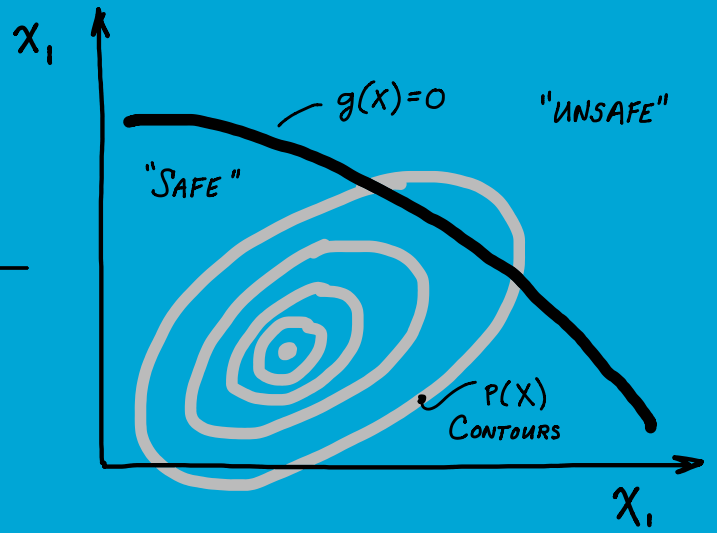
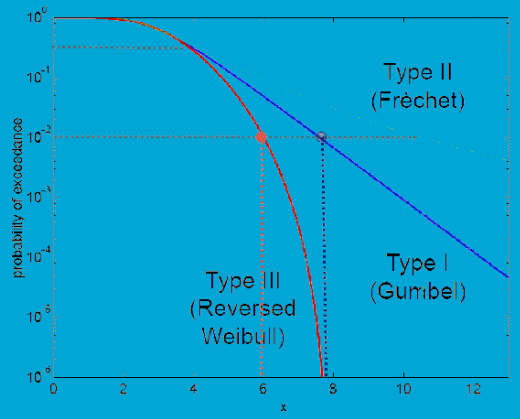
CIEM42X0 Probabilistic Design

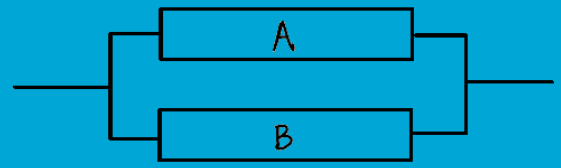
Hydraulic and Offshore Structures (HOS) Track

Civil Engineering MSc Program



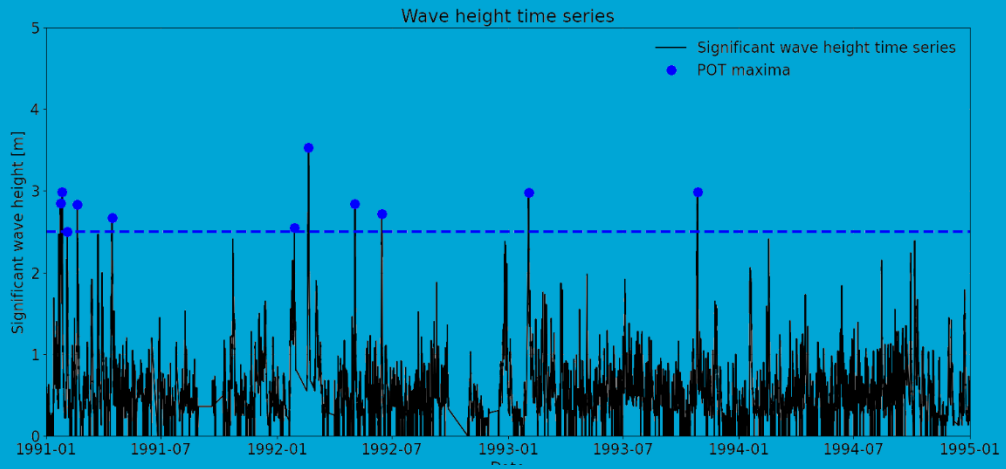
Introduction - Logistics





Patricia Mares Nasarre

Robert Lanzafame



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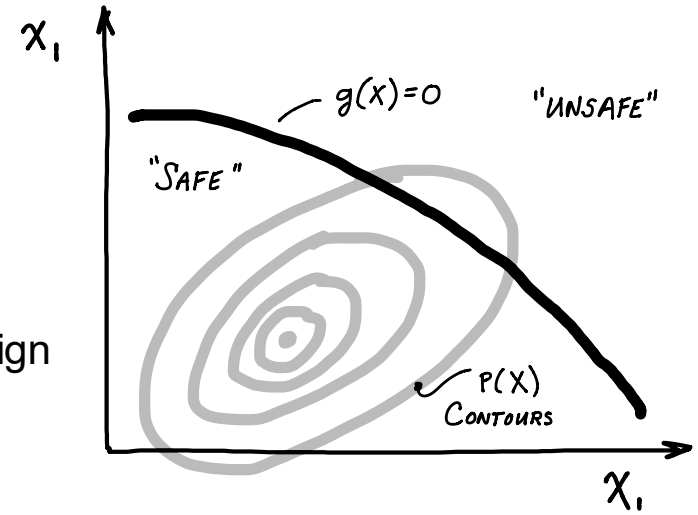
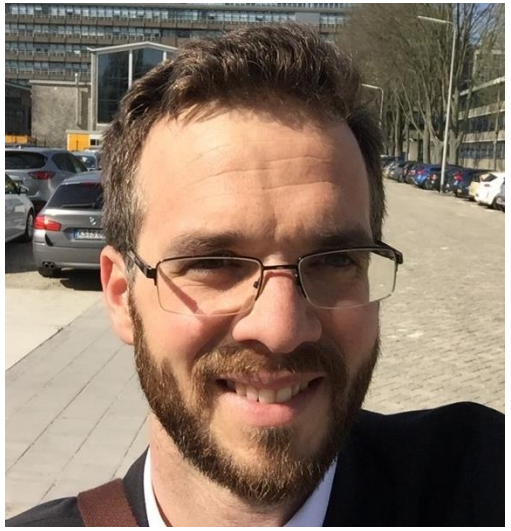


3 main topics: extreme value analysis, component reliability, system reliability

Objective: learn how the methods can be used to gain insight and improve your design

Patricia Mares Nasarre
Extreme value analysis



Robert Lanzafame
Component Reliability

Oswaldo Morales Nápoles
System Reliability

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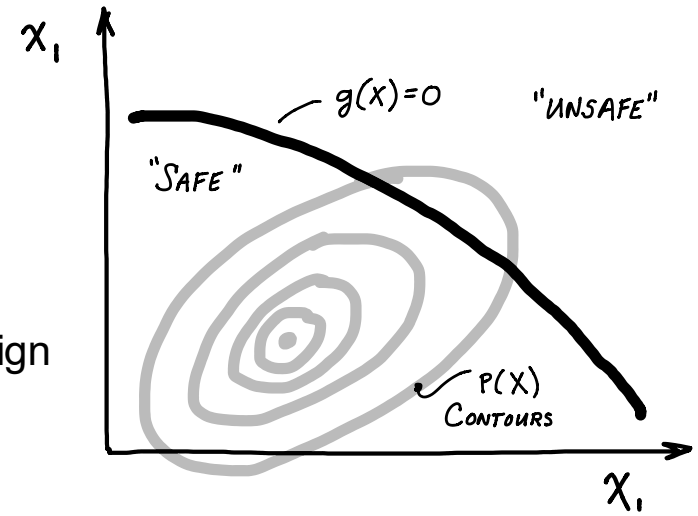

3 main topics: extreme value analysis, component reliability, system reliability

Objective: learn how the methods can be used to gain insight and improve your design

Course setup:

- Tuesday lecture, Friday workshop
- Various assignments (homework or in-class workshops on Friday)
- 3 workshops submitted for feedback/grade (weeks 2, 5, 8) → more info coming; weeks might be updated!

