



Prerequisite and related topics

These descriptions require a basic understanding of the Weibull distribution with censored data.

More Weibull fundamentals are described in www.weibull.de/COM/Weibull.pdf.

Introduction

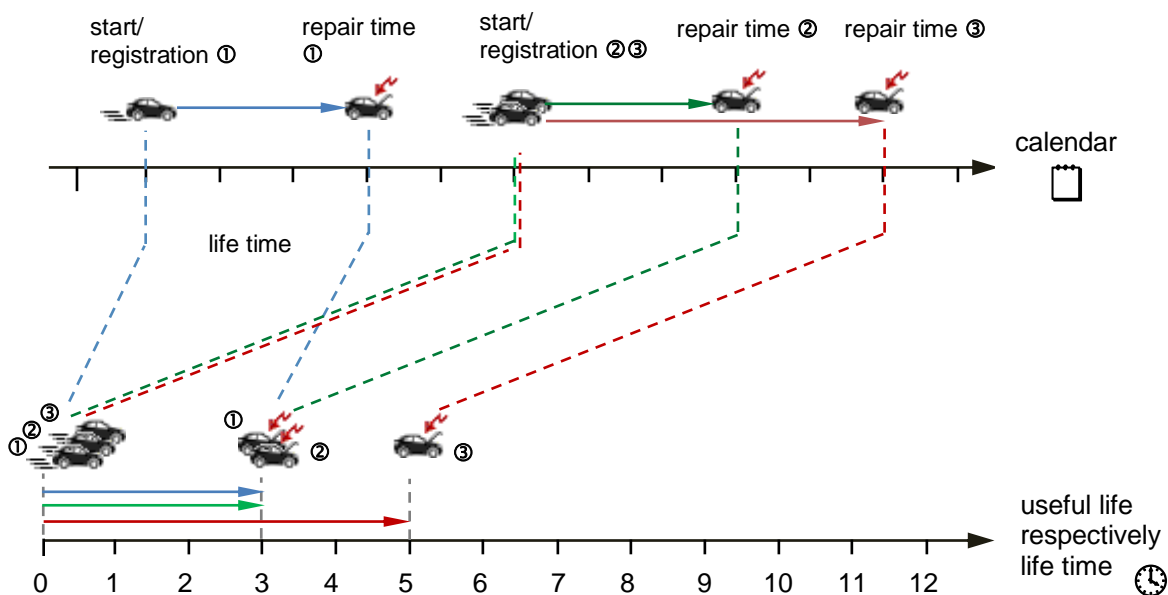
If there is service life data in which not all parts have failed, this data is called incomplete or censored. In particular, if parts that are still intact have shorter service lives than others with a failure, the failure frequencies must be corrected. This description is about data preparation.

Goal and benefit

This description shows how to properly split the data from the failed and healthy units. This is necessary, for example, in order to be able to use the Johnson or maximum likelihood method, which is widely used for censored data. Furthermore, it is about several possible errors or parts in a system.

Basics

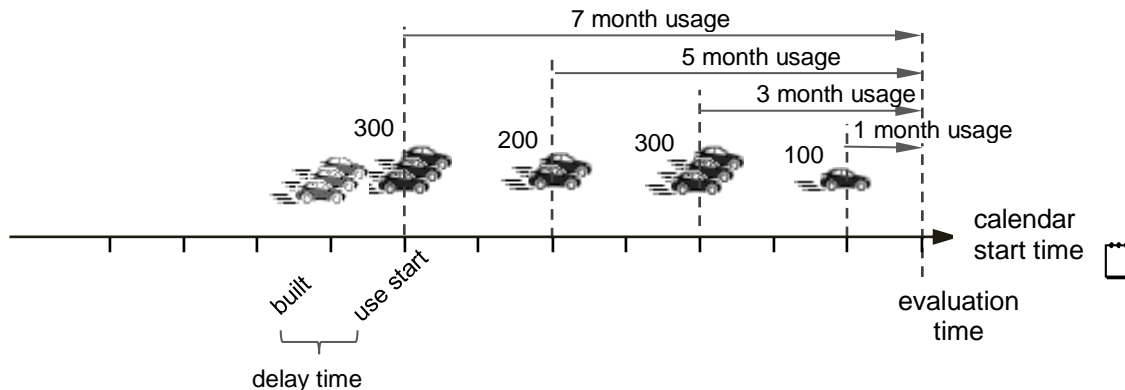
How is the service life and useful life of the intact parts determined? The useful life until failure or the service life is always the time between the start of usage and the time of failure. When considering the useful life (lower graphic), the calendar starting point is irrelevant.



