Martin Bergström, Ph.D., M.Sc (Tech.)

German Aerospace Center (DLR)
Institute of Maritime Energy Systems | Virtual Ship | Max-Planck-Straße 2 | 21502 Geesthacht
+49 4152 84881 20 | martin.bergstroem@dlr.de | https://www.dlr.de/ms/en/

A"

Aalto-yliopisto
Insinööritieteiden
korkeakoulu

MEC-E2009 - Marine Risks and Safety L

Lecture 4: Risk- and goal-based ship design

Tuesday 27, 2022

Learning logs L3 (1)

12 Logs received

Comments and feedback

- The interconnection of topics and the application they have to represent information in the analysis of complex socio-technical systems
- Analytic reduction vs systems theory; how the methods are used in practice in the context of accident causality models?
- MEC-E3004 Safety management in complex socio-technical systems
- How could you really learn about STAMP and STPA?
- Amount of information to be processed (overwhelming?)
- STPA primer handbook and assignment development
- SAFETY FIRST
- Some person express the way the FQ replace or supports the final exam and the weighting factors for it (the explanation was correct)

Aalto-yliopisto
Insinööritieteiden
korkeakoulu

STAMP

- STAMP **is only** an accident causation model, it is not itself an engineering technique.
- However, by using STAMP as a theoretical foundation, new **tools and processes** can be utilized or constructed.
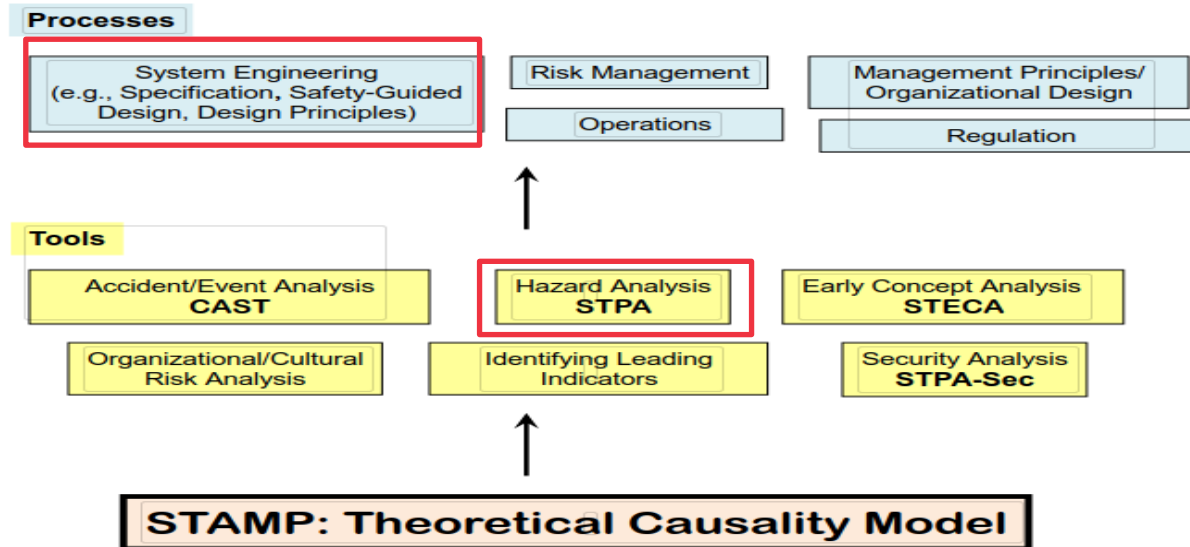
Learning logs L3 (2)

12 received (TBU)

Student number	Week 1	Week 2	Week 3	Week 4	Week 5	Points
586388	Received	**Received**	**Received**			8,8
655866	Received	Received	Received			9
647036	Received	Received	Received			8,5
665856	Received	Received	Received			8,5
665461	**Received**	Received	**Received**			9
712110	Received	**Received**	Received			8,5
606077	Received	**Received**	**Received**			9
654391	Received	Received	Received			9
902360	Received	Received	Not received			4,5
32862N	**Received**	Received	Received			9
1009424	**Received**	**Received**	**Received**			9
100686544	Received	Received	Received			8,5
100524787	Received	Received	Not received			4
100885824	Received*	Received	Received			7

Fast quiz L3

Student number	E-Q1	E-Q2	E-Q3	E-Q4	E-Q5	E-Q1	E-Q2	E-Q3	E-Q4	E-Q5	TOTAL	Grade
655866	100	95	95			0,15	0,25	0,25	0,2	0,15	62,75	
654391	100	100	100			0,15	0,25	0,25	0,2	0,15	65	
586388	80	100	100			0,15	0,25	0,25	0,2	0,15	62	
100686544	85	90	90			0,15	0,25	0,25	0,2	0,15	58	
665856	100		85			0,15	0,25	0,25	0,2	0,15	36,25	
100474280	80					0,15	0,25	0,25	0,2	0,15	12	
665461	100	95	80			0,15	0,25	0,25	0,2	0,15	59	
606077	100	100	100			0,15	0,25	0,25	0,2	0,15	65	
100524787	90	90	85			0,15	0,25	0,25	0,2	0,15	57,5	
712110	95	90	85			0,15	0,25	0,25	0,2	0,15	57,75	
32862N	90	100	95			0,15	0,25	0,25	0,2	0,15	62,25	
647036	100	100	95			0,15	0,25	0,25	0,2	0,15	63,75	
100885824	80	90	90			0,15	0,25	0,25	0,2	0,15	57	
902360	70	90				0,15	0,25	0,25	0,2	0,15	33	
1009424	100	100	100			0,15	0,25	0,25	0,2	0,15	65	

