



Safety Instrumented System reliability evaluation with Influencing Factors

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Introduction

- **Safety Instrumented System (SIS) reliability evaluation**
 - IEC 61508: probabilities of failure
 - the relevance of existing models strongly depends on the quality of input data as *failure rates*
- **Influencing factors [relating to the reliability]**
 - *the internal and external parts of an item which act on its reliability, for example by causing failure rate changes*
 - e.g. design, material properties, solicitation, environment...
- **For risk analysis**
 - to allow a more efficient risk management by acting both on systems and environment / conditions of use

Introduction

- **Failure rate evaluation**

- reliability data feedbacks (statistical models)
 - may include influencing factors (Cox model, neuronal network...)
 - require significant equipment field and appropriate procedures
- data handbooks
 - systems are sometimes very heterogeneous
 - generic values do not always fit system specificities
- predictive models (physical models)
 - electronic components: MIL HDBK 217, FIDES, RDF, Telcordia...
 - mechanical components: NSWC
- frameworks for human and organizational factors
 - in risk analysis: WPAM, RIA, ORIM, ARAMIS, BORA-Release...
 - tools have been developed for expert judgments



failure rate evaluation with influencing factors – frewif methodology

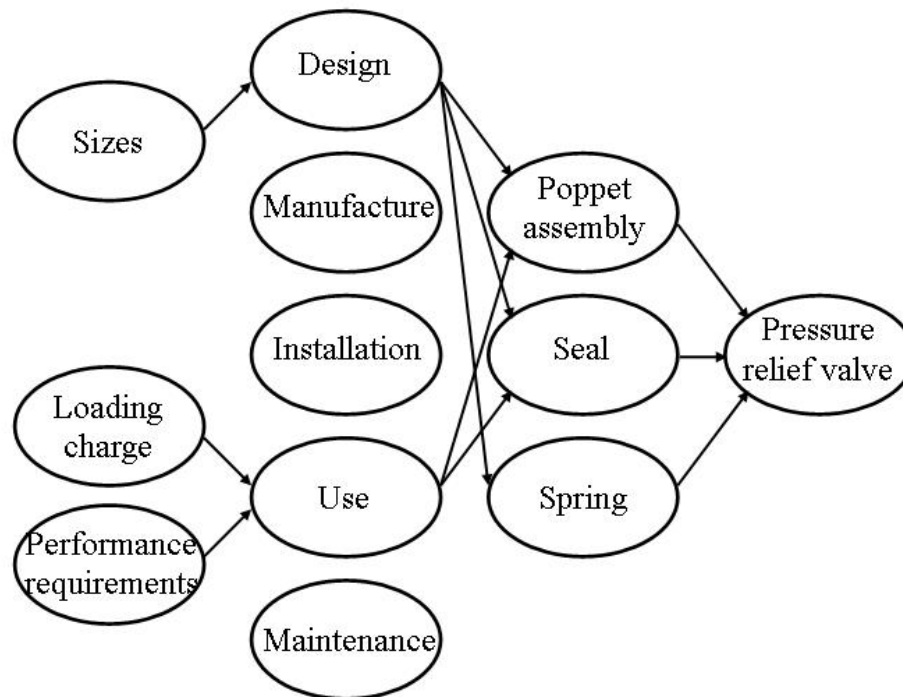
1. Case study presentation
2. Qualitative analysis
3. Quantitative part
4. Results

1. Case study presentation

- **Presentation**
 - seven ***safety relief valves***
 - different design, environment and conditions of use
 - few feedback data
- **Aim**
 - ***evaluate the failure rate*** of each valve by tacking into account the ***influencing factors*** → to have argued and coherent results
- **How**
 - compensating the lack of knowledge by a qualitative analysis
 - integrating the available data by a quantitative part

2. Qualitative analysis: RID

- Reliability influencing diagram (RID)



- Main component groups

- **poppet** (70% of failure causes)
- **seal** (5% of failure causes)
- **spring** (25% of failure causes)

- Relevant life cycle phases

- design
- use

- Influencing factors (with weight)

- **sizes** (3): small, medium or big
- **loading charge** (2): low, medium or high pressure
- **performance requirements** (1): restrictive or indulgent allowable leakage rate