The useful life shown in the lower time axis corresponds to the x-axis in the Weibull diagram i.e., the service life.

Weibull analysis for field with parts

Now how are the intact (censored) units divided and their useful life determined, which they will still live to see? To do this, we look at the period from the start of use to the time of evaluation:



With the number of units produced in the calendar period, it must be taken into account that these units will be used later or will start later. This time is referred to as the delay time. As a rule, an average delay of 1-2 months is assumed. If the month of production and the registration date are known e.g., for vehicles, the average delay time can be calculated from this. This results in the table of failures and the table of units produced:

complaints

month	number
3	2
5	1

production

month	number
1	100
3	300
5	200
7	300

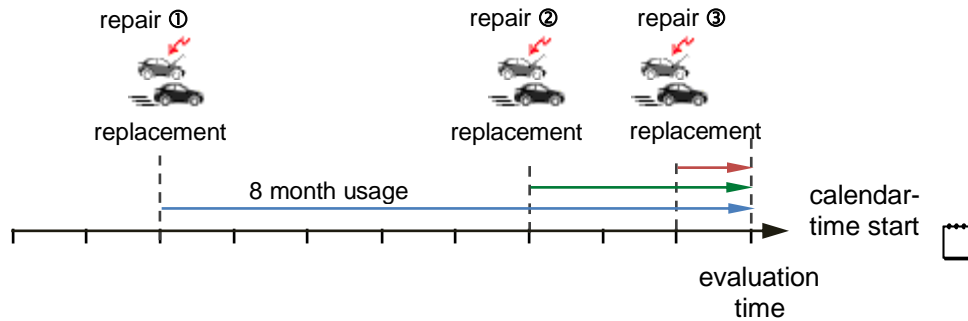
For the representation in the Weibull diagram, failures and the intact units must be listed with the times they have been in use. The intact units result from the production quantity minus the failures. Physically, the concrete failures must be subtracted from the quantity where they were produced. In simplified terms, allocation is often made based on the usage time, which results in the following table:

Intact units

month	number
1	100
3	298
5	199
7	300

First of all, the number of failures plus the number of intact units has to add up to the total production. Since every failure has to be replaced by a spare part, the reference value n increases again by the number of failures. The previous deduction of the failures from production cannot be compensated for here, because the useful life of the failures and the spare parts are different:

Weibull analysis for field with parts



In addition, there are 3 further units with 8, 3 and 1 months useful life after installation up to the time of evaluation:

replacements

month	number
1	1
3	1
8	1

+

intact units

month	number
1	100
3	298
5	199
7	300

⇒

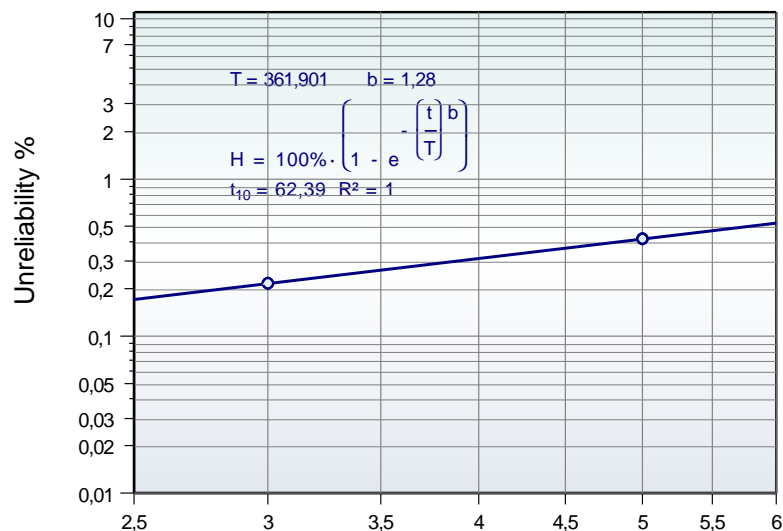
total number intact

month	number
1	100+1
3	298+1
5	199
7	300
8	1

Ultimately, the Weibull distribution table results in the following combined table of failures and total number of intact units. The intact units are marked here by definition with a minus:

