Chapter 6.
Reliability Data Sources

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Learning Objectives

The main learning objectives associated with these slides are to:

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

The slides include topics from Chapter 6 in **Reliability of Safety-Critical Systems: Theory and Applications**. DOI:10.1002/9781118776353.

Outline of Presentation

Types of Data

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

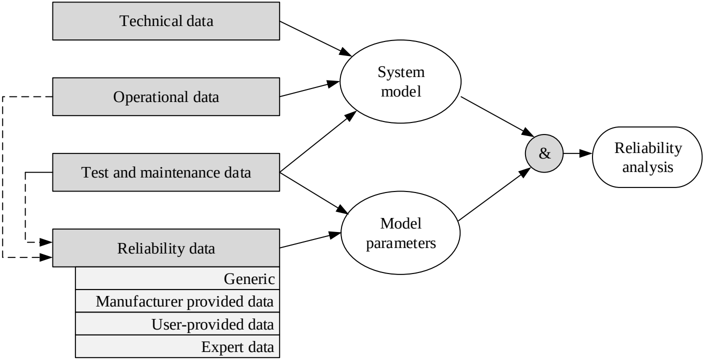
- **Technical data/information:** Data and information that is needed to identify and understand how elements, channels and subystems are operating
- **Operational data:** Data and information about mode of operation, environemental exposure, operating conditions and so on
- **Reliability data:** Failure 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 maintenenance, 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 usagen conditions* (e.g., offshore oil and gas industry).
- **Manufacturer (brand) 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 (experience) 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 Data Sources

- **Maintenance system:**
  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:

Standards	General	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.

Data Dossier

It is important to document where the failure rates origin from, and what assumptions that have been made.

☞ 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 in the textbook. Also data handbooks may provide similar layout of their data dossiers.

Data Dossier in PDS Data Handbook

5.1.10 Smoke Detector

Module: Input Devices Component: Smoke Detector	**PDS Reliability Data Dossier**
Description / equipment boundaries The detector includes the sensor and local electronics such as the address-/ interface unit.	***Date of Revision*** 2009-12-18 ***Remarks*** Fire central not included

Recommended Values for Calculation

Total rate	*Coverage*	*Undetected rate*
λ_D = 1.2 per 10^6 hrs	c_D = 0.40	λ_{DU} = 0.7 per 10^6 hrs
λ_S = 2.0 per 10^6 hrs	c_S = 0.30	λ_{SU} = 1.4 per 10^6 hrs
λ_{crit} = 3.2 per 10^6 hrs	P_{TIF} = $1 \cdot 10^{-3}$	
	r = 0.4	

Assessment

The failure rate estimate is an update of the 2006 figure which was primarily based on OREDA phase III as well as some phase V data. The rate of DU failures is estimated still assuming coverage of 40 % (observed in OREDA incomplete and complete phase III were 29% and 50%, respectively). The rate of dangerous and safe failures has been slightly decreased based on observations from failure reviews and later OREDA phases. For safe failures 30 % coverage - mainly based on OREDA phase III observations as well as expert judgement - has been assumed. It should be noted that for some type of smoke detectors with more extensive self test, the coverage may be significantly higher. This must be assessed for each specific detector type.

The P_{TIF} is based on expert judgements and is based on the assumption that the detectors are exposed. The estimated r value is based on observed failure causes for critical detector failures (40% "expected wear and tear" and 60% "maintenance errors"). A summary of some of the main arguments is provided in section 3.3.

Failure Rate Reference

Overall failure rate (per 10^6 hrs)	*Failure mode distribution*	*Data source/comment*
λ_{crit} = 3.7	λ_D = 1.3 per 10^6 hrs λ_{DU} = 0.8 per 10^6 hrs λ_{STU} = 1.4 per 10^6 hrs P_{TIF} = 10^{-3}	Recommended values for calculation in 2006-edition, [12] Assumed c_D = 40%
λ_{crit} = 3.7	λ_D = 1.3 per 10^6 hrs	Recommended values for calculation in 2004- and

New technology

New technology is by DNV-GL RP considered as:

- (Totally) new technology (unproven design principles)
- Proven technology in new environment
- Proven technology operated in a new way

How can we identify applicable reliability data in this case?

New technology and SIS

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.

Is it possible to apply previous reliability data at all?

Brissaud et al (2010) have proposed an approach for this purpose. See the more exact reference in the textbook.

A Suggested Approach

1. Identify λ_B, using generic reliability databases, observed failures, or expert judgments for the reference (proven) technology. 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 assumed to be highly influential for this 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: $y_{0,1}$, $y_{0,2}$ ..$y_{0,k}$.

A Suggested Approach (cont.)

Example of nominal values 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

A Suggested Approach (cont.)

3. Weight the influencing factors, using input from several experts and physical and engineering knowledge. Make sure that $\sum_{i=1}^{k} \omega_i = 1$.

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%

A Suggested Approach (cont.)

4. Identify the new values of the influencing factors and denote these by $y_{c,1}$, $y_{c,2}$ ..$y_{c,k}$

Example

No	Influencing factor	New value	Weight	No	Influencing factor	New value	Weight
1	Temperature	$0 - +4^o$	15%	4	Technology maturity	Medium (due to design changes)	15%
2	Environment	Subsea, 400 meter 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%

A Suggested Approach (cont.)

5. Determine the effect of the new values $\sigma_{c,\,i}$ 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 *hostile* than $y_{0,\,i}$
6. Calculate the failure rate λ_{P} for the new technology using equation (1) on next slide

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

A Suggested Approach (cont.)

Equation:

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

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 $i = 1 \cdots k$.

A Suggested Approach: Case study

In this example, we assume for the 6 influencing factors that:

- $\sigma_{c,i} = 0.5$, when $y_{c,i}$ is more *benign* than $y_{0,i}$
- $\sigma_{c,i} = 2.0$, when $y_{c,i}$ is more *hotile* than $y_{0,i}$ (except for influencing factor i=2, where a value σ of 10 is used)

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

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

A Suggested Approach: Some Considerations

There are several questions that may arise, and that may influence the uncertainty associated with the new failure rate:

- Have all relevant influencing factors been captured?
- Are the weights reasonable? Will also the weights change with the new technology?
- Are the values of $\sigma_{c,i}$ reasonable?

A reasonable question is how to capture and express uncertainty about the failure rate in this context. This is not a part of the method as it is now.