2. Qualitative analysis: some tools

Category	Influencing factors
Design	System type Working principle Sizes (height, volume, weight) Materials Component quality (quality requirements and controls) Special characteristics (supply)
Manufacture	Manufacturer Manufacture process (procedures, controls)
Installation	Location (access facilities) Assembly/Activation (procedures, controls)
Use	EUC* EUC* type Special characteristics Solicitation Type of load (cycling, random) Frequency of use Loading charge/Activation threshold Electrical load (voltage, intensity)
Environment	Mechanical constraints (vibration, friction, shocks) Temperature Corrosion/Humidity Pollution (dust, impurities) Other stresses (electromagnetism, climate)
Requirements	Performance requirements Failure modes (recorded failures)
Maintenance	Frequency of preventive maintenance Quality of preventive maintenance Quality of corrective maintenance

* Equipment Under Control

- Selection of influencing factors and corresponding indicators

- it is possible to measure or evaluate the states
- the states have to allow making difference between systems
- exhaustive for reliability

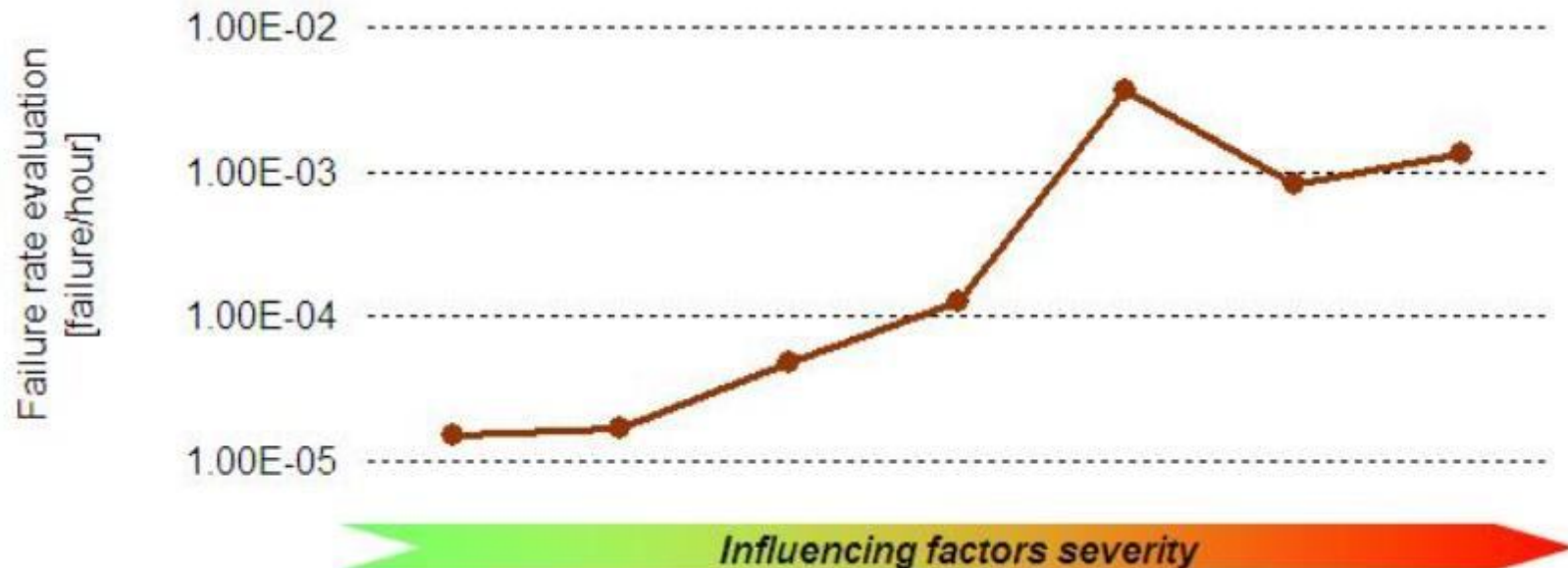
- Setting indicator states

- technical reports
- operational / feedback data
- measurements
- investigation with key staff
- ...