month	number
1	-101
3	2
3	-299
5	1
5	-199
7	-300
8	-1

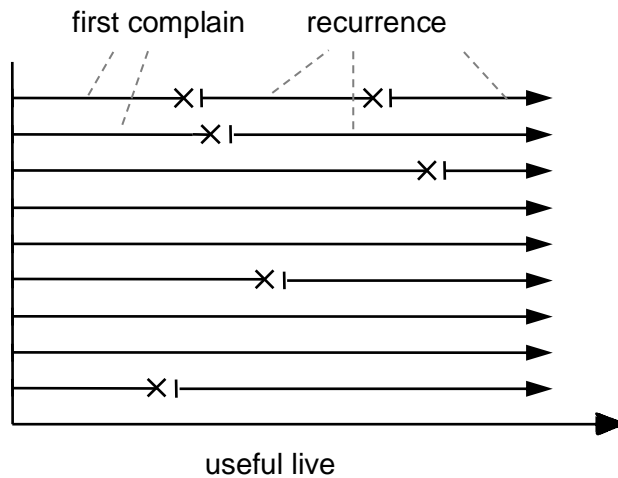
This table gives the Weibull net shown on the right with the Johnson method.



Repeated failure of a repaired part

In the event of a complaint, the affected part will be replaced with a new one, as described. However, this replacement (spare part) can fail again. When that happens, it's called a recurrence event. The useful life of the repeat case must relate to the time of the previous failure.

Weibull analysis for field with parts



The logic is the same as for the spare parts described in the previous section.

In principle, one can say that all spare parts that are still "running" increase the number of units by defining their useful life in a table. Any parts that failed from the original production reduce the number of intact units from that production.

Several different components in the system

For the reference variable n for calculating the median rank values, the number of system units (e.g. vehicles) must be multiplied by the number of parts, because theoretically a system can often fail due to its parts. Mathematically, this assumes that the parts fail independently of each other.

Correctly, one would have to make a separate Weibull analysis for each component, because each component has its own failure characteristics and thus different b . The system is then combined into a common Weibull via a serial block diagram. In other words, the overall reliability of the system is known $R_{system} = R_{comp1} \cdot R_{comp2} \cdot R_{comp3} \dots R_{compz}$. However, the problem then is that some parts have too few failures to be able to determine a representative component reliability using a component Weibull. For this reason and for reasons of simplification, a "system Weibull" should be made here.

However, the determined gradient b of the system can only be interpreted to a very limited extent or not at all, because it is a mixture of different causes of failure. However, this is more about a business perspective than a correct Weibull interpretation.

Several identical components in the system

A good example of identical components are the spark plugs in the engine. A 4 cylinder has 4 spark plugs. The reference variable n would therefore have to be multiplied by 4 in relation to the number of vehicles. However, the spark plugs cannot be individually identified or distinguished. In addition, they are always exchanged together in customer service. They should therefore be considered as a unit.

The situation is different with redundant components. If there are two identical processors that make a controller redundant for safety reasons, these are to be differentiated with processor 1 and processor 2, for example. The failure characteristics would even be the same here. Otherwise, the same considerations apply as in the previous chapter.

A redundancy increases the availability of the system, but not the situation of the repair (an exception are silent redundancies where the first failure is not noticed).

Weibull analysis for field with parts

Simultaneously exchanged parts per complaint

In the event of a complaint, several parts are often exchanged at the same time. There are different scenarios here:

1. All parts are independently defective at the same time
2. The failure of one part causes the failure of the others in whole or in part
3. Only one part is really defective, the others have been exchanged without justification

Case 1 is very unlikely, case 2 is more realistic. Only a component analysis can clarify this, but this is often not possible for practical reasons. The parts would have to be returned for this. However, if an analysis is possible, the unauthorized exchanged parts should be removed from the list of complaints.