Unit Website(s): textbook links, calendar, announcements, logistics, etc

Assessment: incorporated in projects and exams for each unit
→ use code from assignments!

Contact Patricia Mares Nasarre for questions.

→ bookmark the website!
→ The comp-mod site too!
tudelft-citg.github.io/HOS-**prob-design**-25/
tudelft-citg.github.io/HOS-**comp-mod**-25/

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Demonstration (not on slides)

- Website
- Online Textbook

- This week
  - Read Chapter 1
  - Review MUDE
  - Set up your environment

Programming

This will be homework → Python setup ☺

- "You need to set up a new environment by Friday week 2 (for week 1, MUDE env should work)
  - pyExtremes
  - OpenTURNs
  - Git**Hub**

- **Env instructions provided in the webpage: https://tudelft-citg.github.io/HOS-prob-design-25/**

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Summary

- Review MUDE weeks 1.7 & 1.8
- Set up your new environment
- Let Patricia know if you have questions!

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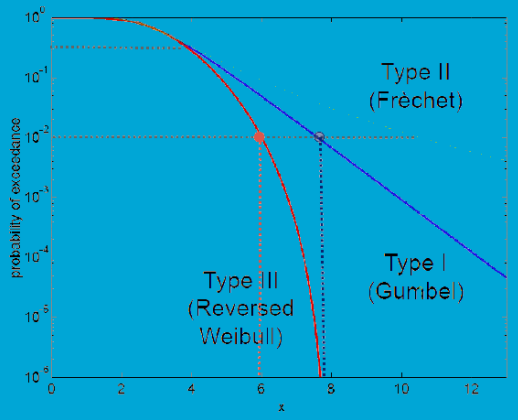
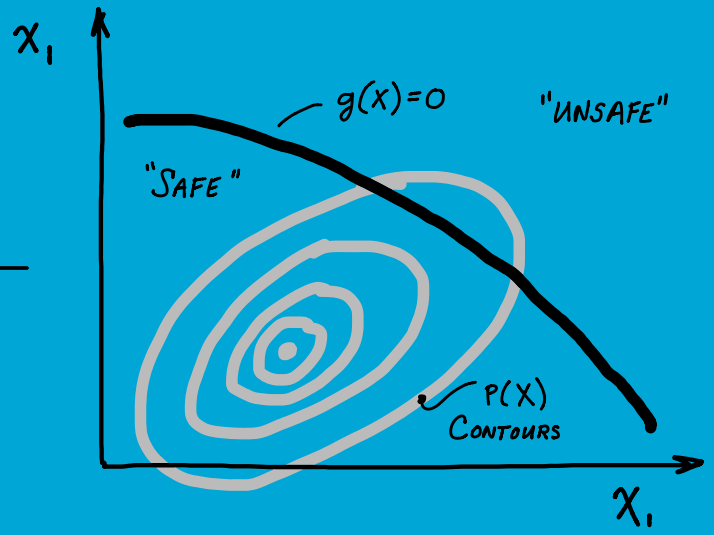
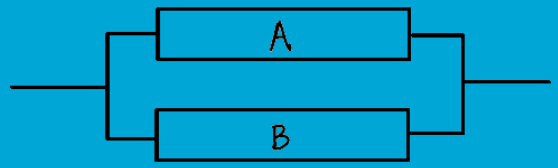
Hydraulic and Offshore Structures (HOS) Track

Civil Engineering MSc Program

Reliability-Based Design Philosophy

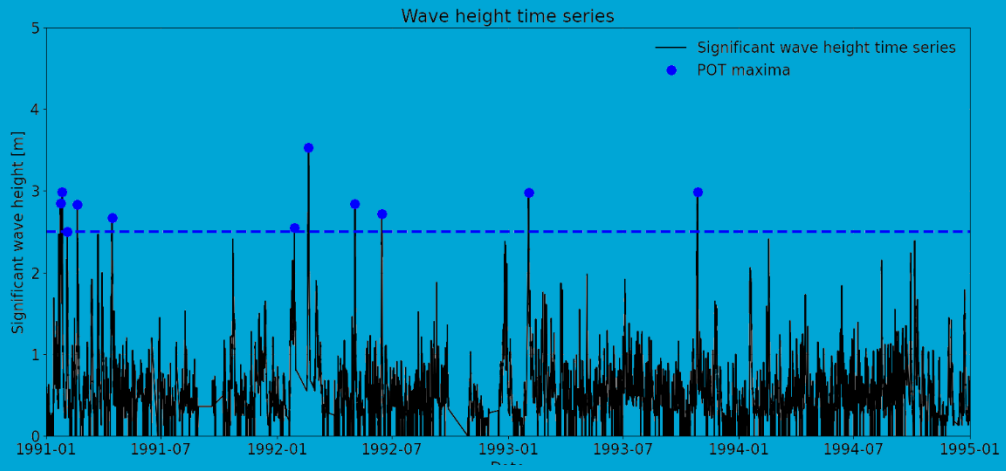






Patricia Mares Nasarre

Robert Lanzafame



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Outline

1. Refresher: univariate distributions
2. Risk analysis
3. Reliability analysis

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1. Univariate (continuous) distributions – What's that? 🤔

- Univariate → 1 variable
- Continuous → Continuous variables (not discrete)
- Univariate (continuous) distributions:
  - *Mathematical model which relates the values of a random variable and their probability*