- Rating influencing factors

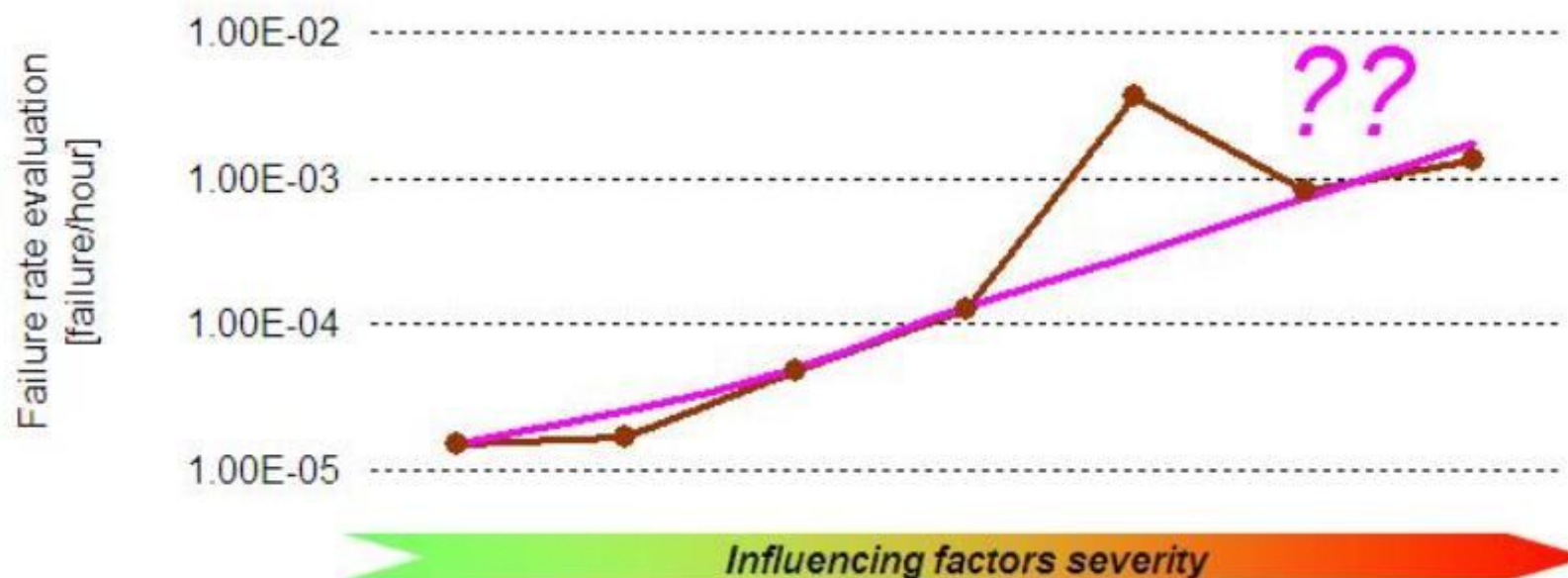
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3. Quantitative part