No participation

Min	Max	Grade
0	50	0
50	60	1
60	70	2
70	80	3
80	90	4
90	100	5

Intended learning outcome

Students will be able to

- explain the role of rules and regulations in ship design
- explain the difference between prescriptive/rule-based design and goal/risk-based design
- explain pros and cons of prescriptive/rule-based design and goal/risk-based design
- list some practical applications of goal/risk-based design

Approximate time plan

Design terminology (~10 min)

Prescriptive-based design (~10 min)

Goal/risk-based design (~ 40 min)

Break

Goal/risk-based maritime regulations (~ 45 min)

Summary (~5 min)

Q&A and discussion

Reading material

- Papanikolaou, A. (Ed.), 2009. *Risk-Based Ship Design Methods, Tools and Applications*, pp 1-31 + pp 97–147 (Regulatory framework)

- Jenkins, V., 2012. *Goal / Risk Based Design – Benefits and Challenges*. Dubai, Interferry

- Hermanski, G., Daley, C., 2010. *On formal safety assessment (FSA) procedure*

Motivation

Photo: Reuters

Photo: Eva Frisnes / abcnews.go.com

Photo: AP

Photo: LEHTIKUVA/ARKISTO/PETER STONE/

Design terminology

What is design?

No exact definition

- The application of knowledge/science to solve a problem

- Knowledge synthesis

- Optimization

- Engineering
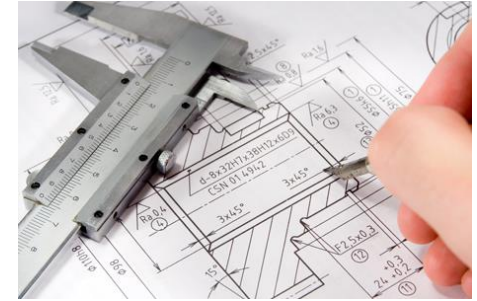

Picture: www.asme.org
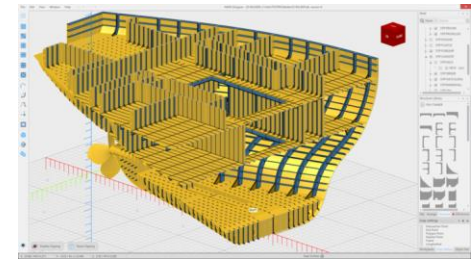
Picture: www.napa.fi

Design models

**Any design task involves the determination of a design model**

- Can take various forms but is always an abstraction (generalization) of an artefact
- Approximate representation

Should be limited to areas of interest

- The level of detail (model fidelity) should be adapted to the design task
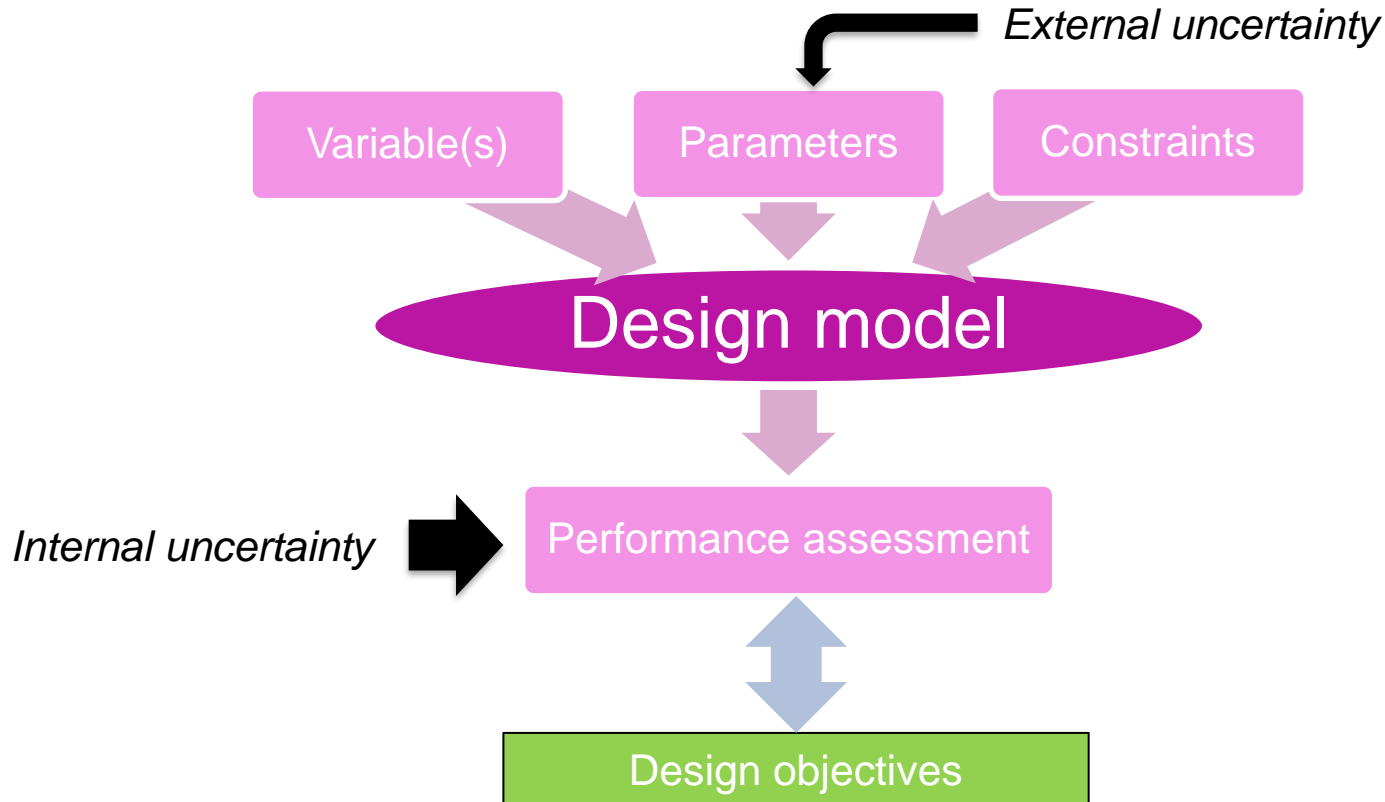- A higher level of detail/complexity is not necessarily better

