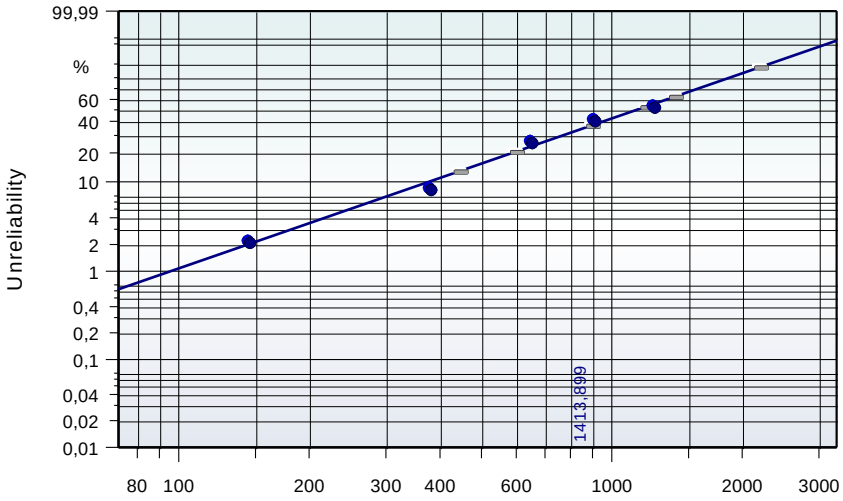
Add the appropriate data from the Clipboard, or load a file. In the case that the data start not in the first row use the dialog Paste special and use the option “Row higher”. Column C must include the word “censored” or “suspension”, to define the parts, which are not failed. If the column B – Frequency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

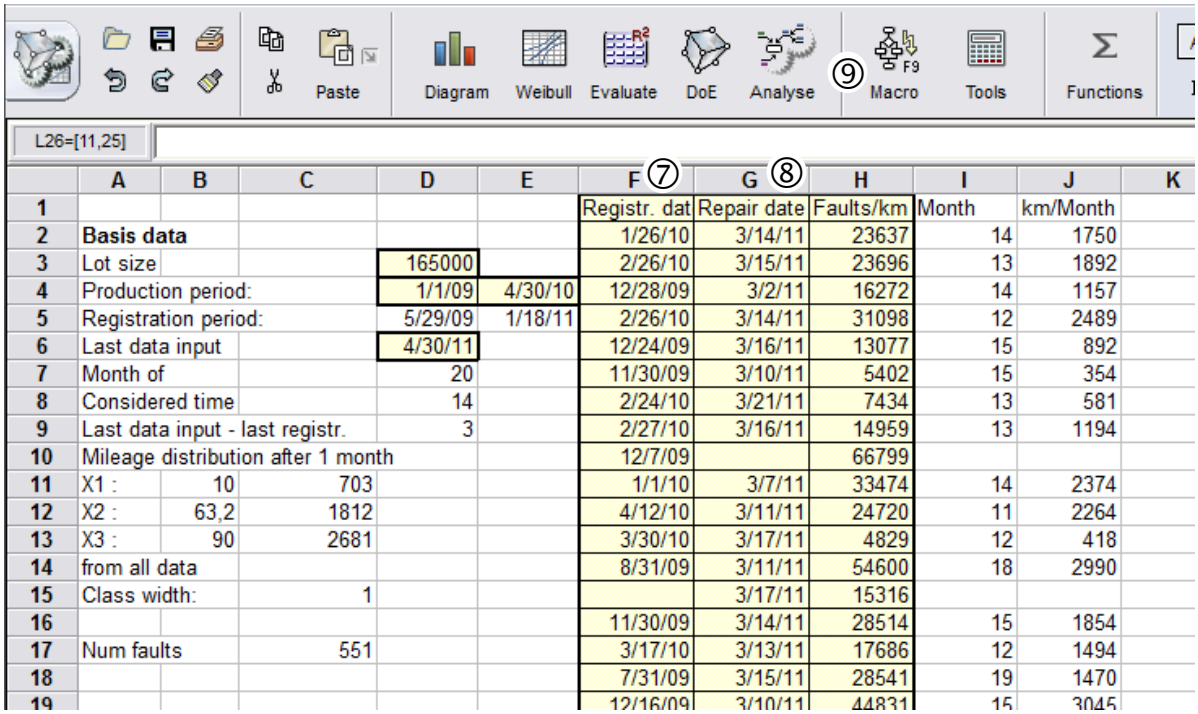
Those suspensions reduce the unreliability either by the Least-Square- or the Maximum-Likelihood method. The first method is the default option.
To change this use the menu Diagram/ Diagram-type… and then "Determination parameters"



Weibull-Analysis for field data

One of the most important methods for field data is the prognosis of censored running times. This means that some customers have not reached yet the mileage where others have already a failure.

In the template *Weibull_Prognosis_Milage.vxg* the mileage distribution is calculated from the list of failures and its repair- and registration-date. Therefore the repair-date and the registration-date are additionally needed.
Open the Spreadsheet via the menu Data/…. or use the icon in the main bar.



	A	B	C	D	E	F	G	H	I	J	K
1						Registr. dat	Repair date	Faults/km	Month	km/Month	
2	**Basis data**					1/26/10	3/14/11	23637	14	1750	
3	Lot size			165000		2/26/10	3/15/11	23696	13	1892	
4	Production period:			1/1/09	4/30/10	12/28/09	3/2/11	16272	14	1157	
5	Registration period:			5/29/09	1/18/11	2/26/10	3/14/11	31098	12	2489	
6	Last data input			4/30/11		12/24/09	3/16/11	13077	15	892	
7	Month of			20		11/30/09	3/10/11	5402	15	354	
8	Considered time			14		2/24/10	3/21/11	7434	13	581	
9	Last data input - last registr.			3		2/27/10	3/16/11	14959	13	1194	
10	Mileage distribution after 1 month					12/7/09		66799			
11	X1 :	10	703			1/1/10	3/7/11	33474	14	2374	
12	X2 :	63,2	1812			4/12/10	3/11/11	24720	11	2264	
13	X3 :	90	2681			3/30/10	3/17/11	4829	12	418	
14	from all data					8/31/09	3/11/11	54600	18	2990	
15	Class width:		1				3/17/11	15316			
16						11/30/09	3/14/11	28514	15	1854	
17	Num faults		551			3/17/10	3/13/11	17686	12	1494	
18						7/31/09	3/15/11	28541	19	1470	
19						12/16/09	3/10/11	44831	15	3045	