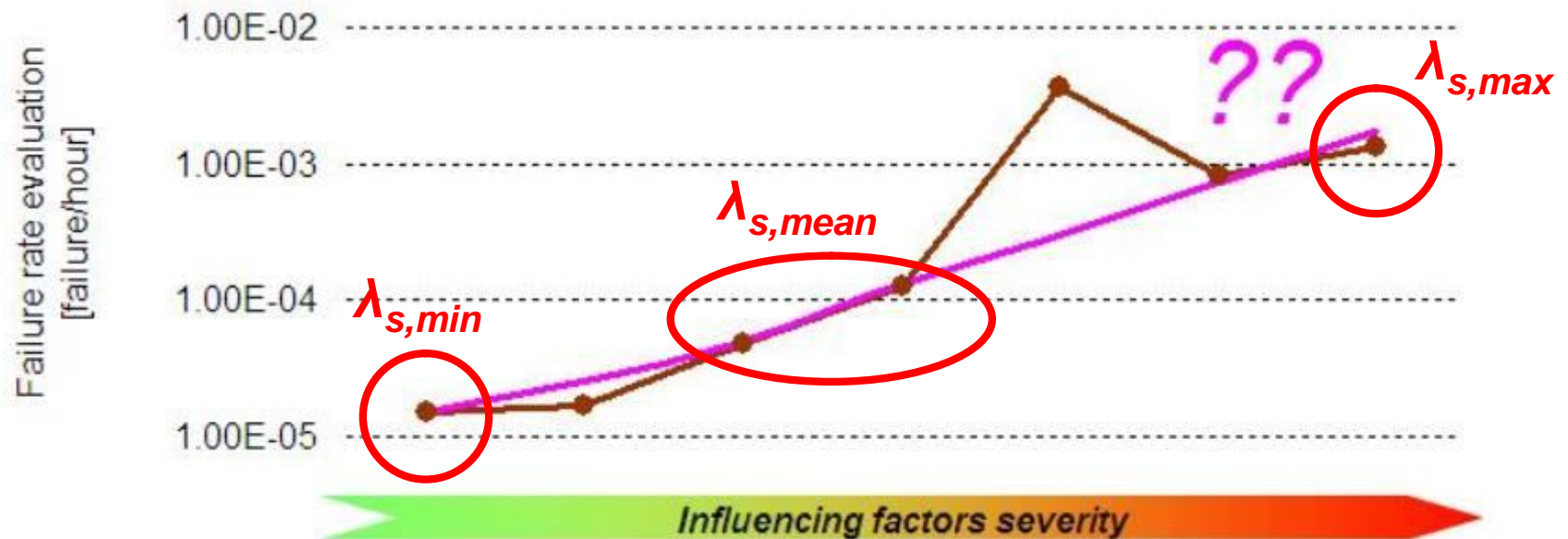
Valve	#1	#2	#3	#4	#5	#6	#7
Sizes	good	good	medium	medium	bad	bad	bad
Loading Charge	good	medium	medium	medium	medium	bad	bad
Perf. Requirement	good	good	good	bad	bad	good	bad
MLE (3 TtF/Valve)	1.52E-05	1.66E-05	4.77E-05	1.28E-04	3.65E-03	8.23E-04	1.33E-03

3. Quantitative part



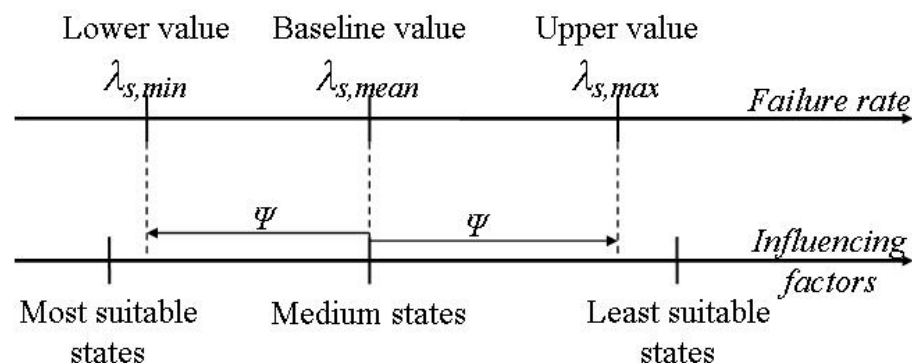
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3. Quantitative part: general model

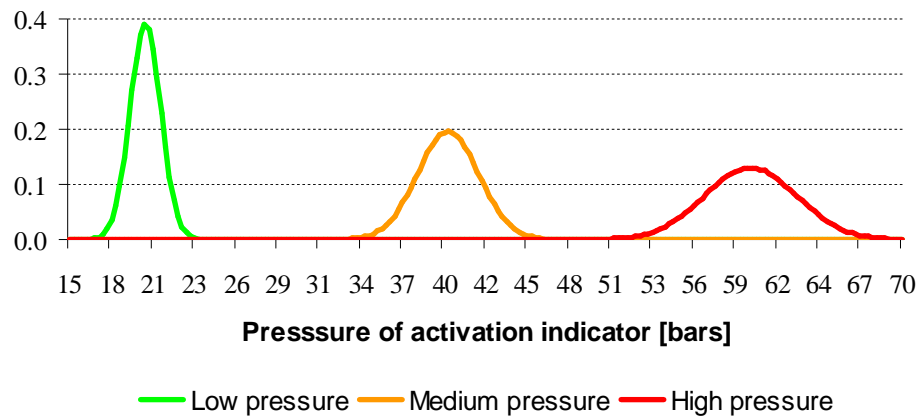
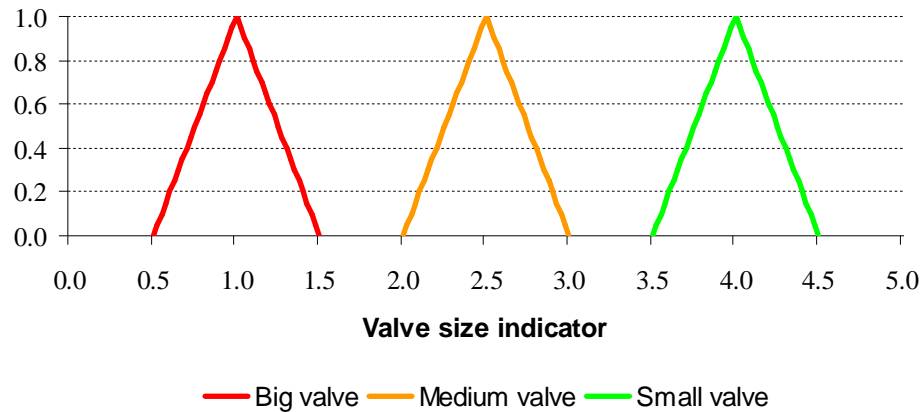