Picture: http://akerarctic.fi/
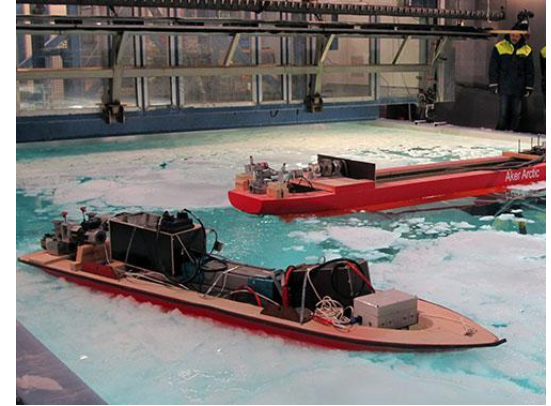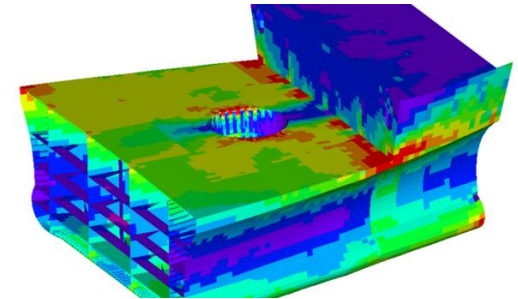
Picture: https://mec.ee

Design model components

Prescriptive-based design

Prescriptive regulations

Ship design is traditionally regulated by prescriptive design rules and regulations

- Dates back to a time when ship design was more art than science
  - *Often determined based on experience*
- Determined in the <u>form space</u>
  - Determine the required means of achieving safety objectives
- Alternative names
  - *<u>Deterministic rules</u>, i.e., rules that require a specific solution assumed to provide a specific deterministic performance*
  - *<u>Specification rules</u>, i.e., rules that specify the required solution*

(Re)design → Build → Test → Evaluate → (Re)design
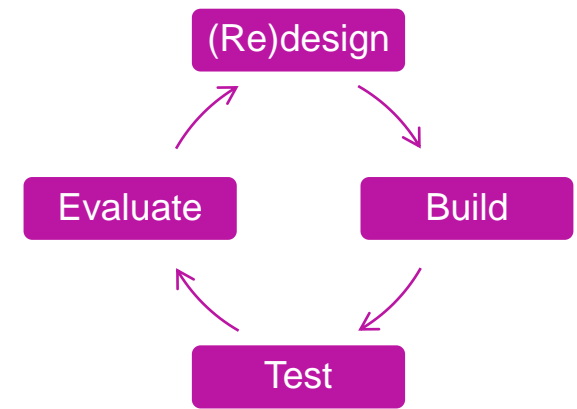
Picture: Willy Stöwer

SOLAS (The International Convention for the Safety of Life at Sea) convention (1st version)

Prescriptive regulations

Examples of prescriptive rules:

- To avoid structural failure
  - *Min scantlings, corrosion margins, design loads, etc.*
- To avoid loss of stability
  - *GZ-curve requirements, etc.*
- To mitigate the consequences of a collision
  - *Longitudinal bulkheads, etc.*
- To mitigate the consequences of grounding
  - *Double bottom requirements*
- To mitigate the consequences of a fire
  - *Max allowed fire zone size, etc.*

Prescriptive rules → Prescriptive-based design

Additional examples of prescriptive rules:

$$W_{ds} = 0.5 + \frac{DWT}{20000}$$

$$t_b \geq (2 + f_{bkt} \sqrt{Z}) \sqrt{\frac{R_{eH-stf}}{R_{eH-bkt}}}$$

$$t = 667\,s \sqrt{\frac{f_1 \cdot p_{PL}}{\sigma_y}} + t_c \,[\text{mm}]$$

$$Z = \frac{f_5 \cdot p \cdot h \cdot l^2}{m \cdot \sigma_y} 10^6 \,[\text{cm}^3]$$