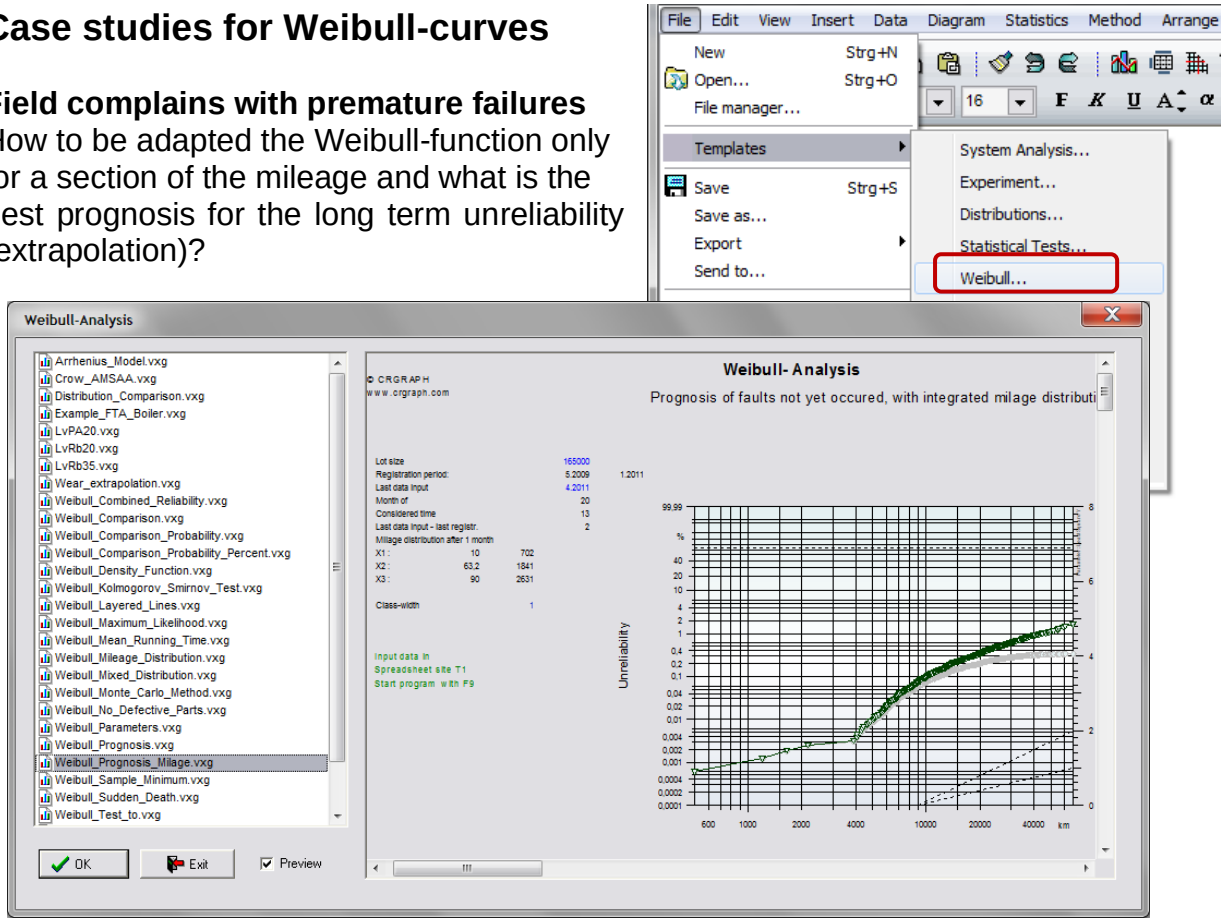
Because of the information of the real start and the time in use (month in service -> repair⑧ - registration⑦) the delay time is not necessary here. Missing registration date will be no problem. All failures defined through the mileage will be considered in the Weibull-net, nevertheless.

After the input of all data in the yellow cells the evaluation will start with the icon ⑨ or with F9.

To guide the user through all steps there are bubble speeches, but please note: Before starting the macro some more spreadsheet cells have to be filled. The bubble speeches will appear always if files or templates are loaded from the directory ..\Templates\. So, in case of developing own templates, those must be saved under the directory ...\Templates\.

Case studies for Weibull-curves

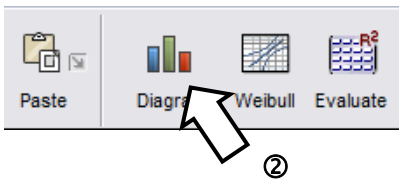
Field complains with premature failures
How to be adapted the Weibull-function only for a section of the mileage and what is the best prognosis for the long term unreliability (extrapolation)?