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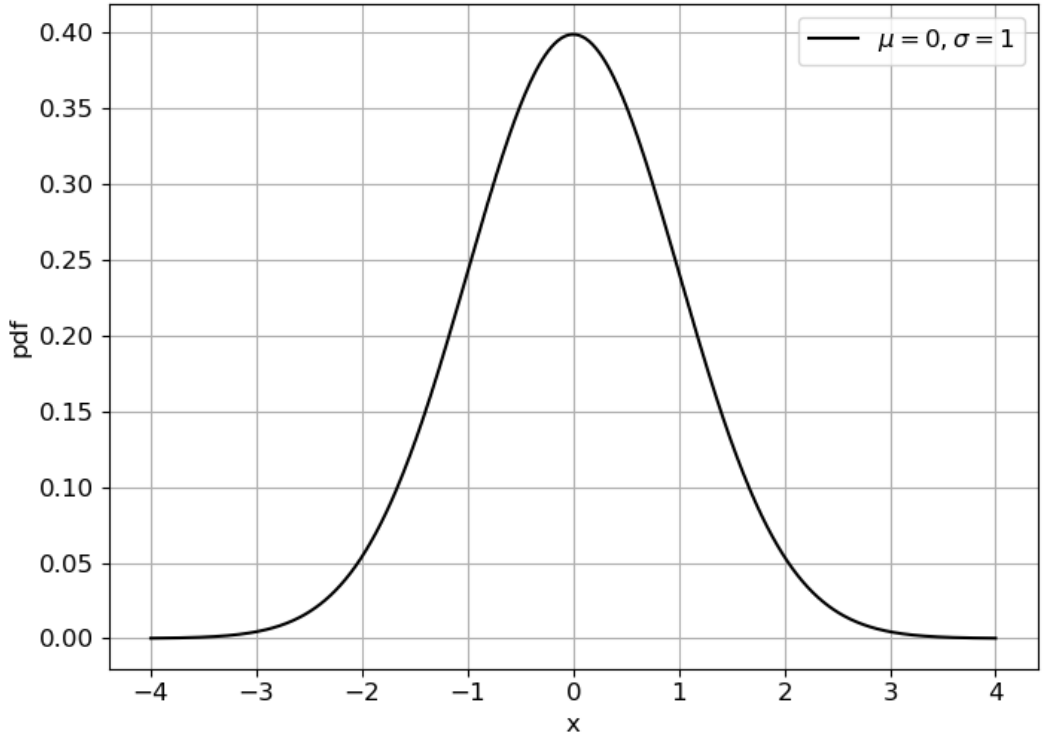
1. Univariate (continuous) distributions – PDF

- Continuous random variables
- Mathematical model which relates the values of a random variable and their probability
- Probability **density** function (PDF) $f_X(x)$

$$f_X(x)dx = P(x < X \leq x + dx)$$

$$f_X(x) \geq 0$$

$$\int_{-\infty}^{+\infty} f_X(x)dx = 1$$



PDF of the Gaussian distribution

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

1. Univariate (continuous) distributions - From PDF to CDF

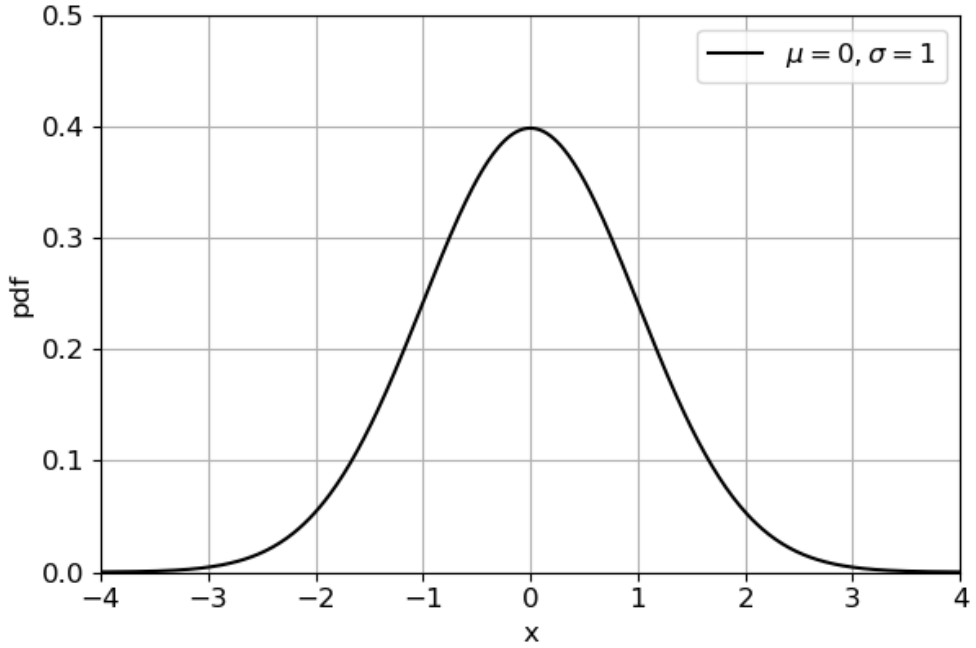
- Probability density function (PDF) $f_X(x)$