Aalto-yliopisto
Insinööritieteiden
korkeakoulu

Pros of prescriptive-based design

Quick and straight-forward to apply, and to verify compliance

- Well suited for "standard" designs
  - *Jenkins (2012): "For vessels which are standard and where there is high confidence that the prescriptive regime achieves a good level of safety, there is little reason to change from a wholly prescriptive approach"*

Based on real life experience (what works) → small risk of ending up with a very bad design (at least for standard designs)

Cons of prescriptive-based design

Limited feasible design space

- Rules act as design constraints, potentially preventing new innovative solutions

The efficiency of the solution depends on the efficiency of the rules

- Traditionally failed to be proactive
    - *Rule development traditionally driven by individual catastrophic events, often in response to public outrage*
    - *Cost-efficiency not always considered*
- Often determined based on existing designs (empirical data)
    - → *The rules might not be effective/optimal for new types of designs or operations*
- The level of safety provided by the rules is not known (the objective is generally not defined)
    - → *Responsibility transferred to rule maker*
    - → *Does not encourage "safety thinking" or safety above the minimum required level*

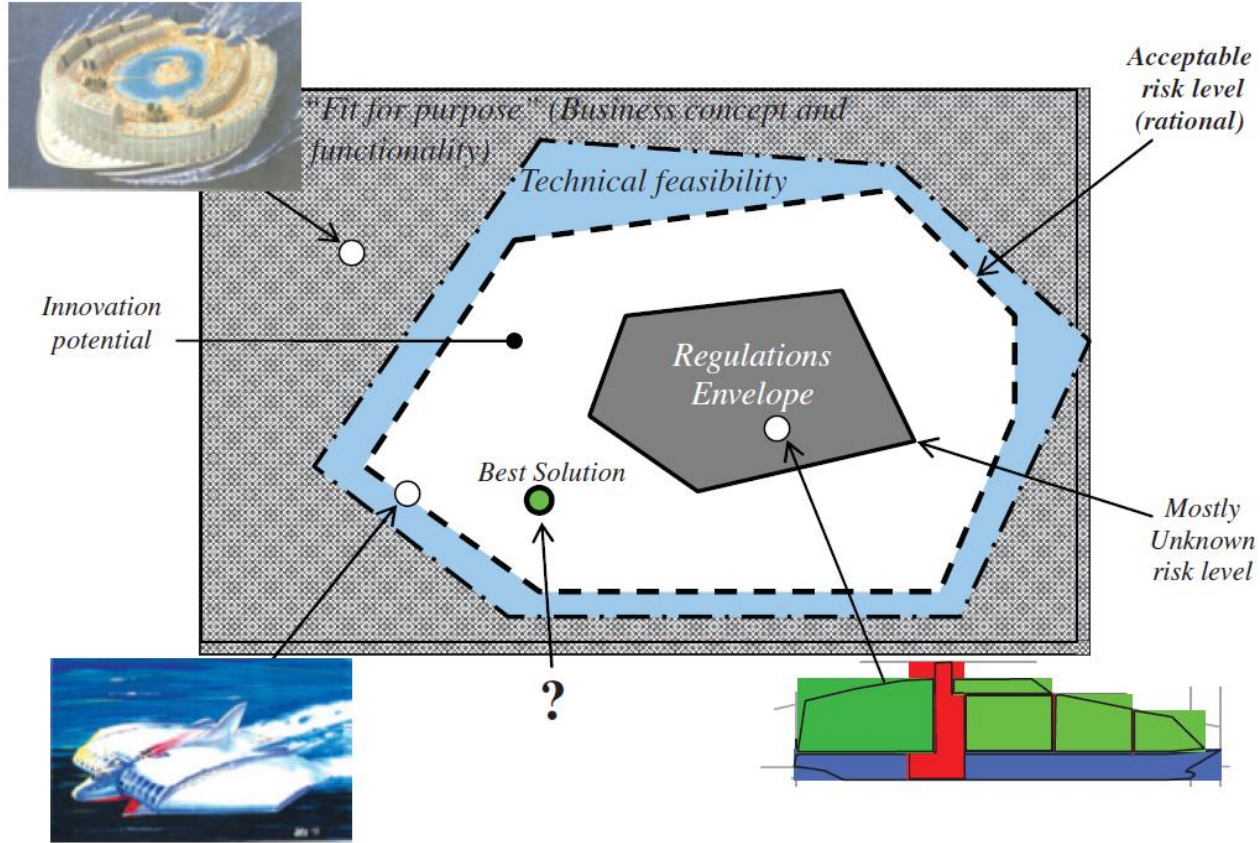# Cons of prescriptive-based design

Figure: Papanikolaou et al., 2009

Goal/risk-based design

IMO's definition of risk-based design

"Risk-based design is a design where the design process has been supported by a risk assessment or the design basis has resulted from a risk assessment. That is, it is a structured and systematic methodology aimed at ensuring safety performance and cost-effectiveness by using risk analysis and cost-benefit assessment." IMO, MSC.1/Circ.1455

Factors driving goal-based regulations

Ongoing trend towards goal-based maritime regulations

- This trend is not only driven by the mentioned issues with prescriptive regulations but also by multiple other factors including

  - *Ever-increasing and improving knowledge and performance assessment tools* → *Ever-improving ability to assess various types of ship performance including safety performance*

  - *Larger, more complex ships*

  - *Strong competition, low profit margins* → *Design optimization*

  - *Increased "safety thinking" (corporate social responsibility)*

    - Accidents are bad for business, safety pays off

What are goal-based regulations?