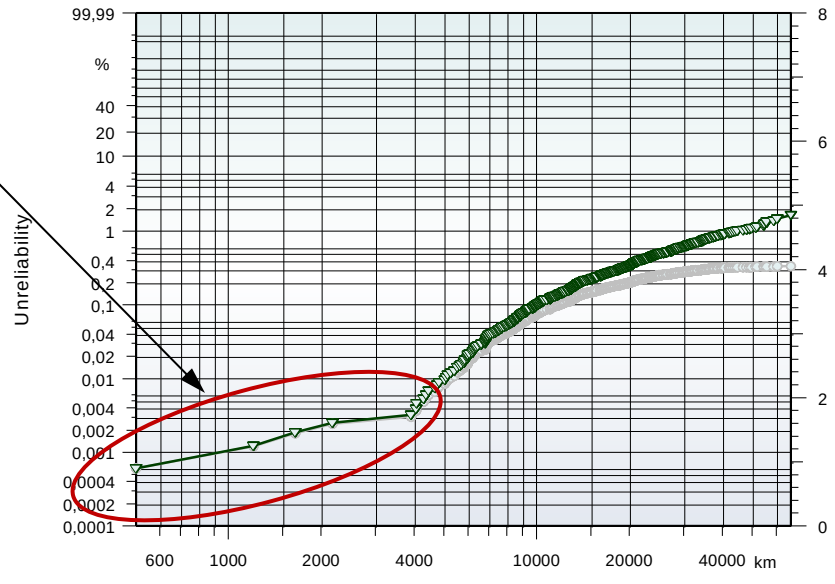


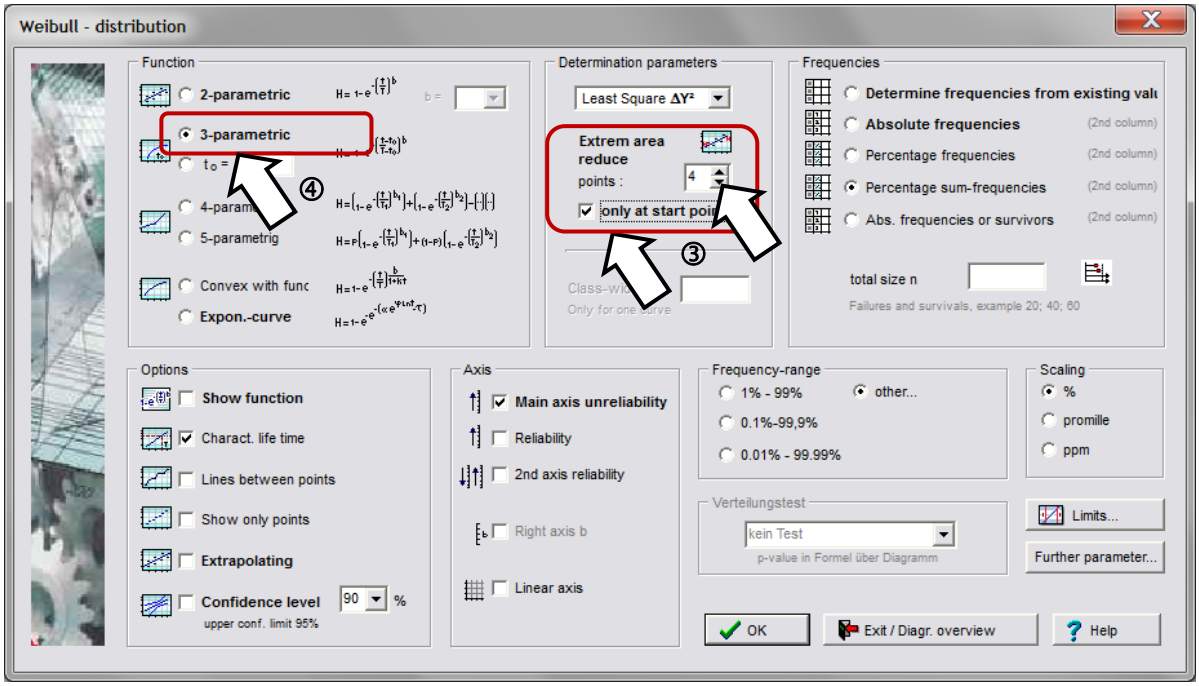
Premature failures.
How can these be excluded from the curvature.

Step ①
Click to one element in the Weibull-chart to activate the diagram.

Step ②
Go to dialog box Weibull.





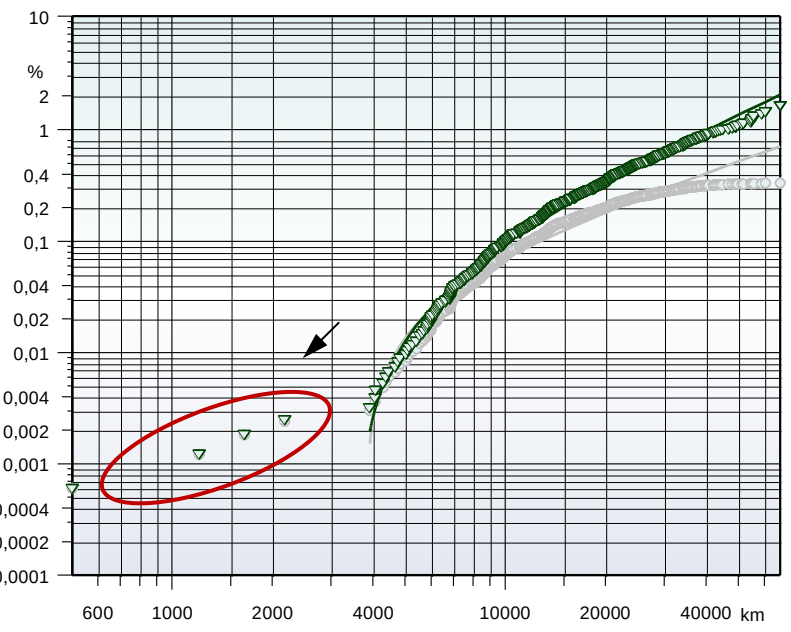


Step ③
Reduce points in the extreme area, in this case only the start points. In this example there are premature failures because of process problems in the manufacture. The quality management has to regard these problems separately.

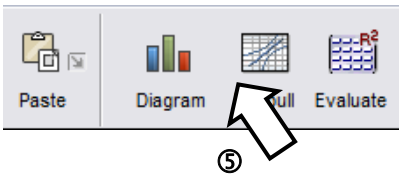
Step ④

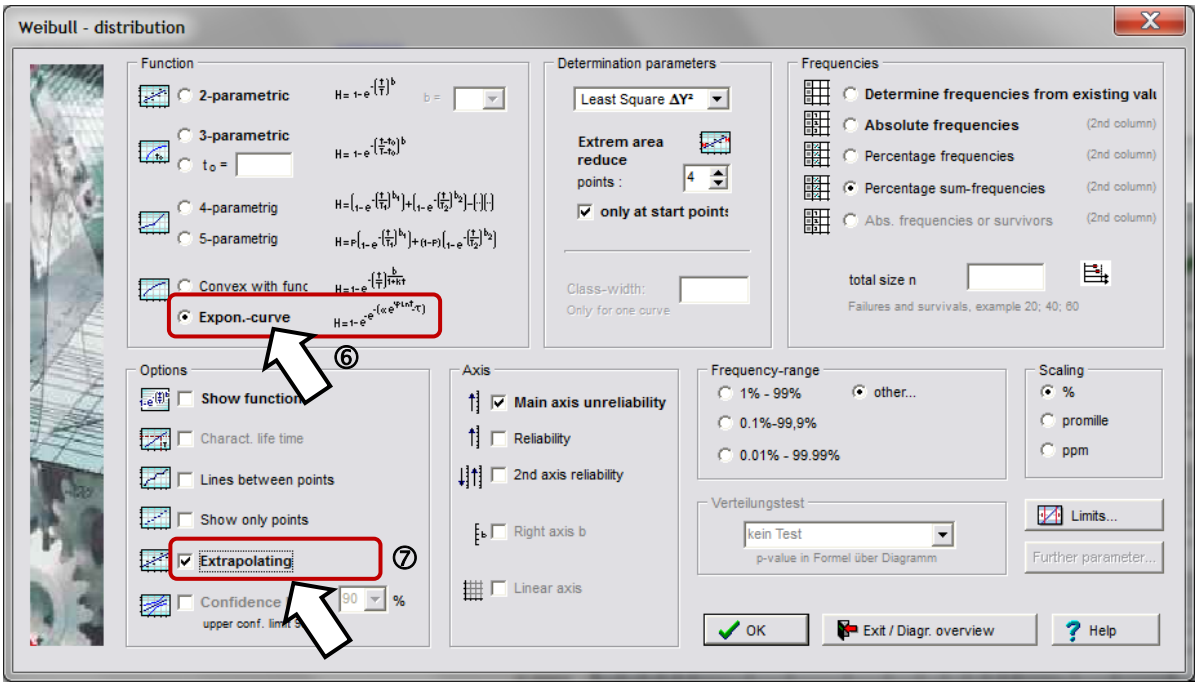
It is believed that the remaining curve is well fitted with the 3-parametric Weibull-function.