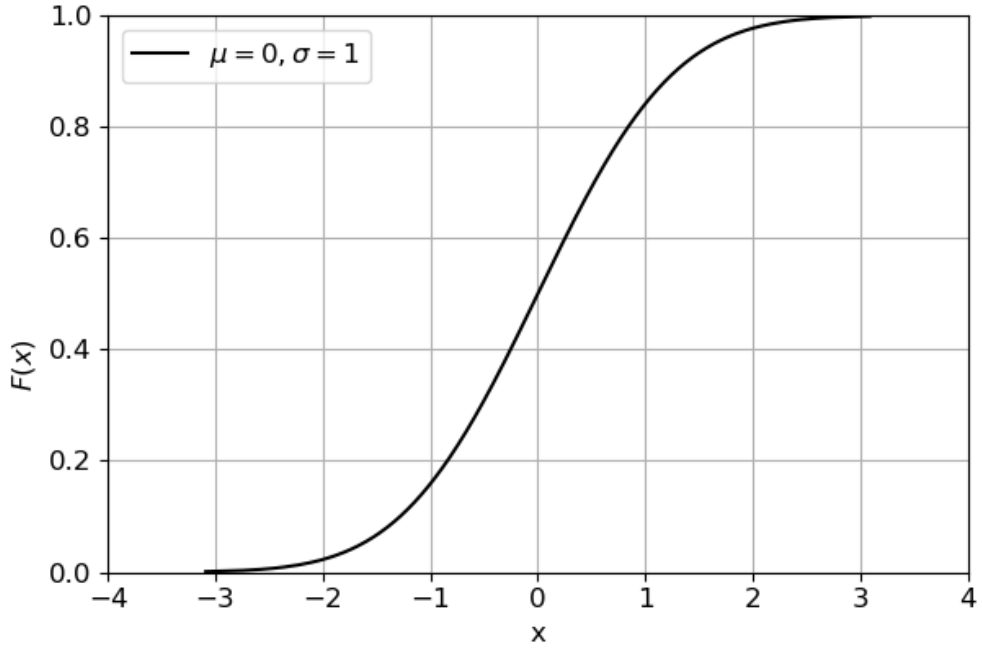
PDF→ how? → CDF

- Cumulative distribution function (CDF) $F(x) = \int_{-\infty}^{x} f(x)dx$

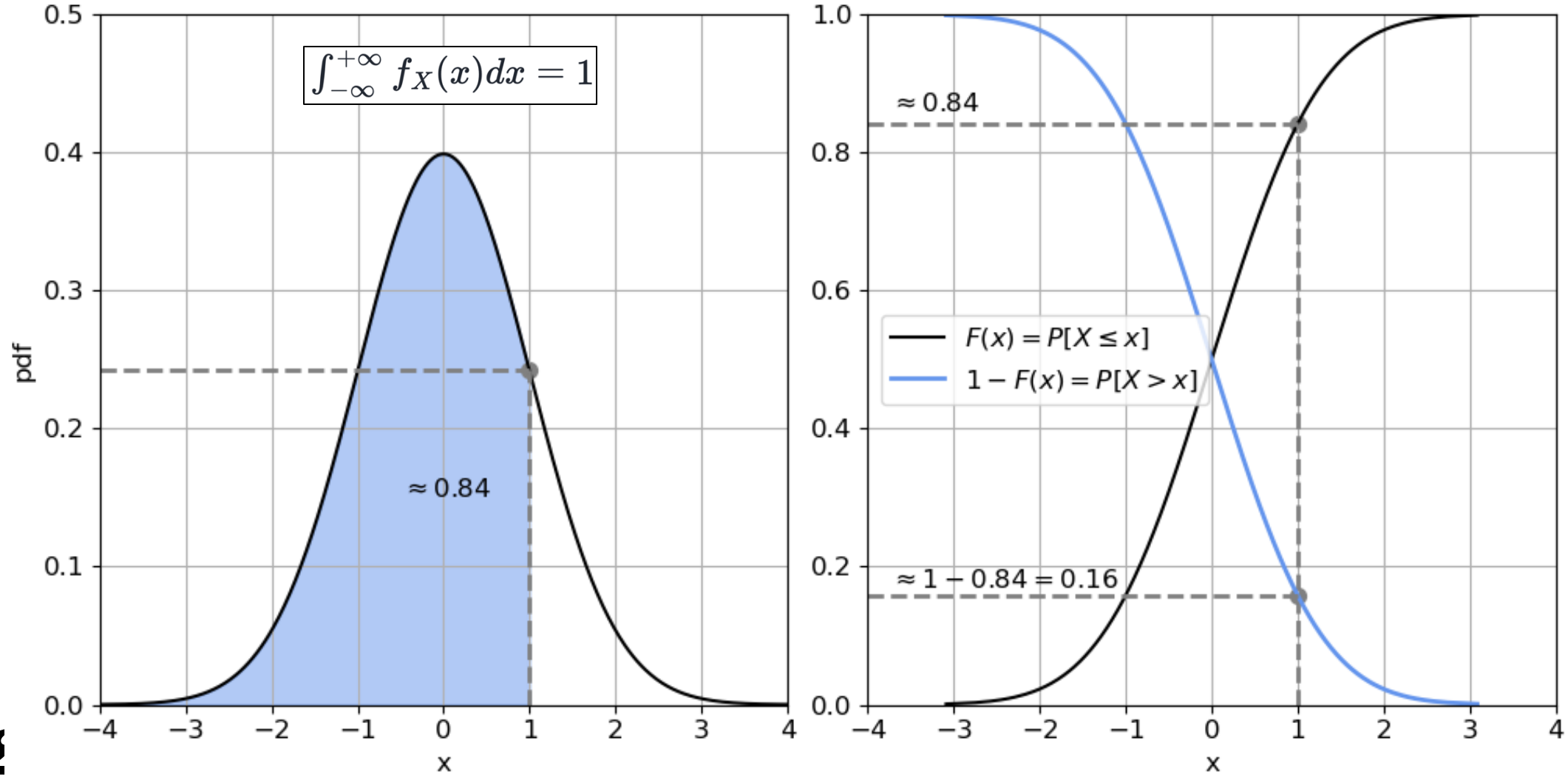
CDF of the Gaussian distribution

$$F(x) = \frac{1}{2}\left(1 + \text{erf}\left(\frac{x-\mu}{\sigma\sqrt{2}}\right)\right)$$





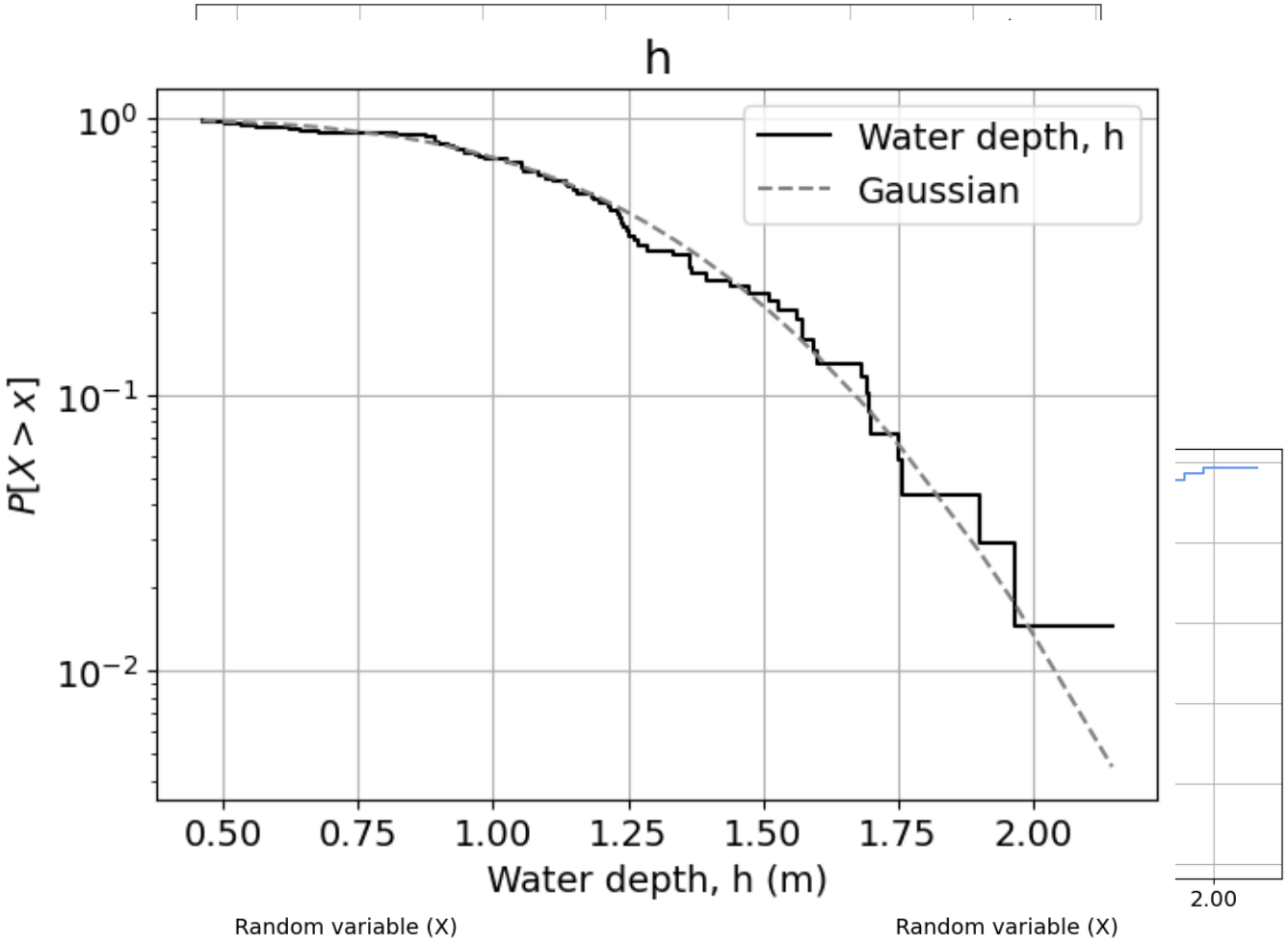
1. Univariate (continuous) distributions– exceedance



1. Univariate distributions– how do we fit it to data?

Given a parametric distribution function (e.g.: Gaussian distribution):

1. Build ECDF from the data
2. Fit the distribution to the ECDF using method of moments or MLE
3. Goodness of fit: graphical methods or hypothesis test
4. Is it good enough for your purposes? Then, use it!