In goal-based regulations, design criteria are determined in the <u>function space</u> in terms of <u>goals</u> and <u>functional requirements (FRs)</u> to meet the goals

- *The goal(s) defines the overall aim(s)*
  - Example goal: to ensure adequate subdivision and stability in both intact and damaged conditions.
- *The FRs define the performance required to meet the goal(s)*
  - Example FRs: (a) ships shall have sufficient stability in intact conditions when subject to ice accretion; and (b) ....
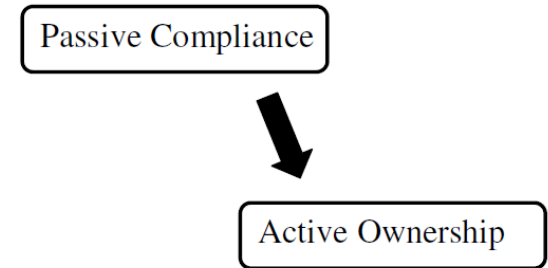
Goal-based regulations → Goal-based design (GBD)

Passive Compliance

↓

Active Ownership

Figure: Jenkins (2012)

Aalto-yliopisto
Insinööritieteiden
korkeakoulu

What are risk-based regulations?

Risk-based regulations are like goal-based regulations in which the goal and functional requirements are defined in risk terms

- Example: the maximum accepted individual risk is 10^{-3}

Risk-based rules→ Risk-based design (RBD)

- Can be considered as a subcategory of goal-based design
- Other / broader definitions of RBD:
  - *"Design under uncertainty"*
  - *"RBD is a formalised methodology that integrates systematically risk assessment in the design process with prevention/reduction of risk embedded as a design objective, alongside "conventional" design objectives" (Papanikolaou et al., 2009)*

Goal/Risk-based design
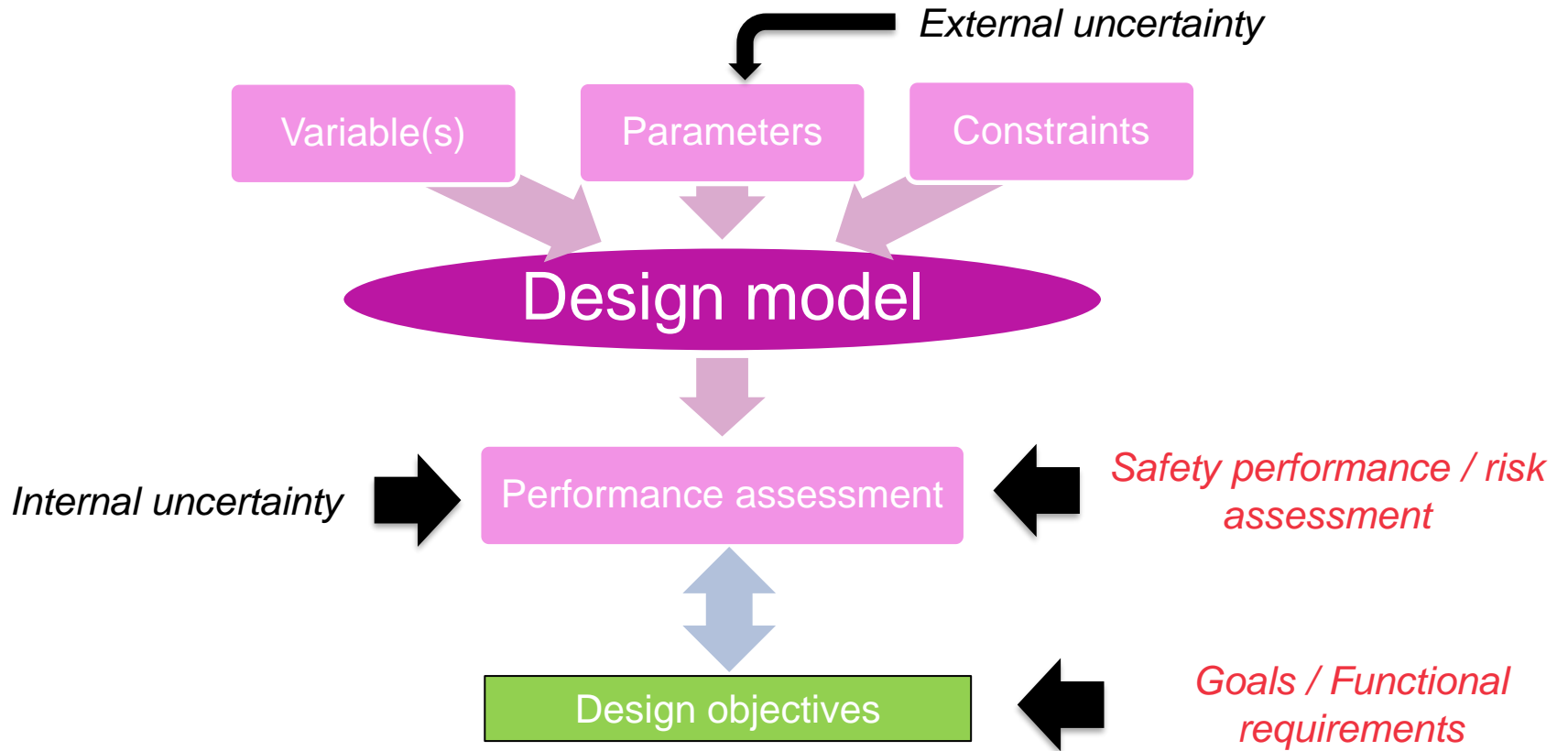
Prerequisites for goal/risk-based ship design