The 3-param. function is already significantly better, but at the end of the Weibull-curve there are relative strong deviations. The question is, if there are better functions available for this problem?



Step ⑤
Go to dialog box Weibull once again.

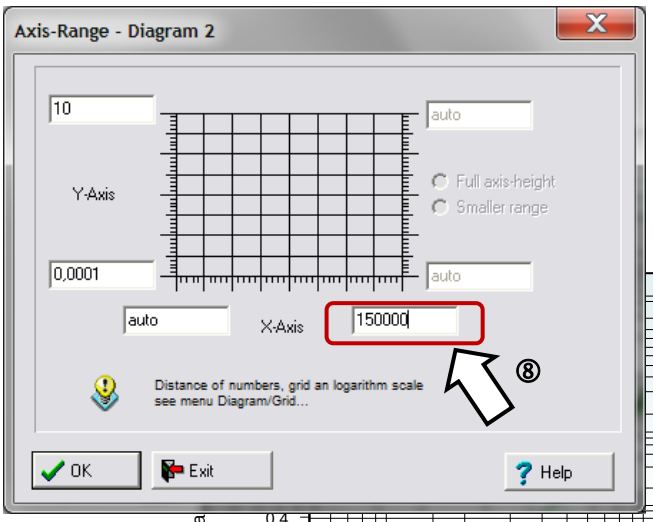


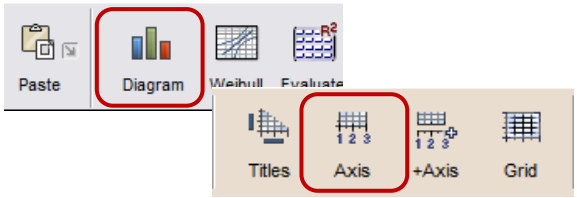


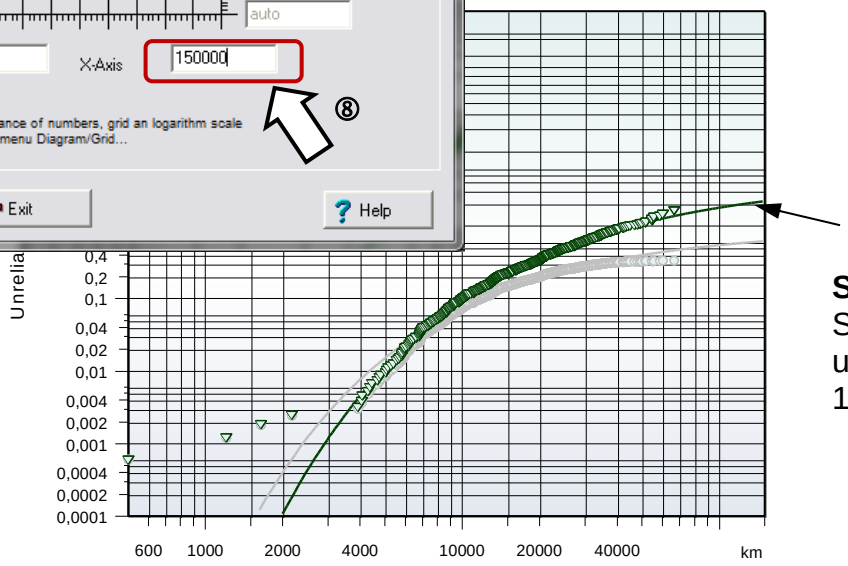
Step ⑥
Selecting the so called Exponential-curve, which is more suitable for the points at the end, because it is more bended there (consideration of the reduction of older vehicles in the field).

Step ⑦
If not already done, use the option Extrapolation to get a statement about higher mileages.

Step ⑧
Expand the axis range to 150,000km. For this make a double click in the last axis number or use the icon Axis range.