Outline

1. Refresher: univariate distributions
2. **Risk analysis**
3. Reliability analysis

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2. Risk Analysis – what is risk?

"a situation involving exposure to danger" → focused on consequences

"the possibility that something unpleasant or unwelcome will happen" → focused on the probability of happening

Which definition do we typically use?

Risk is the probability of an undesired event multiplied by the consequences.

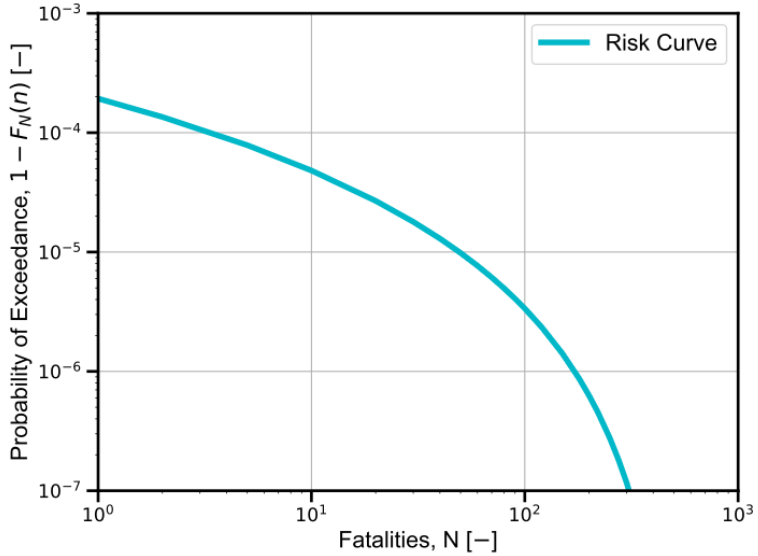
$$E(d_i) = p_i \cdot d_i$$

Expected damage, typically expressed in €/year

Expected damage for a given set of scenarios i=1,…, n

$$E(d) = \sum_{S_{i=1}}^{n} p_i \cdot d_i$$

But what are the contributions to that risk?
Is there a scenario with very high consequences?
Or very likely to occur? → Risk curve



→ FN curve

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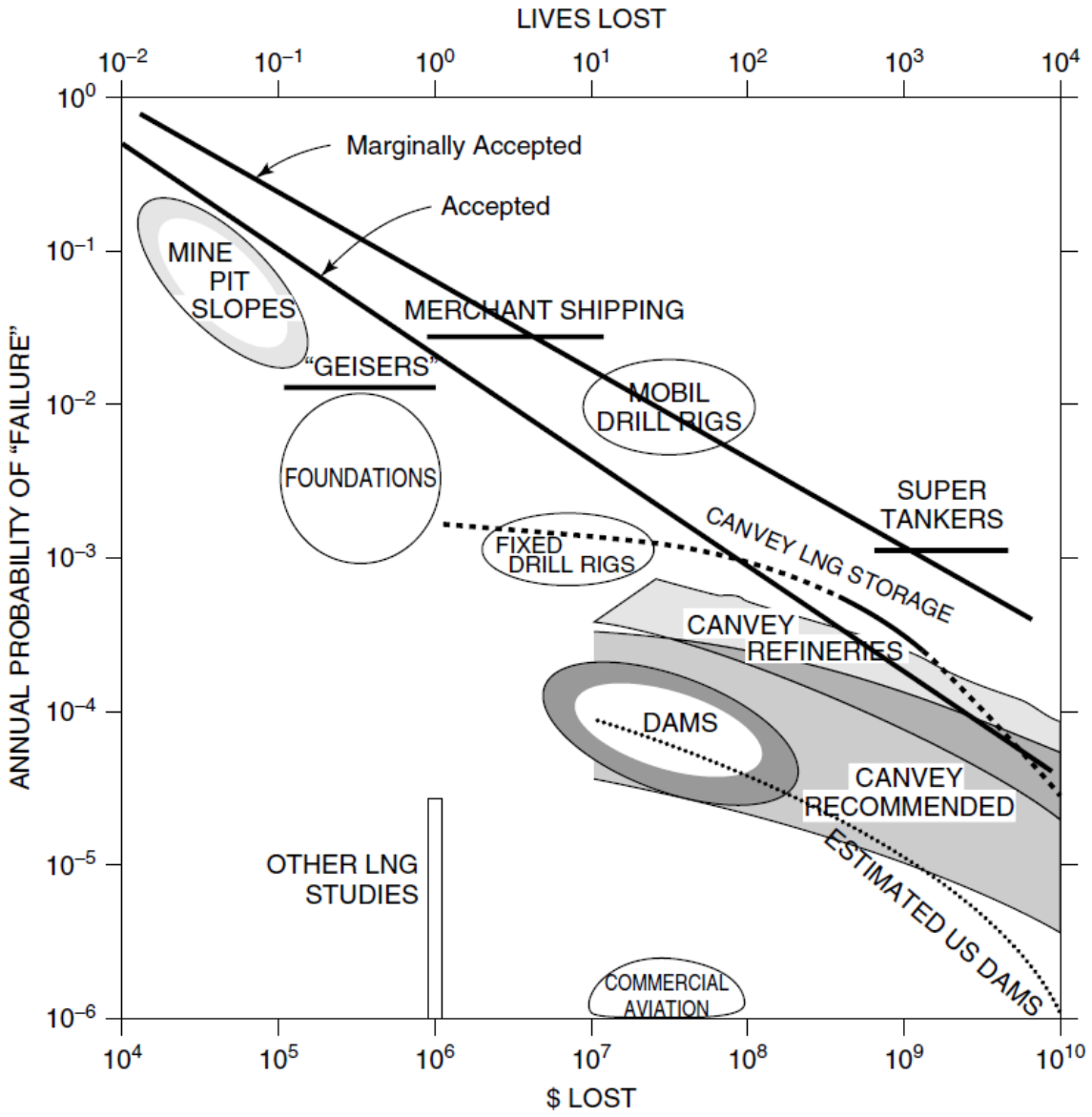
2. Risk Analysis – why?

Why do we use the concept of risk?

- Decide on acceptability
- Safety levels in the design process
- Need for measures in existing systems

Quantitative measure to transfer from decisions to technical field.