If this is not done and a Weibull evaluation is nevertheless created, this is more of a business point of view, because the costs and spare parts have been incurred. However, as already mentioned, the gradient b determined can only be interpreted to a very limited extent or not at all.

Tabular representation

1. Single failure

Ident	Prod. date	Start/regist	Repair date	Part/variant
BDP58219	14.5.2021	15.6.2021	21.2.2022	Powerunit

Ident occurs only once

- ⇒ Failure with 8 months of use (21.2.2022-15.6.2021)
- ⇒ Intact service life spare part added (eval. date - 21.2.2022)

2. Case of recurrence

Ident	Prod. date	Start/regist	Repair date	Part/variant
BDP52353	15.3.2021	22.4.2021	30.6.2021	Change aggregate
BDP52353	15.3.2021	22.4.2021	30.4.2022	Change aggregate

Same ident, production, approval and same part

- ⇒ First failure with 2 months of use (30.6.2021-22.4.2021)
- ⇒ Repeat case 10 months usage (30.4.2022 - 30.6.2021)
- ⇒ Intact service life spare part added (eval. date - 30.4.2022)

3. Multiple replacement

Ident	Prod. date	Start/regist	Repair date	Part/variant
BDN51721	16.4.2021	13.5.2021	27.6.2021	Change aggregate
BDN51721	16.4.2021	13.5.2021	27.6.2021	joint top

Same ident, production, registration, repair but different parts

- ⇒ 2 Complaints with 1 month usage (27.6.21-13.5.2021) (early failure)
- ⇒ 2 x intact service life spare parts added (eval. date - 27.6.2021)

As described, it must apply here that all parts were defective at the same time, independently of one another, which is a deliberate simplification.

Weibull analysis for field with parts

Weibull evaluation for operating hours or km

If it is not the calendar time that determines the service life, but rather the actual useful life or the distance traveled in km, then information about the operating hours or the distance traveled is also required. A system may have mechanical and electronic components that can fail. For example, a vehicle transmission also has a control unit.

The number of operating hours is decisive for this, while the km distance is more relevant for the mechanical scope. If the system is evaluated as a whole, you have to decide on a unit. It is recommended to consider the critical component here and to relate the unit to it.

The calculation for operating hours or km is based on the same principles as described, except that the service life shown in the Weibull network is no longer the difference between repairs and the start of use, but the specified hours or km. The question, however, is how the intact units are scored. The answer is relatively simple if you have an average number of operating hours/month or mileage/month. With this, each period of use can be converted into months in the alternative "lifetime unit".

If the parts produced still have an expected lifetime of 10 months up to the evaluation date and the average mileage/month is 2000 km/month, then 20000km is entered in the table for these parts. The mean mileage distribution information can be estimated from the outage data by dividing the km by the usage time.