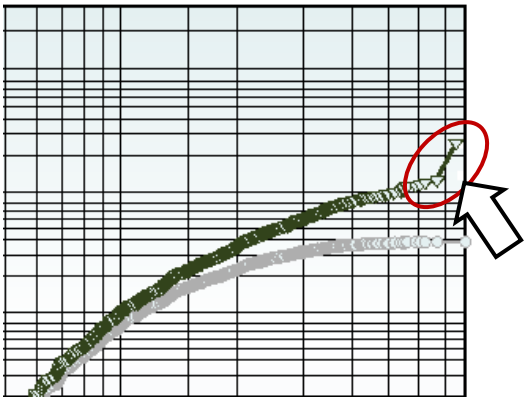




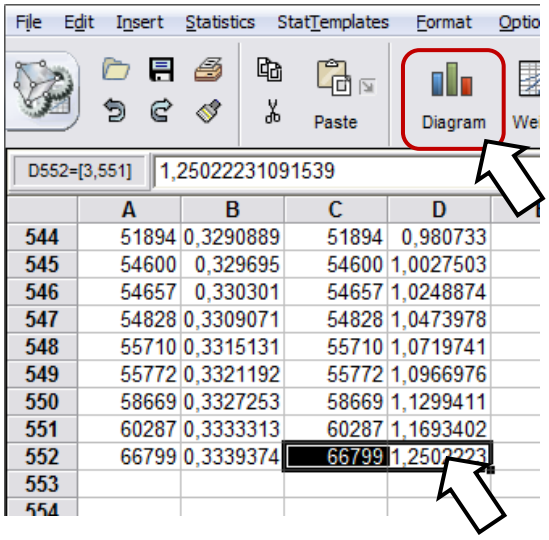


Step ⑨
Statement of the unreliability at 150,000km

Representation with reduced number of points



It can happen that the candidate prognosis overrides at the last point and is much too high. The prognosis in this area seems unrealistic and the point should be deleted (the last point of the gray actual data remains on the level of the previous point). To achieve this, it does not help, as previously described, in the dialog box of Weibull to reduce points. This only affects to the curve, the points are still visible in the diagram. The point of the prognosis has to be deleted from the table. First click on the Weibull diagram and use the right mouse button to pop-up menu item Data Source. (The presentation is here on the spreadsheet page T2). Delete the last two cells, the running time and the percentage.



	A	B	C	D
544	51894	0,3290889	51894	0,980733
545	54600	0,329695	54600	1,0027503
546	54657	0,330301	54657	1,0248874
547	54828	0,3309071	54828	1,0473978
548	55710	0,3315131	55710	1,0719741
549	55772	0,3321192	55772	1,0966976
550	58669	0,3327253	58669	1,1299411
551	60287	0,3333313	60287	1,1693402
552	66799	0,3339374	66799	1,2502223
553				
554				

It is then important not to restart the macro. It would be overwrite table T2 with the last values. Rather, should only the graph be updated via the icon *Diagram / Update*

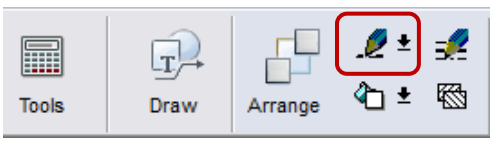
In the chart now the rear point of the forecast does not appear any longer. One can also delete the actual data on the left. But then one would not be able to see how far the last failure was.

If one can not assume that this is an outlier, and if there are several points not on a common curve, it is assumed that this is a mixed distribution. The reason is usually a different failure mode. See the description in the section on the next page.

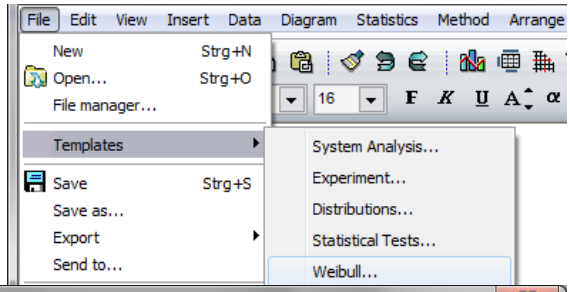
Representation of two prognosis curves in a common Weibull chart

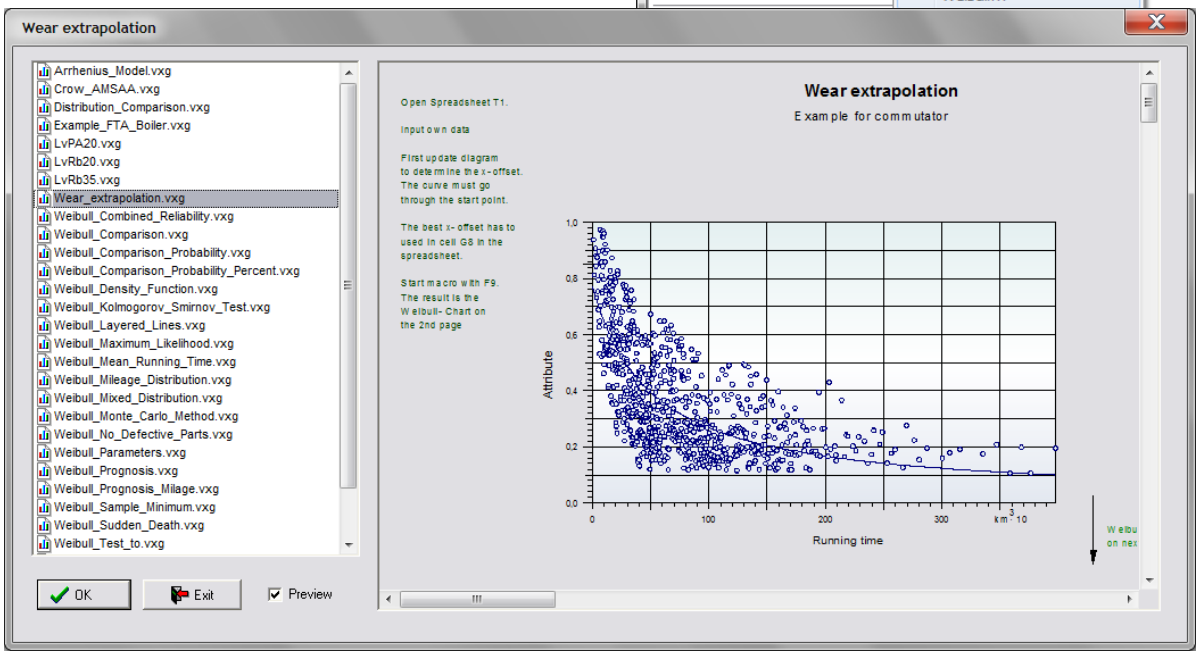
Via the spreadsheet page T2 side, it is also possible to replace all data series. Should e.g. predictions are compared with that of another evaluation (column C and D), so you can exchange the data of the columns A and B (curve of the actual data is no longer needed). After updating the graphics the gray curve is the forecast made before from the evaluation and which has been copied. But before the data is copied in column A and B, one should delete the columns for the case that the old rows of data are longer than the new one.

Colors of the presentation can be changed later.



Mixed distribution
How to recognize different causes of the failures?
A good example is provided by the template *\Templates\ 05_Weibull\ Wear_extrapolation.vxg*.



