Reliability Analysis using the Reliability Prognosis Model (RPM) of Wuppertal

The Reliability Prognosis Model of Wuppertal is a functional tool for performing valid and fast analysis of warranty or fair dealing data. The results of the reliability prognosis are applicable for answering multiple questions regarding warranty, quality, reliability, safety or supply chain issues. The following information gives a brief overview about the benefits and the required data of reliability prognosis. Furthermore, a short process of the model will be given.

1 Benefit of the Reliability Prognosis Model

As mentioned, the Reliability Prognosis Model can be used to answer questions concerning multiple issues. The main focus formerly was in determining reliability characteristics for the research and developing department. While improving the model within the last years several new applications were made. The following points give a short overview about using the RPM.

1.1 Warranty Management

- Calculation of future warranty costs
- Supporting the risk management for warranty extension
- Calculation of serial spare parts or End-of-Life components for spare part management
- Uncover warranty fraud
- Possibility to assess supplier
- Statistical analysis of registration delay (e.g. Optimization of Supply-Chain-Management)
- Statistical analysis of reporting delay (Optimization of Information Process Supplier-OEM or internal)

1.2 Functional Safety (ISO 26262, IEC 61508)

- Calculation of own hazard rates concerning the real load of the relevant components
- Usage for proven-in-use-argumentation corresponding to ISO 26262
- Conformity to standards

1.3 Information for Research & Development (R&D)

- Evaluation of system modifications
- Support for assessing new components
- Usage of proven-in-use-components

- Feedback for R&D

1.4 Common Advantages

- Statistical analysis of company own field data using an approved model
- Application at well-known OEM and supplier for years
- Both single analysis of data and interpretation of experts possible
- Continuous enhancement (State-of-the-art of science)

1.5 Specific statistic values (selectable modules)

- Analysis of driving behavior by theoretical distribution function (Weibull-, lognormal-, normal distribution)
- Calculation of theoretical km-dependent reliability characteristics (failure function, reliability function, hazard rate, failure rate)
- Possibility of choosing different Failure functions (Weibull-, lognormal, normal distribution), additional calculation of stability index
- Graphical output of empirical and theoretical reliability characteristics (also for additional visual control)
- Possibility of choosing different parameter estimations or manual fitting by means of a wizard function
- Calculation of failure candidates by means of the method of Pauli in case of censored data
- Module to deal with time-near warranty data (concerning registration and reporting delay including graphical output)
- Module concerning sub-populations (epidemic root cause)
- Calculation of theoretical time-dependent reliability characteristics based on km-dependent reliability characteristics (including the specific load by using the driving behavior)
- Possibility of calculating constant hazard rates for a defined time span (e.g. further application in Fault-Tree-Analysis, Reliability-Block-Diagram, Markov-Process, etc.)
- Graphical output of theoretical time-dependent reliability characteristics
- Automatic calculation of warranty costs
- Automatic calculation of serial spare parts
- Automatic calculation of End-of-Life components
- Module concerning the customer behavior

2 Required Data

The Reliability Prognosis Model of Wuppertal is based on field data. Therefore, the output of the model is only as good as the given data. There are some information that have to be given if a time-dependent reliability prognosis hast to be performed. Furthermore, the precision of the model can be improved if additional information is available. Also additional questions can be answered if needed (opt.):

- **Registration date of the car,**
- **Failure date** and **Mileage until Failure Date,**
  - if this information is not known the repair date can be used as a substitute
- **Repair Date** and **Mileage until Repair Date,**
- **Guarantee period,**
- **Allocation base** for the period under observation (if not known, the allocation base can be determined out of the amount of registered cars, the selling quantity or the production quantity
  - *opt.: partitioned into months,*
- **Sub-segment factor:** Ratio of the observed market to the whole selling market of the component (opt.: additionally divided into customers)
- **Return rate:** Ratio of defective components, send back for checking
- *Manufacturing date of the car*
  - *opt.: if registration delay should be considered,*
- *Entry date of the guarantee case*
  - *opt.: if reporting delay should be considered,*
- *ID-number (e.g. part number) of the component, if different components are included (opt.)*
- *Important additional information (e.g. defective part, failure description, country specific information) for differentiated analyses (opt.).*

As always essential for data analysis: The more precise the data is collected, the better it is suitable for prognosis.

