Chapter 14
Reliability Databases

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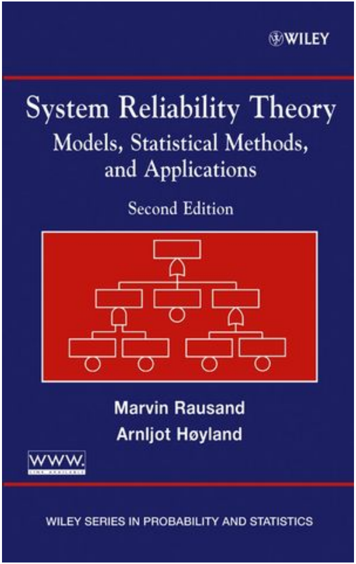
Slides related to the book

System Reliability Theory
Models, Statistical Methods,
and Applications

Wiley, 2004

Homepage of the book:
http://www.ntnu.edu/ross/books/srt



Purpose

The purpose of this slide series is to:

- Introduce and discuss different data types
- Give examples of different data sources
- Present an approach for estimating reliability data, when limited experience is available for the prevailing operating environment

Types of data

Many different types of data (or information) may be relevant in the analysis of system reliability:

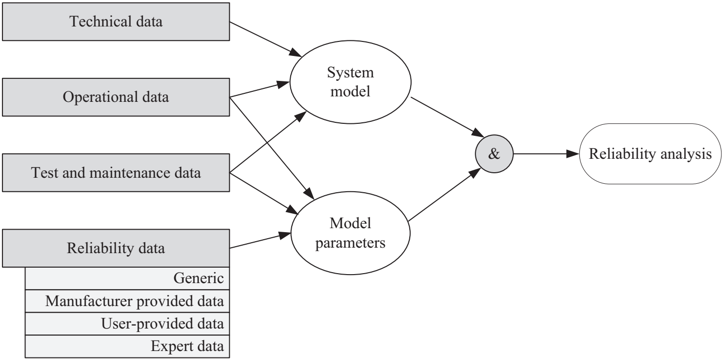
- Technical data/information: Data and information that is needed to identify and understand how elements, channels and subsystems are operating
- Operational data: Data and information about mode of operation, environmental exposure, operating conditions and so on
- Reliability data: Failure rates or mean time to failure (MTTF), or data that support the estimation of these. The following sub-categories of reliability data are often used:
- Test and maintenance data: Associated data of relevance for the analysis related to testing and maintenance, such as proof test intervals, mean test or inspection time, mean repair time, diagnostic test intervals, mean restoration time after a DD failure, proof test coverage, and so on.

Types of *reliability* data

Reliability data may be classified into:

- Generic data: Data collected by an organization and published in handbooks. The collected data may be for specific component types (not brands), and may be a combination of operating experience, manufacturer data applicable for a specific industry sector or specific usage conditions.
- Manufacturer provided data: Data provided for a particular component brand, based on manufacturers internal statistics on reported failures, in-house testing, or failure rate estimation techniques.
- User-provided data: Data collected by a specific user, at a specific site or plant or for a selection of sites/plants.
- Expert judgment: Data constructed on the basis of experts opinions and experience. May be an option when systematic data collection has not been carried out or when new technology is introduced to a system.

Application of data



Types of Reliability Databases (or sources)

- Component failure event databases:
  Typically extracted from a site's or plant's maintenance system, and is not accessible unless approved by the site/plant owner
- Accident and incident databases:
  Published by organizations and authorities), often with basis in mandatory reporting of serious incidents (e.g., events with a major accident potential) or accidents.
- Component reliability databases:
  Data handbooks and data bases constructed on the basis of generic data.

Generic data sources

A high number of generic data sources are available:

International standards	Others	Offshore/Process industry
IEC 61709	MIL-HDBK-217F	OREDA
IEC TR 62380	NPRD-2011 (RIAC)	PDS data handbook
ISO 13849-1	FIDES	Exida
	Telecordia SR332	
	Siemens SN29500	
	MechRel Handbook (NSWC-11)	

More information about each data source is provided in the textbook.

Limited applicability of generic data

E/E/PE technology is developing fast, an generic data provided at the component level (e.g., a logic solver) becomes outdated almost before it is published.

- In order to use generic data, it may be necessary to *adjust* the data according to new technology attributes, new environmental conditions, new operating conditions, and so on
- This slide series explains the approach suggested by Brissaud et al (2010). See the more exact reference in the textbook.

Approach - 1

Basic assumption:

- A plant-specific failure rate, λ_{P}, may be estimated with basis in a nominal (generic) failure rate, λ_{B} and the values assigned to a set of influencing factors:

$$\lambda_{\mathrm{P}} = \lambda_{\mathrm{B}} \cdot \prod_{i=1}^{k} \omega_{\mathrm{i}} \cdot \sigma_{\mathrm{c,i}} \tag{1}$$

where k is the number of influencing factors, ω_{i} is the weight of the influencing factor, and $\sigma_{\mathrm{c,i}}$ is the value assigned to influencing factor i, with $i = 1 \cdots k$.

Approach - 2

Steps:

1. Estimate λ_B in a normal operating context, using generic reliability databases, observed failures, or expert judgments. There is no specific rules about confidence limits, but it may be considered if a more conservative value should be selected rather than a maximum likelihood/mean value.
2. Identify factors that are considered to have the highest influence on the component's failure rate. Try to keep the number of factors as low as possible, and combine factors that are highly dependent on each other. For the k remaining factors, do as follows:
   - Denote each influencing factor y_1, y_2 ..y_k
   - Define the *nominal level* (e.g. industry average) for these factors, and denote these by: $y_{0,1}$, $y_{0,2}$ ..$y_{0,k}$.