To enable goal/risk-based design the following prerequisites must be present:

- A regulatory framework that enables/supports GBD/RBD
- Design framework and performance assessment tools
- Qualified engineers

Risk

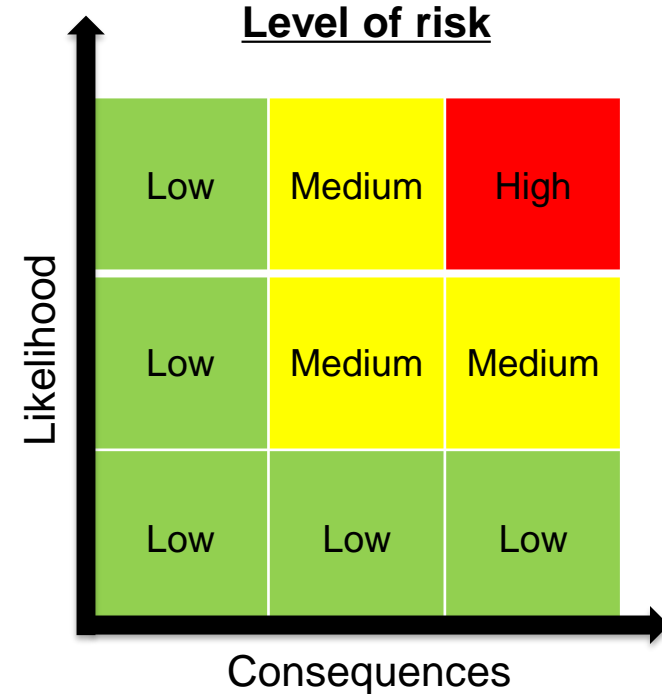**ISO: Risk is a positive or negative effect of uncertainty on objectives**

$$Risk = \sum (L_i C_i)$$

L_i = the likelihood of all plausible risk events
C_i = the related consequences

Plausible risk events

- Collision, fire, grounding,...

Level of risk

	Low	Medium	High
Likelihood	Low	Medium	Medium
	Low	Low	Low

Consequences

Aalto-yliopisto
Insinööritieteiden
korkeakoulu

Risk

- Risk ~ A measure of safety performance
- Risk can be defined in various ways depending on the circumstances
  - *Likelihood, probability, frequency,…*
  - *Quantitatively or quantitatively*
- Different risk categories
  - *Safety risk (risk to human life and health)*
  - *Environmental risk*
  - *Operational risk*
  - *Financial risk*
  - *….*

$$Risk = \sum (L_i C_i)$$

L_i = the likelihood of all plausible risk events
C_i = the related consequences

Risk assessment

A risk assessment must answer three questions
- What can happen? / What can go wrong?
- How likely is it?
- What are the consequences?

The level of risks can be assessed by various means
- Risk models
  - *Fault Tree Analysis (FTA)*
  - *Event Tree Analysis (ETA)*
  - *Bayesian networks*
  - *...*
- Expert opinion
- Empirical data
- Simulations
- ...

Example FTA

Example ETA

Aalto-yliopisto
Insinööritieteiden
korkeakoulu
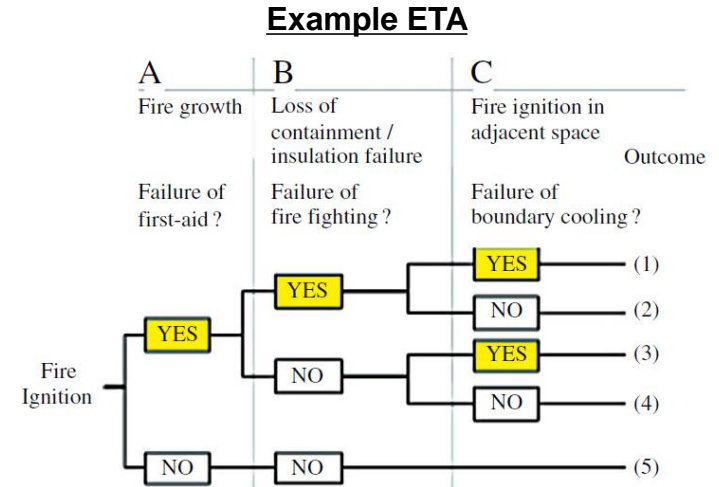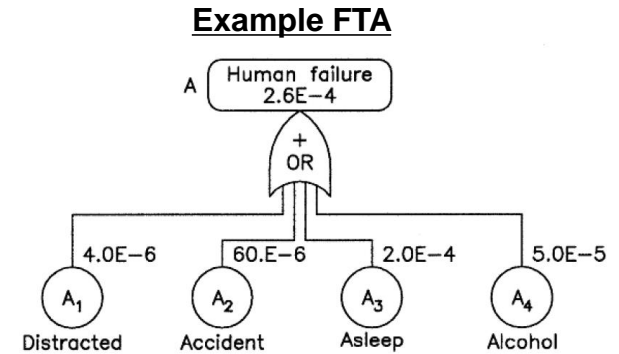
General risk acceptance criteria