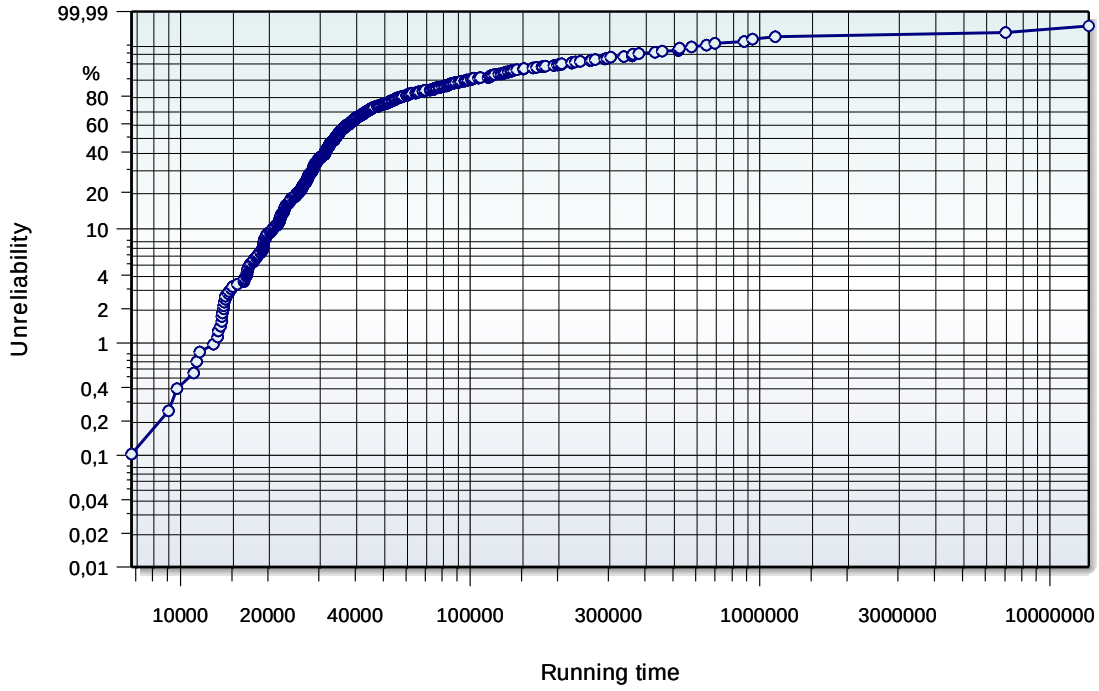


Step ①
Go to diagram Weibull on the 2nd page (scroll down with the mouse).

$$T = 62768{,}34 \quad b = 1{,}35$$

$$H = 100\% \cdot \left(1 - e^{-\left(\frac{t}{T}\right)^b}\right)$$

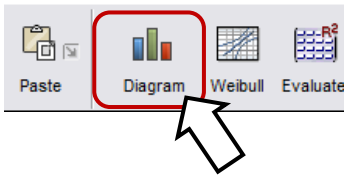
$$t_{10} = 11815 \quad R^2 = 0{,}657$$

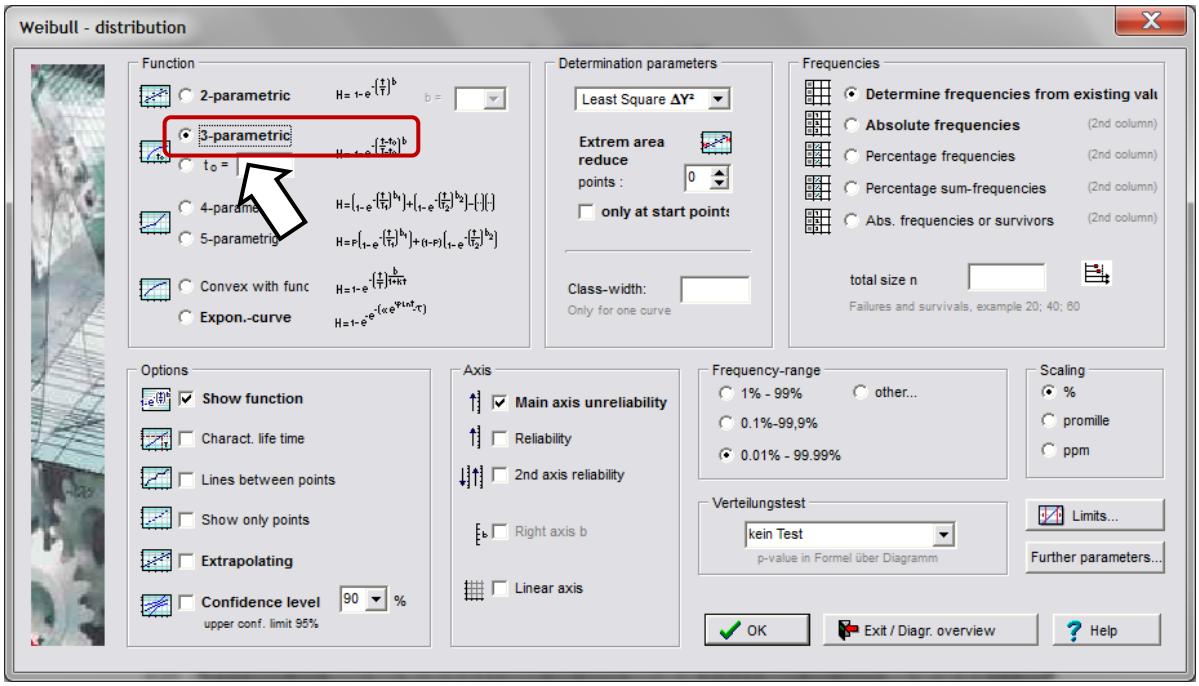


Can this curve be described better with the 3-paramtric Weibull?

Step ②

Go to dialog box Weibull (Weibull-Diagram should be clicked before to be the active one). Select the 3-parametric Weibull function.