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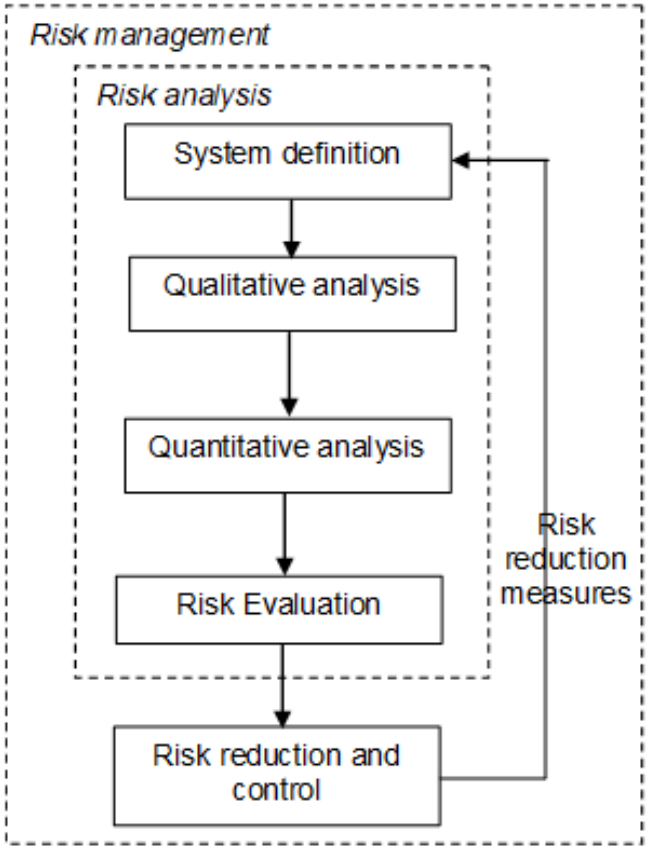
2. Risk Analysis – Steps



- System definition = scope, objectives, schematize the system into components (more later!)
- Qualitative analysis = undesired events and consequences. How the system can fail
- Quantitative analysis = quantification of risk; component and system reliability and consequences
- Risk evaluation = decision, is it acceptable?
- First four steps repeated several times to reach an optimal design

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Outline

1. Refresher: univariate distributions

2. Risk analysis

3. **Reliability analysis**

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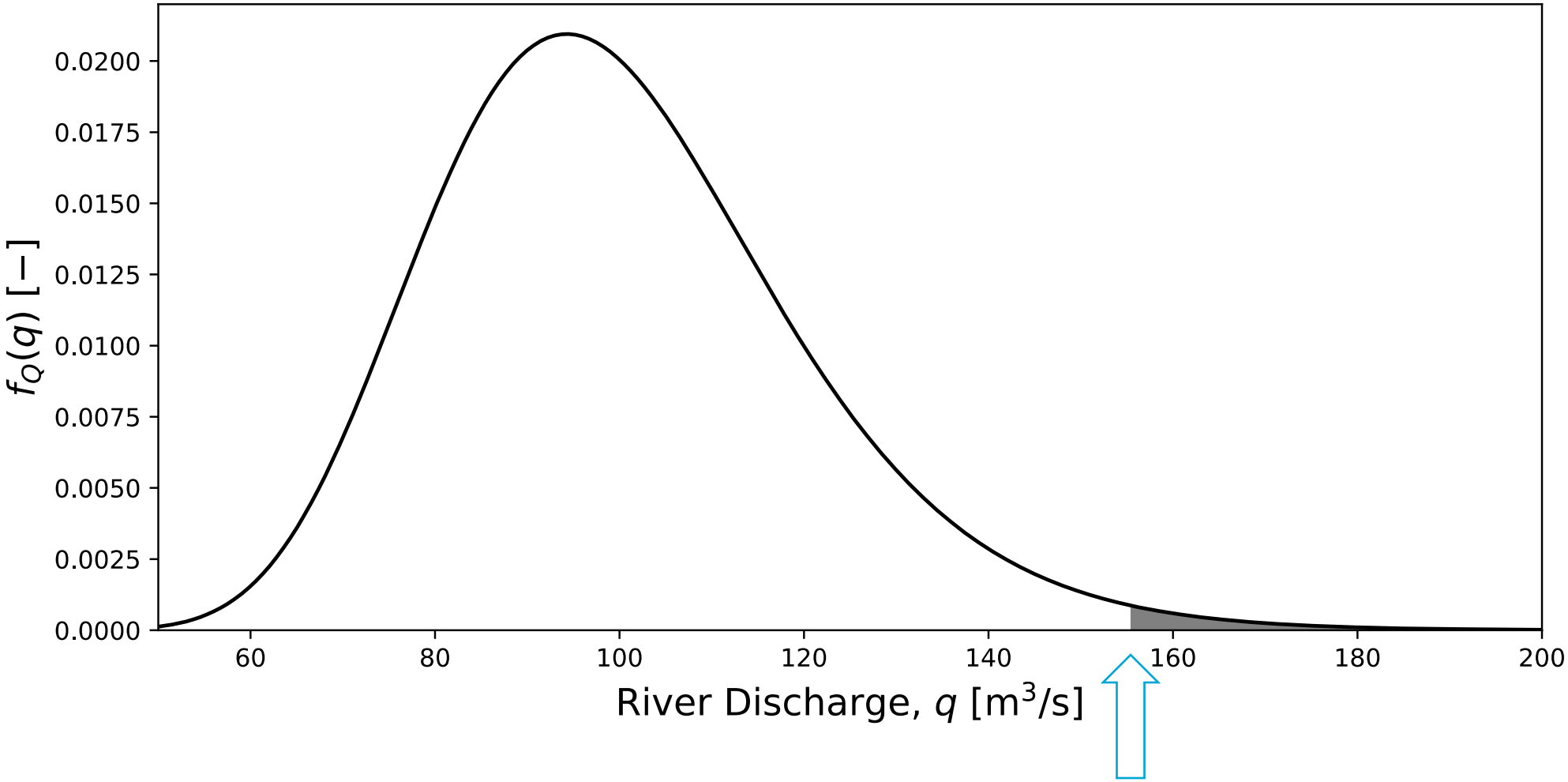
3. Reliability Analysis – how do we define failure?