Safe design ~ a design with an acceptable/low level of risk

$$(R_{design} \leq R_{acceptable})$$

- For safety and environmental risks: $R_{acceptable}$ specific by authorities
- For other types of risk (e.g., operational risk): $R_{acceptable}$ specified by the owner

Risk control measures (RCM)

Risks are managed by Risk Control Measures (RCM) that either or both

- Reduce the likelihood of an accident
- Mitigate its consequences

Risk control measures (RCM)

Passive risk control measures

- Design
  - *Watertight compartments, double hull,..*
- Equipment
  - *Lifeboats, life rafts,...*

Active risk control measures

- Operational measures
  - *Crew training, risk avoidance,...*

In principle, goal/risk-based design allow the application of both passive and active risk control measures

Image: www.gard.no

Image: www.usmships.com

Pros of goal/risk-based design

Pros of goal/risk-based design include the following:

- "Any" solution that meet the goal(s) and the related functional requirement(s) is acceptable → Expanded feasible design space
    - *Design constraints → Design objectives*
- Safety becomes measurable → Possible to determine goals, application of the most cost-efficient risk control measures

    → Safety performance optimization (removal of excess safety margins or "fat")
- Proactive risk management not limited to experience
- Safety responsibility is transferred from the regulator to the designer (owner) → Encourages "safety thinking"

Cons of goal/risk-based design

Cons of goal/risk-based design include the following:

- Time and resource consuming (requires a significant investment)
  - *Only motivated if significant potential for gains*

- Risk of misleading performance assessments
  - *Larger, more expensive ships → increased risk*
    - The reliability of the applied risk assessment approach must reflect the scale of the potential consequences

- If both passive (design) and active (operational) risk control measures applied
  - → *The ship need to be operated as planned throughout its lifetime*
    - Challenging for instance in the case of change of ownership → New safety culture, operating conditions, different (lower) level of competence,…
    - Sufficient documentation needed

GBD/RBD in other industries

UK offshore industry

- Regulatory system based on mandatory 'Safety Cases'
  - *Objective: "to ensure an adequate level of safety for a particular installation, based upon the management and control of the risks associated with it"*
  - *The mandatory 'Safety Case' includes a detailed description of the installation itself as well as of its operation and operational environment. Based on this description, the 'Safety Case' must identify and assess related risks, and describe how these are controlled*
    - Based on the principle that owner takes responsibility for assessing the risks associated with his installation, and for documenting how his safety management system limits those risks to an acceptable level
    - Application usually in accordance with the principle of *As Low As Reasonably Practical* (ALARP)
    - Regular review, updating as necessary
    - Operations cannot start or continue without a by the authorities approved 'Safety Case'

GBD/RBD in other industries

Norwegian offshore industry

- Self-regulatory system
  - *The operator is responsible for meeting the rules*
    → No responsibility is transferred to the regulator
    → The operator has full responsibility
  - *Compliance is achieved through a combination of audits, verifications, investigations, meetings, and surveys by the regulator*
    - Authorities allowed insight into the decision-making process, access to relevant documentation
   - Authorities act on unacceptable situations, but do not approve any documentation or targets

(http://www.offshoreenergytoday.com)

Offshore vs. maritime industries

Offshore industry

- Very large investment per installation
- Few installations, few operators
- Extensive planning and construction time, long lifetime

Maritime industry

- Large number of ships, large number of operators
- Short production series
- Short time from order to delivery
- Strong competition, low profit margins
- A truly global industry
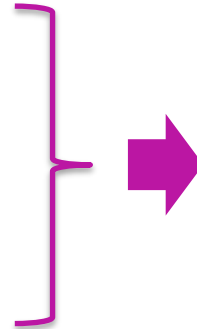
- **Extensive, case-specific safety assessments generally not feasible**
- **Not feasible to maintain an ongoing and close interaction with all involved authorities**

Goal/risk-based maritime regulations

Goal/risk-based maritime regulations

Important goal/risk based maritime regulations include

- Goal-based standards (GBS)
- Formal safety assessment
- Safety equivalence
- Probabilistic damage stability
- Probabilistic oil outflow performance
- Polar Code