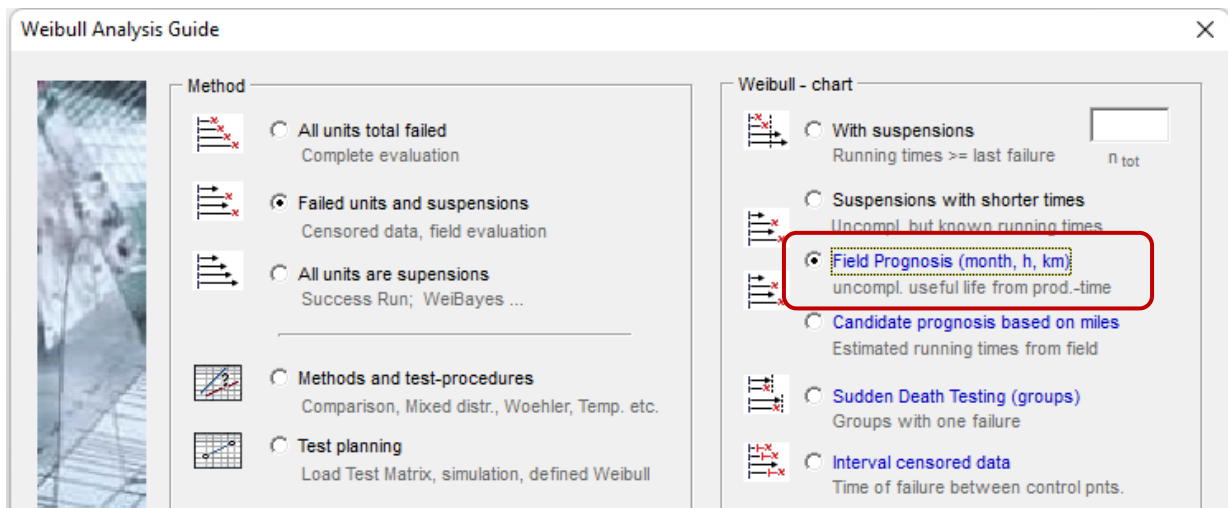
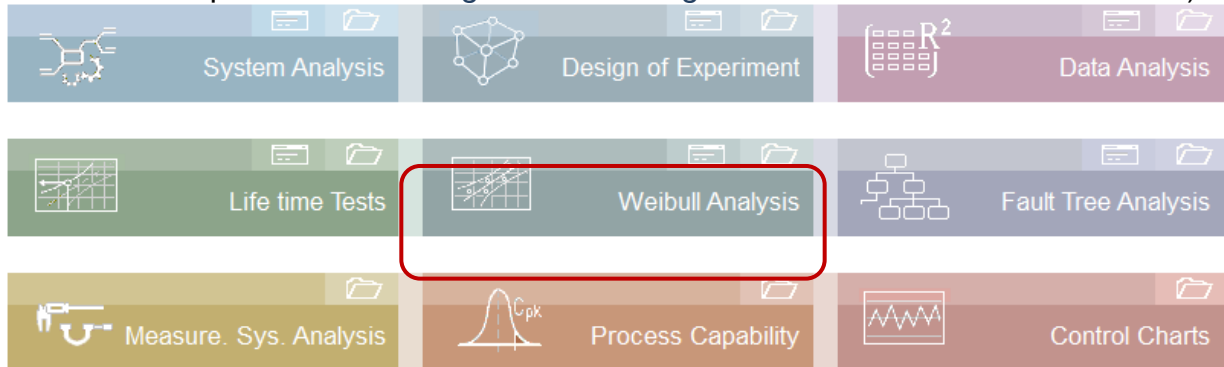
It should be noted that the determination of the running distance distribution from the complaint data is a one-sided random sample analysis. It is also said that this is a negative selection that only refers to failed units and is not representative of the whole. Therefore, if possible, the distribution of running distances should be obtained from other data sources that have a larger sample of at least 1000 units. The same applies to the distribution of operating hours.

Weibull analysis for field with parts

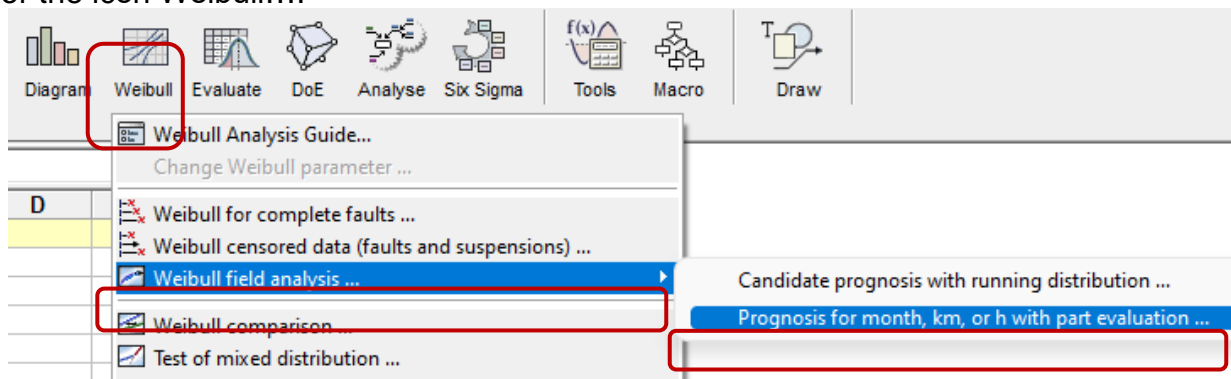
Using Visual-XSel 17.0

www.cgraph.com

To get started, use the Weibull analyzes in the guide (the menu items shown and the associated template *Weibull_Prognosis_Field.vxg* is available since version 17.0007).



or the icon Weibull....