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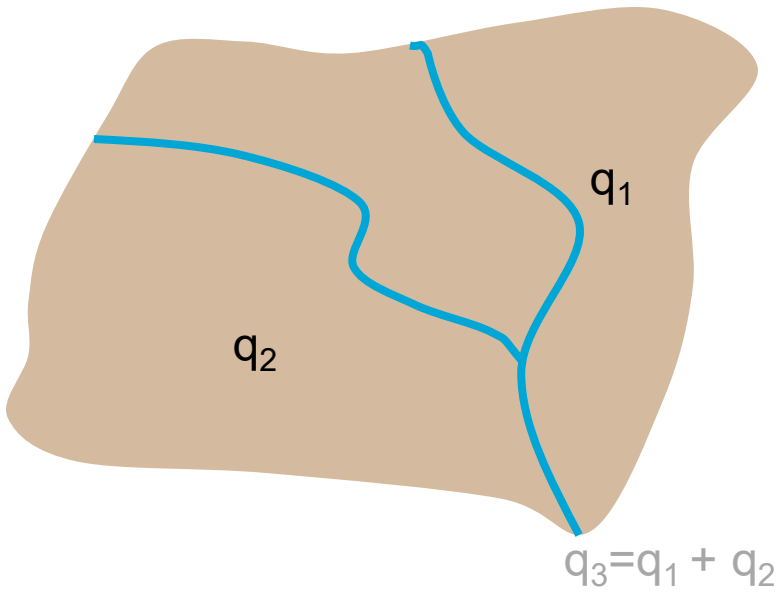
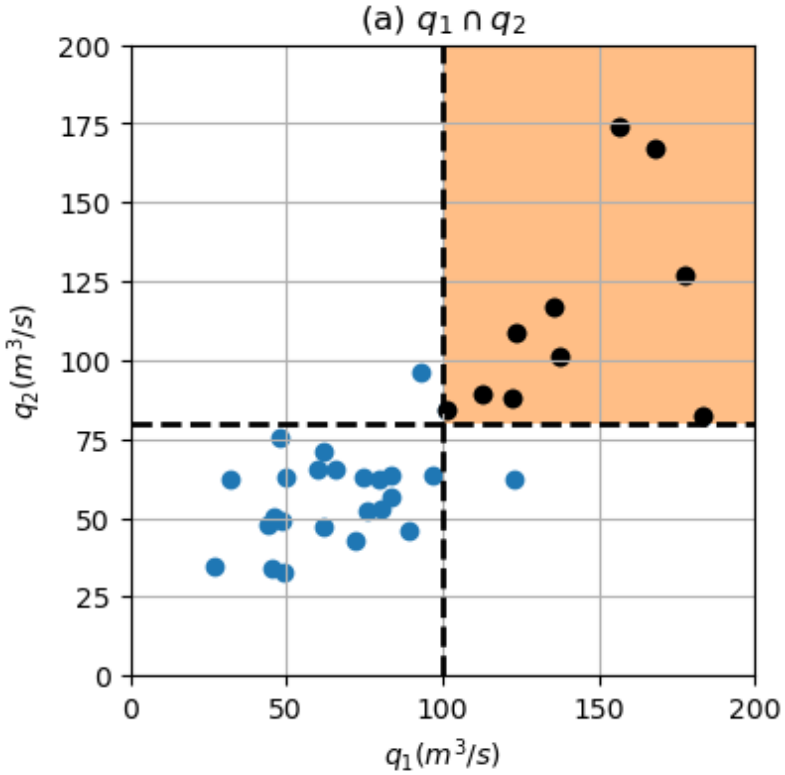
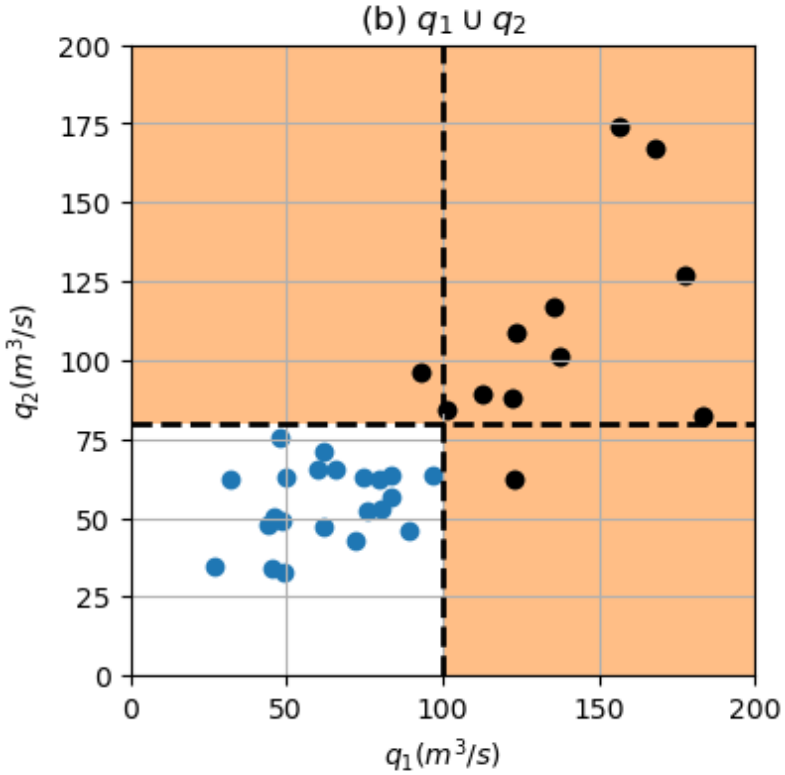
3. Reliability Analysis – how do we define failure?







