Component Reliability in the T-Book – The New Approach

Presentation at PSAM 12, Monday 6/23/2014, Honolulu, Hawaii, USA

Lloyd's Register Consulting

Working together
for a safer world

Outline

- Introduction and brief history of the T-Book
- Summary of previous work (since 2005)
  - Study of the statistical methods used in the T-Book
  - Test and analysis of homogeneity
  - Pros and cons using a using a multi-parametric model
  - Evaluation of grouping criteria
- Homogeneous grouping of components
- Multi-parametric model for standby components
- Conclusions

Introduction and brief history

- Main objective of the T-Book is to provide Nordic reliability data for each component that is considered a PSA.
- The failure characteristics are primarily based failure reports and LORs stored in the central database TUD.
- The T-Book comprises only critical failures, i.e. failures that stop the function of components or lead to repair
- Several projects launched with purpose to improve the methods and tools used.
- The presentation will briefly summarize what has been done since 2005 and what is currently ongoing.

Table 1: T-Book history

Version	Year	Comment
1	1982	Operational statistics from 21 reactor years
2	1985	Operating data covering about 40 reactor years
3	1992	Data up to the operating year 1987 included (108 reactor years)
4	1994	Data up to the operating year 1992 included (178 reactor years)
5	2000	Data up to the operating year 1996 included (234 reactor years)
6	2005	Data up to the operating year 2005 included (315 reactor years)
7	2010	Data up to the operating year 2007 included (378 reactor years)

Study of the statistical methods used in the T-Book (2006)

- The two-stage Bayesian method used in the T-Book has been specifically developed for the T-Book and is particularly appropriate when data is extremely sparse.
- It is however considered somewhat non-transparent and therefore it was studied if it could be simplified or even replaced by a simpler alternative, if there is one.
- Even though an alternative method developed was identified, the work conducted after this first thesis work has however been focused on:
  - verification of the existing method and
  - component grouping.

Test and analysis of homogeneity (2009)

- The objective was to study homogeneity.
- The T-Book method comprises an assumption of inhomogeneity among the components of a population.
  - For inhomogeneous components it is possible to assign a specific failure rate for each individual component
  - For homogeneous components data can be pooled before a common reliability parameter is derived representing all components in the group
- The objective was to design a statistical method for testing the homogeneity of Nordic data with emphasis on their failure rate
- Tests showed that the failure intensity for continuously operating components for most populations are **homogeneous**
- The test results also indicated that populations of standby components are to a larger extent **inhomogeneous**

Pros and cons using a using a multi-parametric model (2010-2011)

- Using a two parametric model (q_0+λt) deviates from international praxis for stand-by components.
- The model is though intuitively attractive because standby components are naturally associated with two different failure mechanisms.
- Two challenges were pointed out :
  - **Pooling of data has positive impact on PSA.**
    - However, the q_0+λt model implies that data cannot be pooled.
  - **Can a multi-parametric model be used for sparse data?**
    - Challenging even for single parametric models.
- Thus, to keep the q_0+λt model, it has to demonstrated that:
  - the advantages of the model overrides the advantages of pooling data,
  - the model is well suited for the area of application.

Evaluation of grouping criteria (2010-2011)

- Pooling of data has positive impact on PSA, e.g. decreased uncertainty.
- Pooling require groups to be homogeneous, which has not been verified for the T-Book.
- ➢ Thus, alternative grouping criteria was studied.
  - German ZEDB use function oriented grouping criteria which is assumed to result in homogeneous groups (pooling of data).
- Based on this it was concluded that application of function oriented criteria would split up the groups as they are defined today.
- It was recommended to introduce statistical tests to verify homogeneity.
- Alternative grouping together with the test would therefore enhance the quality and usability of presented parameters.

Homogeneous grouping of components

- A pilot study was performed in 2011 that evaluated the conditions for adoption of the ZEDB grouping criteria into the TUD framework
- An underlying concern was that T-Book distributions are restrained because they are derived component-wise and then weighed together plant-wise.
  - Neither parameter sampling nor event sampling will be fully applicable.
- The ZEDB function oriented grouping was applied to pumps for benchmarking purpose.
- This implies the following conditions to be applied:
  - Components in the same group have to have a similar function.
  - There has to be a sufficient amount of operational data for the components.
    - Not always possible to derive function oriented groups due to sparse data

Homogeneous grouping of components (cont)

- Benchmark between ZEDB and T-Book groups had the purpose to answer following questions:
  - Do the groups match?
  - What is making the difference?
  - Is it possible to overcome discrepancies?
- As a rule, the groups match quite well with three main sources for differences:
  - Design differences
  - Systems not separated
  - No distinction between BWR and PWR
- But, re-grouping T-Book components groups will reduce amount of data for each group.
- Purpose was therefore to function oriented grouping criteria for the pumps and to verify that the derived group are homogeneous (pooling of data).

Multi-parametric model for standby components

- The $q_0+\lambda t$ model has been used since 3rd version of the T-Book to estimate failure probability for stand-by components.
- Due to sparse data it has been concluded that the method do not work satisfactorily in all cases.
- In previous work it has been demonstrated that:
  - The model gives about the same results as the simpler λt model when the amount of data is sufficient.
  - For some component groups, a constant failure probability can be assumed to represent the dominating contribution.
- One part of the work T-Book version 8 is to develop criteria to decide when to use $q_0+\lambda t$ model and when to use either λt or q_0.
- The method should be able to demonstrate to what degree operating experience data supports the use $q_0+\lambda t$ model.

Conclusions

- The work performed is significant progress in terms of the quality of the data presented in the T-Book.
- However, there are, and will always be, considerations that need to be taken into account, such as:
  - Is it possible to establish a clear and definitive criterion that supports the choice of which method to use for deriving failure probability q and intensity ν?
  - Can it be demonstrated that the $q+\nu_s t$ model is suitable to use even though this will mean that it will not be possible to pool data?
    - For component groups with sparse data this means that the benefit of pooling can be greater than the benefit of using $q+\nu_s t$ model.
  - Can it be demonstrated that the reliability data derived is not optimistic for all components?
- In the coming T-Book version 8 the plan is to have two parallel versions (old and new methodology), but in future versions the old approach will be phased out.

Co-authors:
Erik Persson Sunde — Lloyd's Register Consulting
Magnus Gudmundsson — Vattenfall

Anders Olsson
Principal Consultant
T +46 70 733 43 08 E anders.olsson@lr.org

Lloyd's Register Consulting
www.lr.org/consulting

Lloyd's Register Consulting

Working together
for a safer world