After opening the template, a speech bubble appears for transferring the data from the clipboard. Be sure to use Paste. This also ensures that the sample data is deleted. A dialog appears for selecting the necessary data columns. A description of this follows below:

Weibull analysis for field with parts

A	B	C	D	E	F	G	H	I	J
	Ident	Prod. date	Start/regist	Repair date	Lifetime	Part/variant		Prod. dat.	Prod. size
1	BDN52353	15.3.2021	22.4.2021	30.6.2021	2,3	Change aggregate		3.2021	100
2	BDN52353	15.3.2021	22.4.2021	30.6.2021	12,3	Change aggregate		4.2021	100
3	BDN52353	15.3.2021	22.4.2021	30.6.2021	5,1	Powerunit		5.2021	100
4	BDN52353	15.3.2021	22.4.2021	30.6.2021	9,5	Circuit		6.2021	100
5	BDN52353	15.3.2021	22.4.2021	30.6.2021	9,5	Change aggregate		7.2021	100
6	BDN51721	16.4.2021	13.5.2021	27.6.2021	1,5	Change aggregate		8.2021	100
7	BDN51721	16.4.2021	13.5.2021	27.6.2021	1,5	joint top		9.2021	100
8	BDN51721	16.4.2021	13.5.2021	24.10.2021	5,4	joint lower			
9	BDN53214	22.4.2021	9.6.2021	23.9.2021	3,5	Change aggregate			
10	BDN53214	22.4.2021	9.6.2021	23.9.2021	9,2	Powerunit			

Use "paste" for your data
(deletes the data from the example)

Delete Paste

B Identification column may be empty if no information is available. It is then assumed that each row is an independent system.

C Column must be defined continuously. This is also used to calculate the range for which the production quantities are to be specified.

D Column with start or registration date can be empty. A delay time must then be specified, with the help of which the respective start date is estimated (Start = production date + delay time).

E The column for the repair date must also be filled continuously. This is used to calculate the useful life (useful life = repair - start). Furthermore, the corresponding service life for the spare part is determined from this.

If the data between repair and start/registration is implausible or incorrect, these complaints cannot be taken into account for the Weibull evaluation. An entry is made in column G, which is incorrect.

F Column: If this is empty, the time of use is written into this column F using the difference between repair and start described above. This also defines the unit of lifetime for the Weibull diagram. If data is specified here, this can be km or operating hours.

G Column for part designation may also be empty. It is assumed that only one component causes the complaints. If information is contained in column G, the number of different entries is evaluated as parts of the system if field L10 says "parts". This means that the production quantity times the number of parts is used as the basis n. If something else is specified in field L10, e.g. a country variant, the production quantity as in column J is used.

I and J Column: If you are not sure which production period the data covers, you can also leave columns I and J empty for the time being. After the first start of the macro with F9, column I is automatically filled correctly. It is possible to have a total number of units divided evenly, or to enter an individual number of units for each month.

The evaluation date in the L2 field is the date on which the table was last updated. From this, the useful life of the intact components are calculated (Time of use = evaluation date - time of use).