$$\lambda_s = \sum_{i=1}^N \lambda_i = \sum_{i=1}^N \left[\lambda_{i,mean} \cdot \prod_{j \in J_i} C_j^* \right]$$

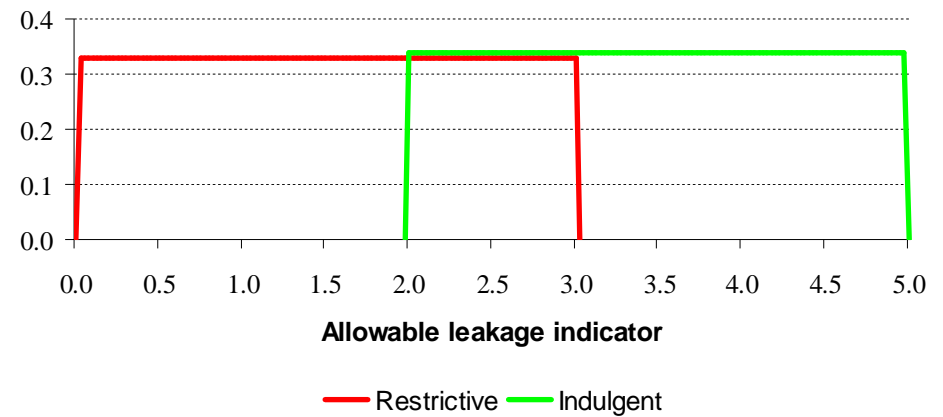
$$\lambda_{i,mean} = c_i \cdot \lambda_{s,mean} \text{ with } \sum_{i=1}^N c_i = 1$$

- Part count model
- Influencing coefficients
 - one coefficient for each influencing factor
 - the relevant coefficients are multiplied to the baseline failure rates
 - $C_j^* = 1$ if the corresponding influencing factor is in a medium state
 - $C_j^* < 1$ (resp. $C_j^* > 1$) if the corresponding influencing factor is in a more suitable state (resp. less suitable state)
- How to calculate the influencing coefficients?

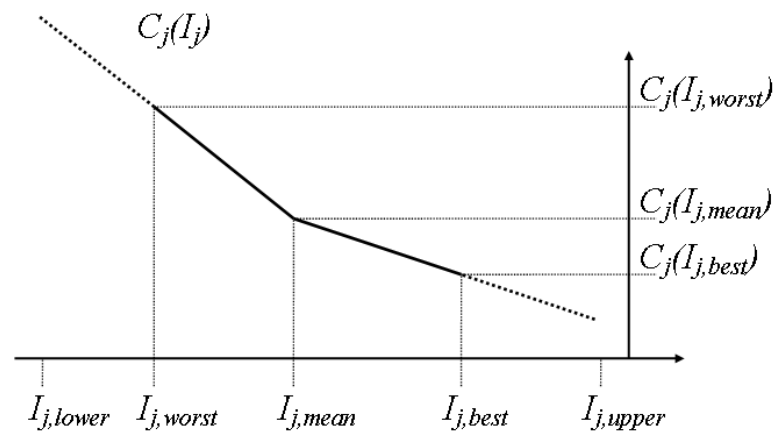
3. Quantitative part: indicator functions