Approach - 3

Example of values assigned as nominal for a selection of influencing factors:

Example

No	Influencing factor	Nominal value	No	Influencing factor	Nominal value
1	Temperature	-5^o - $+20^o$ C	4	Technology maturity	High
2	Environment	Outside, offshore	5	Diagnostic coverage	75%
3	Frequency of use	< 1 per year	6	Testing/ inspection frequency	1 year/ 1 year

Approach - 4

Steps:

3. Weight the influencing factors, using input from several experts and physical and engineering knowledge. Make sure that $\sum_{i=1}^{k} \omega_i = 1$.
4. Record the current (i.e. plant-specific) level of the influencing factors and denote these by $y_{c,1}$, $y_{c,2}$ ..$y_{c,k}$

Example: Adding weight

Example of values assigned as nominal for a selection of influencing factors, with possible weights added:

Example

No	Influencing factor	Nominal value	Weight	No	Influencing factor	Nominal value	Weight
1	Temperature	-5^o - $+20^o$	15%	4	Technology maturity	High	15%
2	Environment	Outside, off-shore	20%	5	Diagnostic coverage	75%	15%
3	Frequency of use	< 1 per year	20%	6	Testing/ inspection frequency	1 year/ 1 year	15%

Example: Assigning plant-specific values

Example

No	Influencing factor	Nominal value	Weight	No	Influencing factor	Nominal value	Weight
1	Temperature	-5^o - $+20^o$	15%	4	Technology maturity	Medium (due to design changes)	15%
2	Environment	Subsea, 400 m water depth	20%	5	Diagnostic coverage	90%	15%
3	Frequency of use	< 1 per year	20%	6	Testing/ inspection frequency	1 year/ 5 years	15%

Approach - 5

Steps:

5. Determine a score $\sigma_{c,\,i}$ for each influencing factor y_i, $i = 1, 2 \ldots k$, using the following rules:
   - $\sigma_{c,\,i} = 1$, when $y_{c,\,i} \approx y_{0,\,i}$
   - $\sigma_{c,\,i} < 1$, when $y_{c,\,i}$ is more *benign* than $y_{0,\,i}$
   - $\sigma_{c,\,i} > 1$, when $y_{c,\,i}$ is more *hotile* than $y_{0,\,i}$
6. Calculate the plant-specific λ_{P} using e. (1).

The approach does not specify how much > 1 or how much < 1.

Example: Calculating λ_P

Example: Quantifying λ_P

In this example, we assume that:

- $\sigma_{c,i} = 0.5$, when $y_{c,i}$ is more *benign* than $y_{0,i}$
- $\sigma_{c,i} = 5.0$, when $y_{c,i}$ is more *hotile* than $y_{0,i}$ (except for influencing factor 2, where 10 is used)

We also assume that $\lambda_B = 2.6 \cdot 10^{-6}$ per hour.

$$\begin{aligned} \lambda_P &= \lambda_B \cdot \prod_{i=1}^{k} \omega_i \cdot \sigma_{c,i} \\ &= 2.6 \cdot 10^{-6} [0.15 \cdot 1 + 0.20 \cdot 10.0 + 0.20 \cdot 1 \\ &\quad +0.15 \cdot 2.0 + 0.15 \cdot 0.5 + 0.15 \cdot 2.0] = 1.02 \cdot 10^{-5} \text{ per hour} \end{aligned}$$

There is of course uncertainties associated with this result: Have all relevant influencing factors been captured? Are the weights reasonable? Are the values of $\sigma_{c,i}$ reasonable?

Data dossier - 1

It is important to document what the sources for each data used in a reliability assessment.

☞ Data dossier: A data sheet that presents and justifies the choice of data for each element included in the reliability model.

An example of a data dossier is shown on the next slide. Also data handbooks may provide similar layout of their data dossiers.

Data dossier - 2

Data dossier

Component: Hydraulically operated gate valve

System: Pipeline into pressure vessel A1

Description: The valve is a 5-inch gate valve with a hydraulic "fail safe" actuator. The fail safe-function is achieved by a steel spring that is compressed by hydraulic pressure. The valve is normally in the open position and is only activated when the pressure in the vessel exceeds 150 bar. The valve is function-tested once a year. After a function test, the valve is considered to be "as good as new." The valve is located in a sheltered area and is not exposed to frost/icing.

Failure mode:	Failure rate (per hour):	Source:
- Does not close on command	3.3×10^{-6}	Source A
	1.2×10^{-6}	Source B
- Leakage through the valve in closed position	2.7×10^{-6}	Source A
- External leakage from valve	4.2×10^{-7}	Source A
- Closes spuriously	3.8×10^{-6}	Source A
	7.8×10^{-6}	Source B
- Cannot be opened after closure	1/300	Expert judgment

Assessment:

The failure rates are based on sources A and B. The failure rate for the failure mode "cannot be opened after closure" is based on the judgments from three persons with extensive experience from using the same type of valves and is estimated to one such failure per 300 valve openings. Source B is considered to be more relevant than source A, but source B gives data for only two failure modes. Source B is therefore used for the failure modes "does not close on command" and "closes spuriously", while source A is used for the remaining failure modes.

Testing and maintenance:

The valve is function-tested after installation and thereafter once per year. The function test is assumed to be a realistic test, and possible failures detected during the test are repaired immediately such that the valve can be considered "as good as new" after the test. There are no options for diagnostic testing of the valve.