Step ③

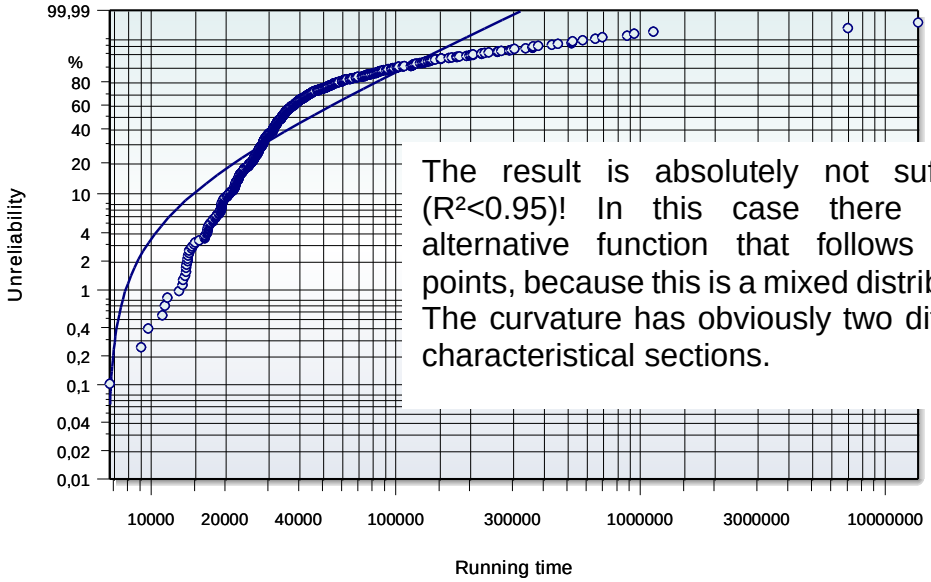
It is believed, that the further curve is describable well with the 3-parametric function.

$T = 58556{,}37 \quad t_0 = 6658{,}009$

$b = 1{,}22$

$$H = 100\% \cdot \left(1 - e^{-\left(\frac{t - t_0}{T - t_0}\right)^b}\right)$$

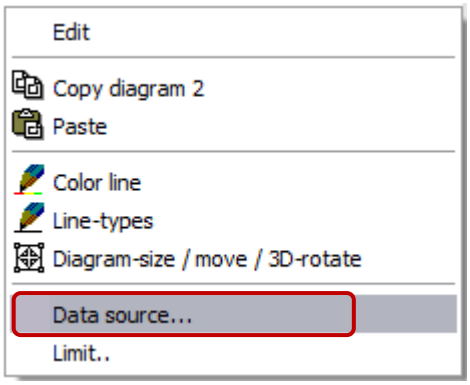
$t_{10} = 14862 \quad R^2 = 0{,}754$

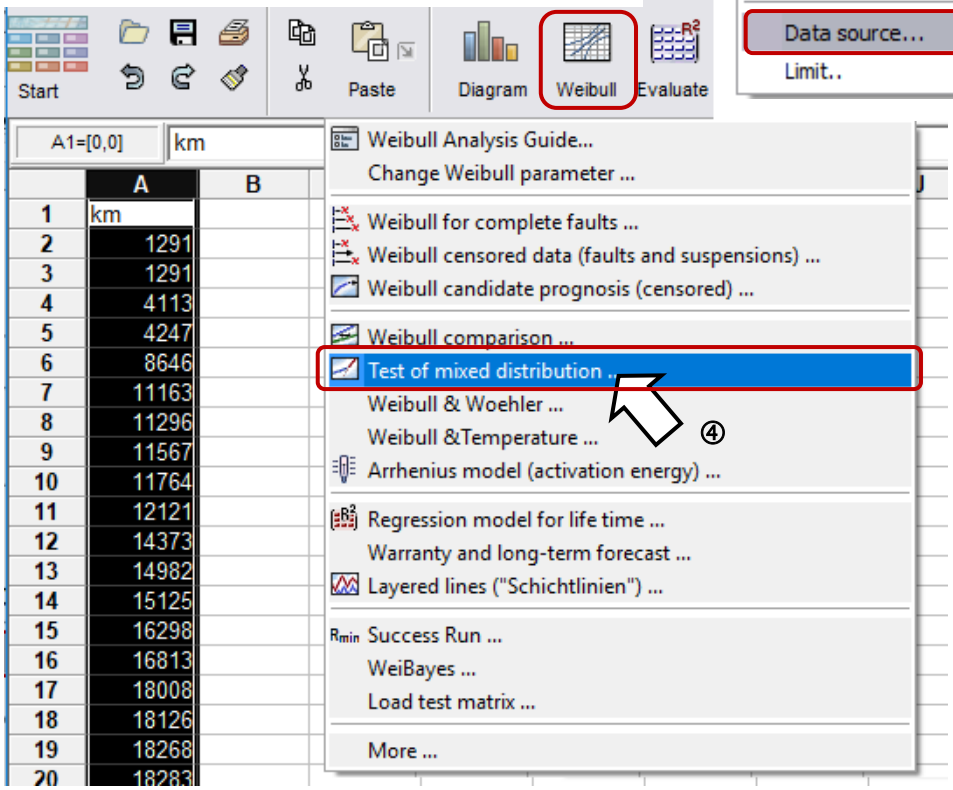


The result is absolutely not sufficient (R^2<0.95)! In this case there is no alternative function that follows these points, because this is a mixed distribution. The curvature has obviously two different characteristical sections.

Step ④

Now it has to be tested, whether there is a mixed distribution. To apply this test, the data of the Weibull curve has to be found first. For this, click the right mouse button and select the menu which shows where the data source is.



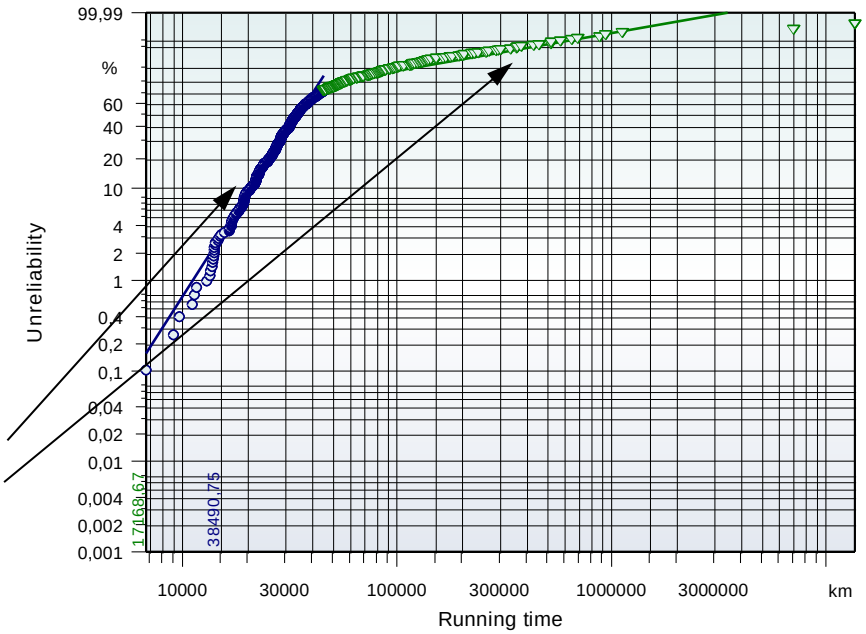


Step ⑤

Select the menu *StatTemplates/Test of mixed distribution (Weibull)*. Make sure that the columns are still marked.