- Probability density functions: $g_j(l_j)$
 - uncertainties
 - variations in time
- Distributions
 - **triangular** for deterministic values
 - **Gaussian** for quantitative values
 - **uniform** for expert judgment



3. Quantitative part: influencing functions



$$C_j^* = \int_{I_{j,lower}}^{I_{j,upper}} C_j(I_j) \cdot g_j(I_j) \cdot dI_j$$

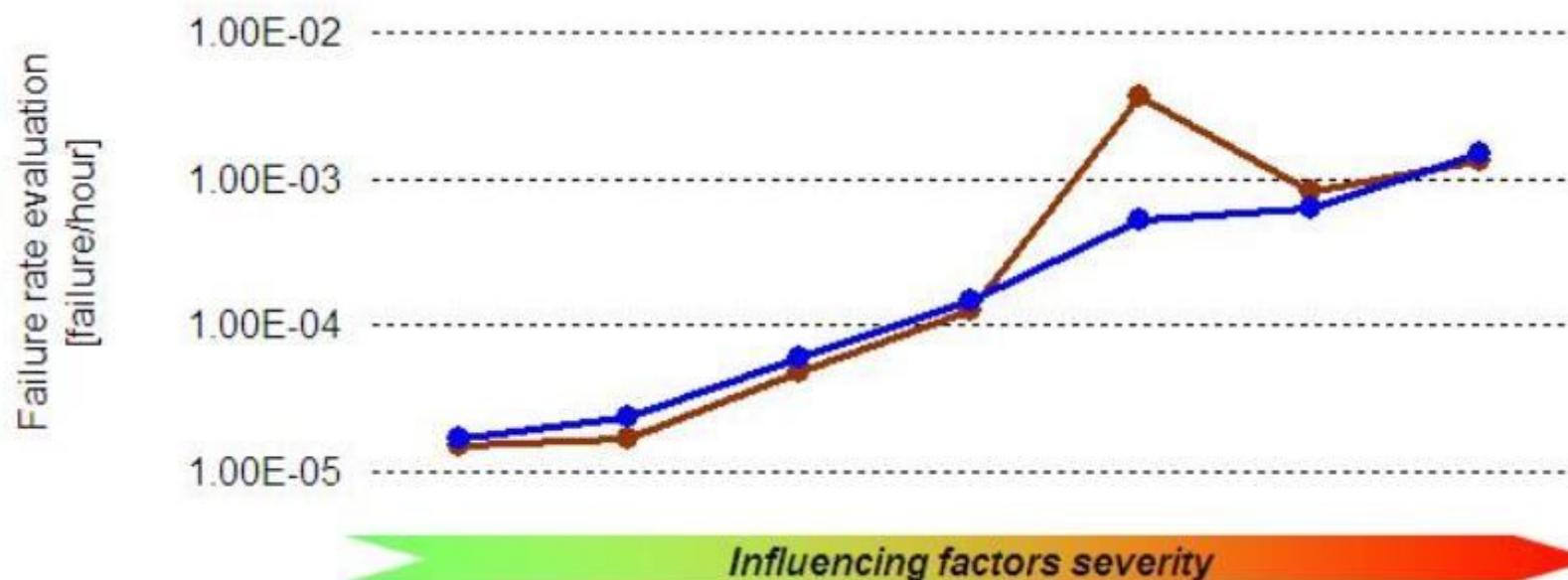
- **Influencing functions: $C_j(I_j)$**

- aim at formulating the influencing coefficients according to the indicator values
- are built using three particular values: *worst*, *mean*, *best*
- take into account general assumptions and influencing factor weights

- **Final results of the influencing coefficients: C_j^***

- are calculated by integrating the product of the influencing functions with the indicator functions, all over the possible indicator values

4. Results



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frewif methodology	1.66E-05	2.33E-05	6.10E-05	1.48E-04	5.17E-04	6.20E-04	1.51E-03

Conclusion

- **Influencing factors in reliability**
 - a definition
 - a classification according to the system life cycle phases and a corresponding checklist
- **New model for *failure rate evaluation with influencing factors* – *frewif***
 - global enough to be usable for a large number of safety systems and influencing factors
 - combines a qualitative analysis to compensate for a potential lack of knowledge, and a quantitative part to integrate available data
 - allows better argued and coherent results for a more efficient risk management which can act both on systems and environment / conditions of use



Thanks for your attention

Questions and comments are
welcome

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