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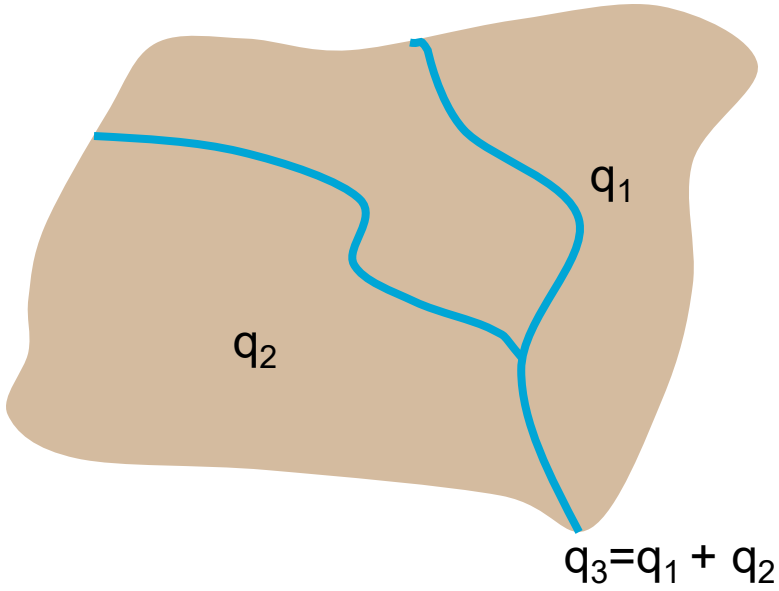
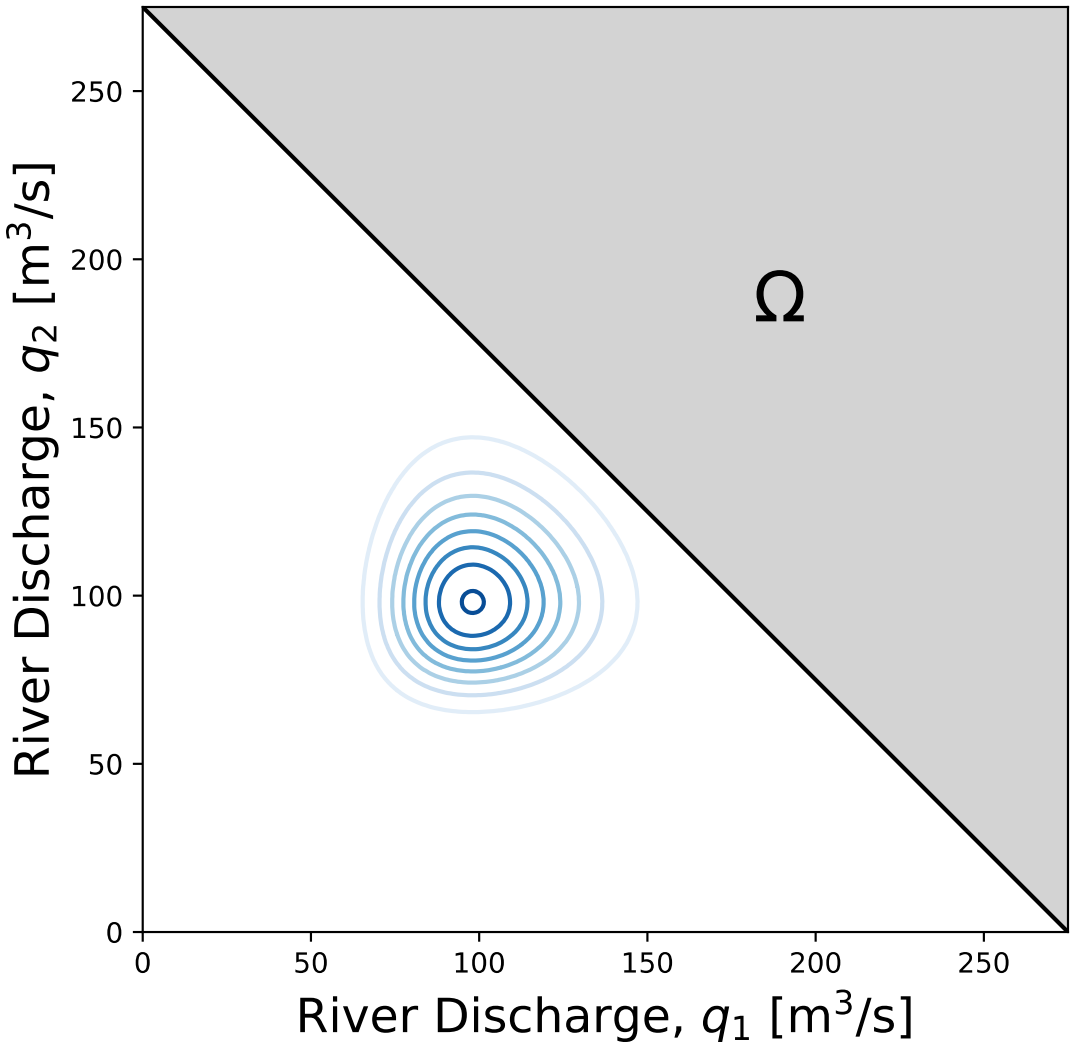
3. Reliability Analysis – how do we define failure?





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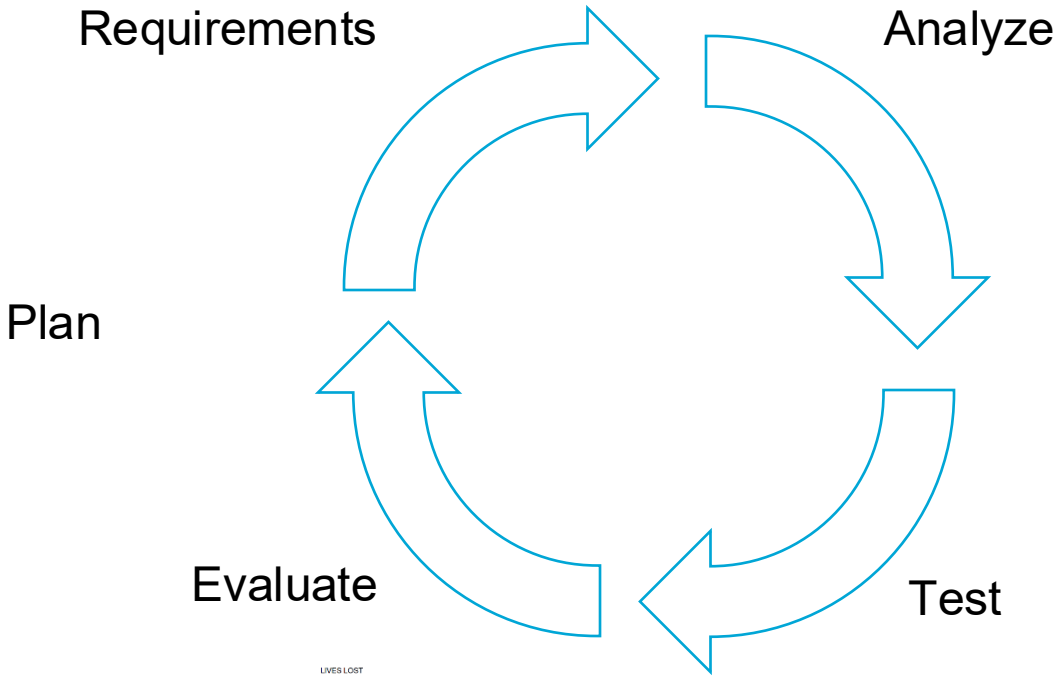
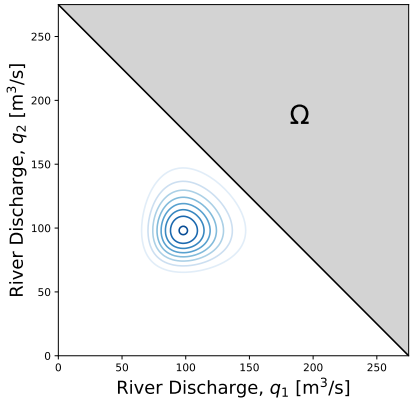
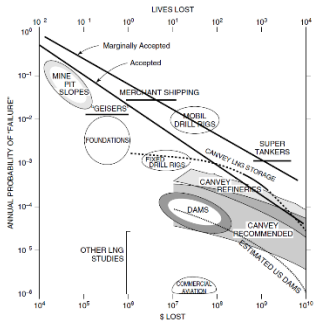
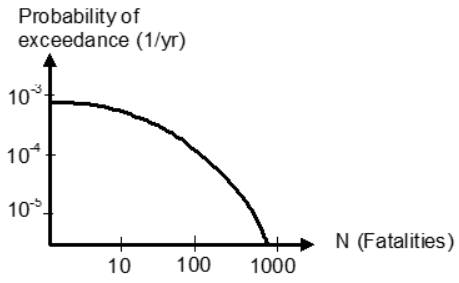
3. Reliability-Based Design Philosophy









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How we will approach reliability-based design

- Risk Analysis: evaluation, assessment, context (MUDE)
- Continuous Distributions, Extreme Value Analysis (MUDE, Week 2)
- Dependence touched lightly
  (covered in cross-over!!! CEGM2005 tudelft-citg.github.io/MORE)
- Component Reliability:
  a function of random variables $p_{\mathrm{f}} = \int_{\Omega} f_X(x)\,\mathrm{d}x$
- System Reliability:
  solving complex systems

Summary of Reliability-Based Design Philosophy

- Reliability methods for analysing and evaluating structures/system
- Risk analysis provides a framework for evaluation
- We will apply this to your design case in our unit!