I	J	K	L	M
Prod. dat.	Prod. size		Eval. date	
3.2021	100		30.5.2022	
4.2021	100			
5.2021	100		Weibull-range right	
6.2021	100		auto	Month
7.2021	100			
8.2021	100		25	% Points
9.2021	100		0	% Points
			Parts	Meaning

Weibull analysis for field with parts

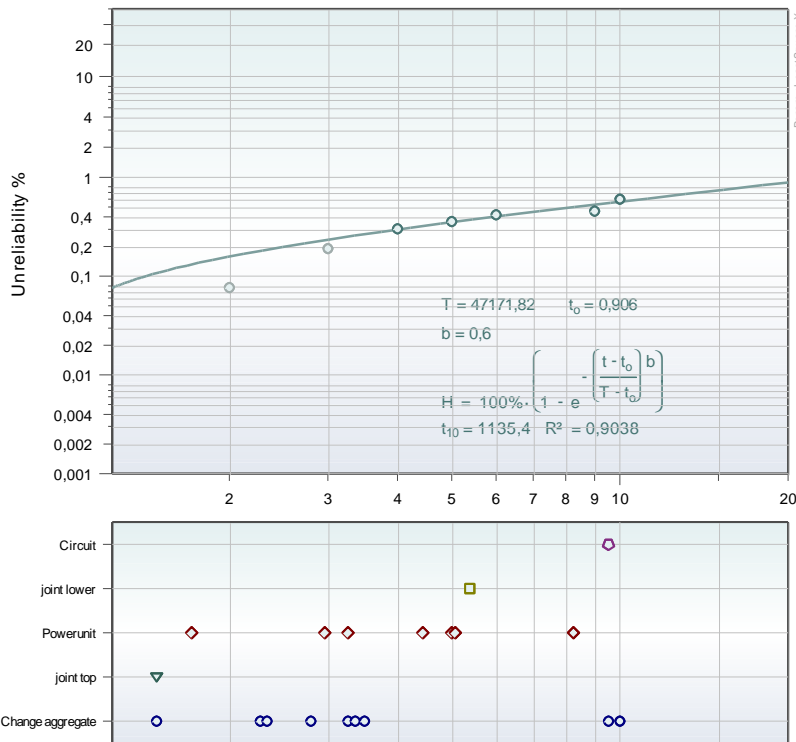
A final scale can be defined in field L5 for later Weibull representation. If it says "auto", the scale is determined based on the maximum useful life and extended for forecasts.

Column I for the production period should be calculated automatically after the first start of the macro with F9 and the production size should be filled in manually.

Various statistics are created through the actual evaluation with F9. The most important is the Weibull representation. Since so-called early failures often occur in production, 25% of the first points from the determination of the 3-parameter Weibull distribution are omitted by default. This value can be changed in field L7. You can also change the 3-parametric distribution by clicking the link in the speech bubble that appears when you mouse over the Weibull formula.

It should be noted that the calculations for the useful life are based on whole months. This is associated with a corresponding classification of the data. In the diagram of the individual components above the Weibull diagram, the exact times of use can be specified. This helps to recognize which components extend over which areas and possibly cause mixed distributions.

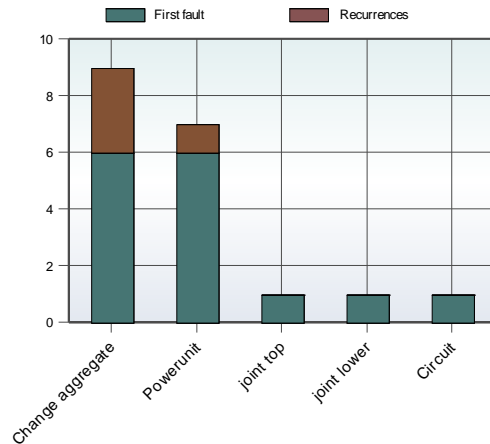
Weibull field analysis for month, hours or km
for systems mit one or more parts or failure modes



Statistics

Lifetime unit	month
Total number entries	19
Wrong entries	0
NumberParts	5
Number recurrence	4
Multiple parts exchange	3
Prod. size (system; comp)	700 3519
Production period	3.2021 9.2021
Registration period	4.2021 10.2021
mean. delay time (month)	1,1
Evaluation date	5.2022

Fault parts



Weibull analysis for field with parts

On the right side there is a table with the most important characteristics. If different components are listed, the Pareto distribution at the bottom right shows how often which part was exchanged.

Depending on the quality of the adaptation of the preset 3-parameter Weibull distribution, especially in the run-out, the so-called double exponential distribution can also be used as an alternative. For this move over the Weibull-formula and press the link in the speech bubble.