Step ⑥

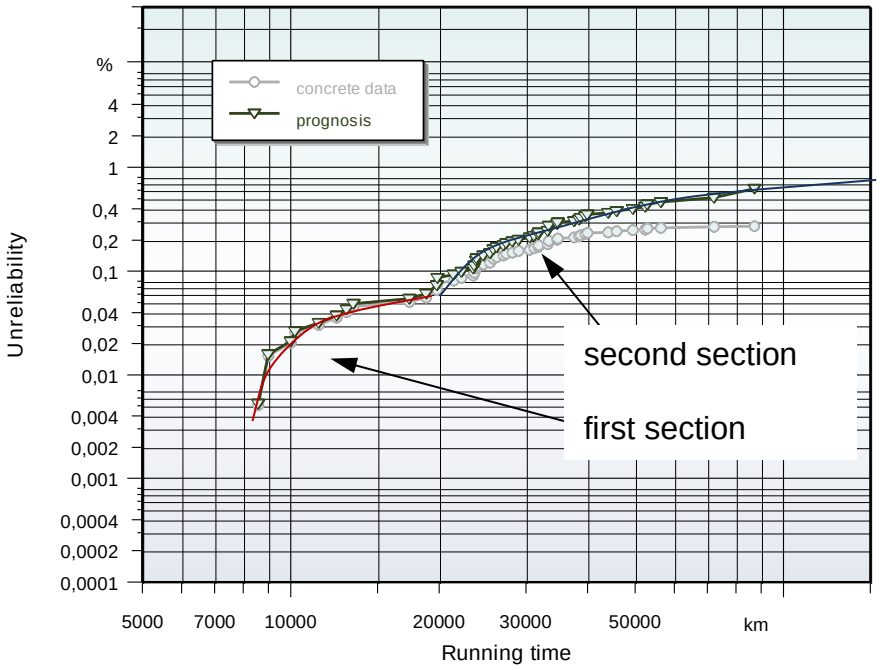
Start the macro with F9 or follow the bubble speech. Then go step by step through the next dialogs. Use in any case the default definitions. After that the result is shown below



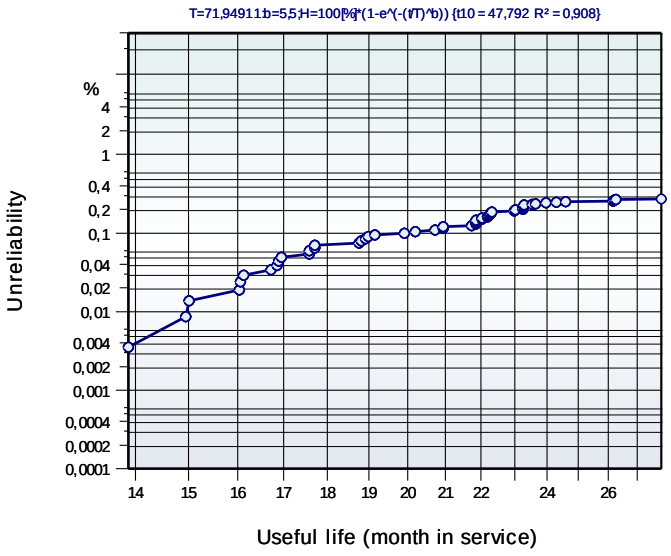
Mixed distribution is confirmed. The chart shows two different unreliability reasons.

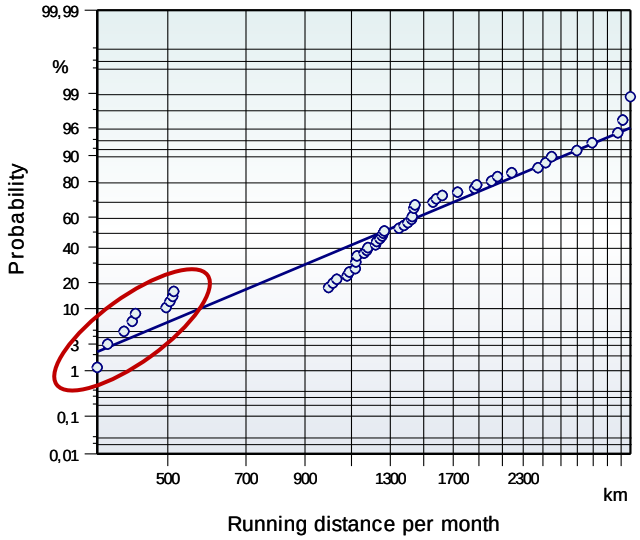
Detecting pseudo-mixed distribution

In the file *..\Templates\05_Weibull\Example_Weibull_Prognosis.vxg* it seemed to be a mixed distribution with to fault-free time.

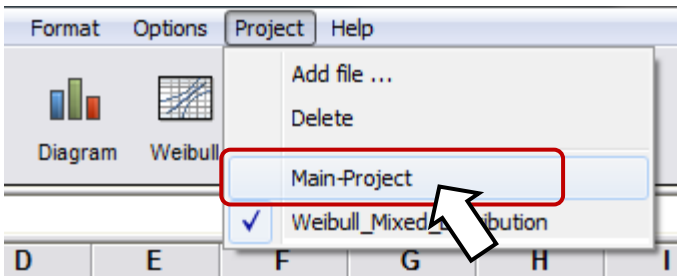


The previously shown test method to determine a mixed distribution can not be carried out, because the method is not applicable to the 3-parametric Weibull distribution. The two sections are very significant and one would say that there are different failure mechanisms, even without testing.
The reason is, however, in this example, a different customer behavior. In the first section there are vehicles in urban traffic and have very less mileage per month. This can be seen in the running distance distribution on page 2 (log-normal distribution to the right). Another clue is that the Weibull distribution based on useful life, does not show a kink (left diagram).





Important:
To go back to the previous representation and data, choose the Main-project! The active template is shown in the example.



Hint for mixed distributions: When using a Weibull function the direction of the points maybe cannot be seen sufficiently. Here it is recommended to select "Lines between points " (menu Diagram / Diagram type).