3 Process reliability prognosis model

In the following figure 1 the general process of the RPM of Wuppertal is shown.

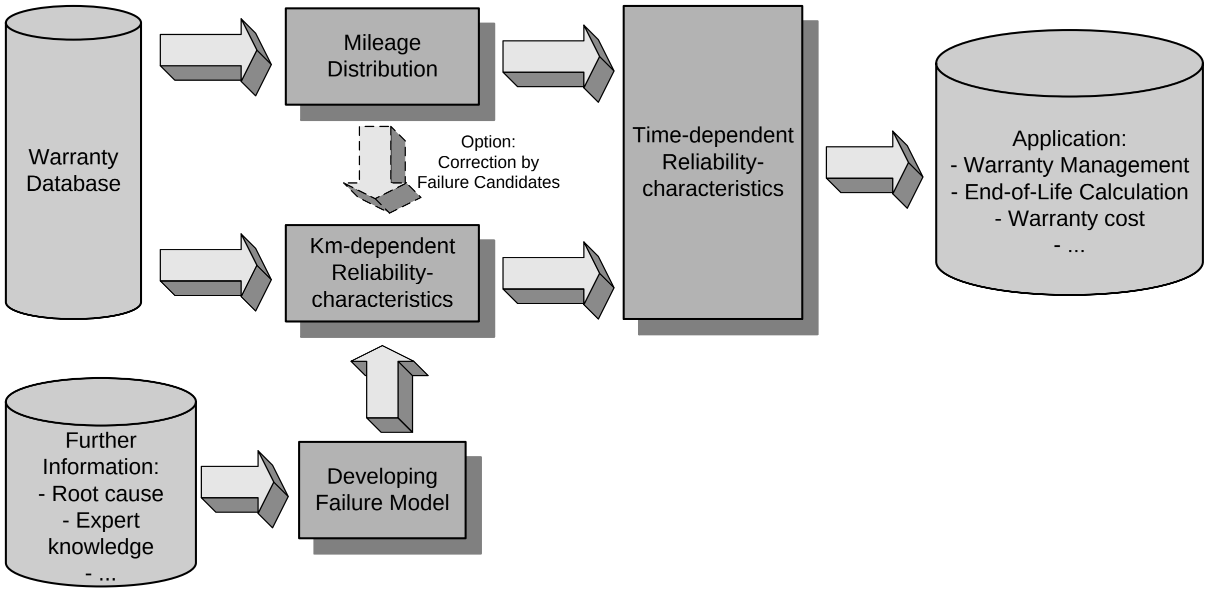

Figure 1: Process diagram of Reliability Prognosis Model of Wuppertal

The model has three major steps, which were not described in detail below.

Step 1:

Out of the available data an annual mileage will be determined. The mileage is used for comparative purposes and in further calculations because it can be handled very easy. As can be shown for passenger cars a lognormal distribution is well suitable for fitting a distribution. Also a Weibull distribution delivers good results. For trucks typically a normal distribution can be taken as a basis.

Step 2:

In parallel to the mileage distribution the km-dependent characteristics will be determined. By using the mileage of the guarantee time, which can be transformed out of the annual mileage, so called failure candidates can be calculated, which will increase the forecast goodness. Failure candidates are those future failures, which will appear at the vehicles at a certain mileage to a later point of time. From many researches arose, that a Weibull distribution fits the empirical data best and that the resulting parameters can be compared well to other results. If necessary, the distribution function can be expanded to fit a sub-population.

Step 3:

In automotive industry time-dependent reliability characteristics are preferred due to a better manageability. These characteristics can be derived out of a clever combination of the mileage distribution and the km-dependent reliability characteristics and therefore directly out of the derived characteristics. As result calendar time-dependent characteristics are achieved, which follow the same distribution supposed in step 2 and which only differ in the values of the distribution parameters. Afterwards by using those results there can be answered many questions with regard to reliability issues, supply chain management or quality management (see chapter 1).