In the following we will have a quick look at each of these

Goal/risk-based maritime regulations

Important goal/risk based maritime regulations include

- <mark>Goal-based standards (GBS)</mark>
- Formal safety assessment
- Safety equivalence
- Probabilistic damage stability
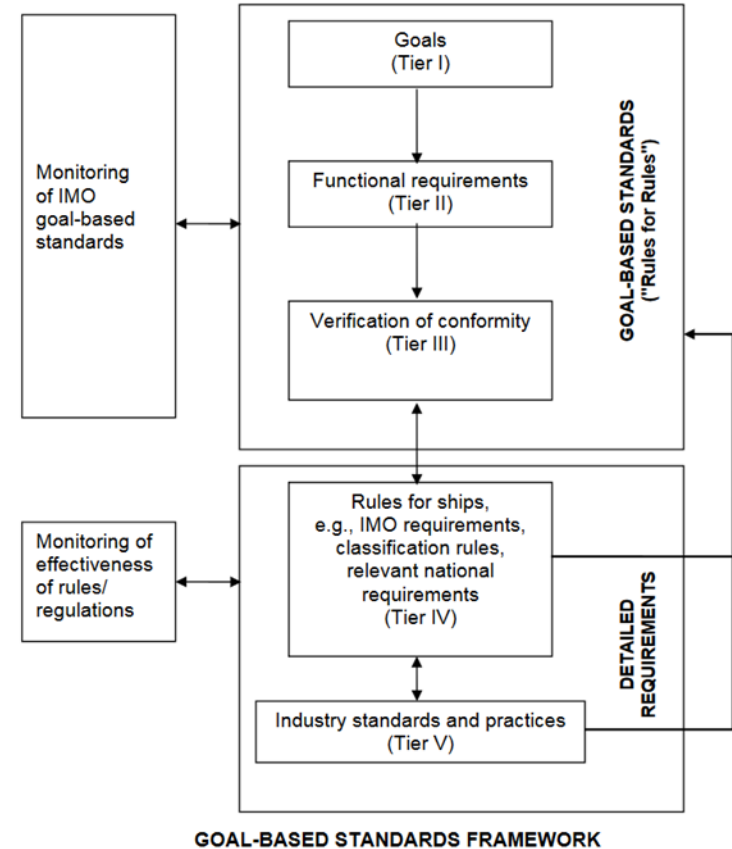- Probabilistic oil outflow performance
- Polar Code

Goal-based standards (GBS)

GBS= The International Maritime Organization's (IMO) rules for how to develop goal-based rules

- Rules for rules

Comprises

- Tier I: Goal(s)
- Tier II: Functional requirement(s) associated with the goal(s)
- Tier III: Verification of conformity
- Tier IV: Rules and regulations
- Tier V: Industry standards and practices
- Monitoring

Monitoring of IMO goal-based standards

Goals (Tier I)

Functional requirements (Tier II)

Verification of conformity (Tier III)

GOAL-BASED STANDARDS ("Rules for Rules")

Monitoring of effectiveness of rules/regulations

Rules for ships, e.g., IMO requirements, classification rules, relevant national requirements (Tier IV)

Industry standards and practices (Tier V)

DETAILED REQUIREMENTS

GOAL-BASED STANDARDS FRAMEWORK
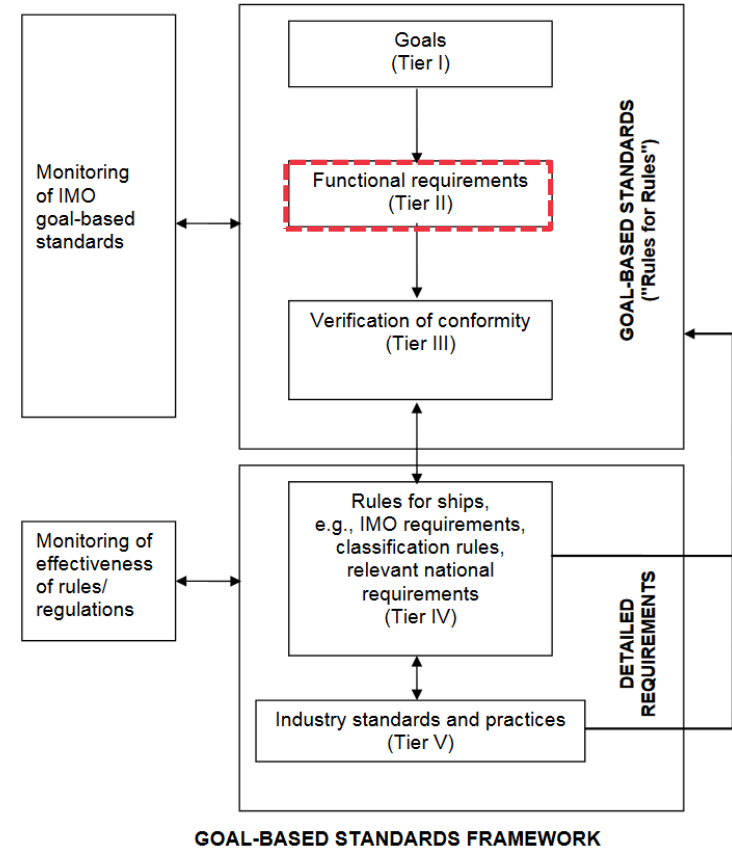
Goal-based standards (GBS)

Tier I: Goals

- Goals are high-level objectives to be met
- A goal should address the issue(s) of concern and reflect the required level of safety
  - *Examples of (top-level) goals*
    - No accidents leading to total ship loss (collisions, groundings, stranding, fires, etc.)
    - No loss of human life due to ship related accidents
    - Low impact to the environment (no air emissions, low noise, low wash)
    - Minimum impact to the environment in case of a ship accident

GOAL-BASED STANDARDS FRAMEWORK
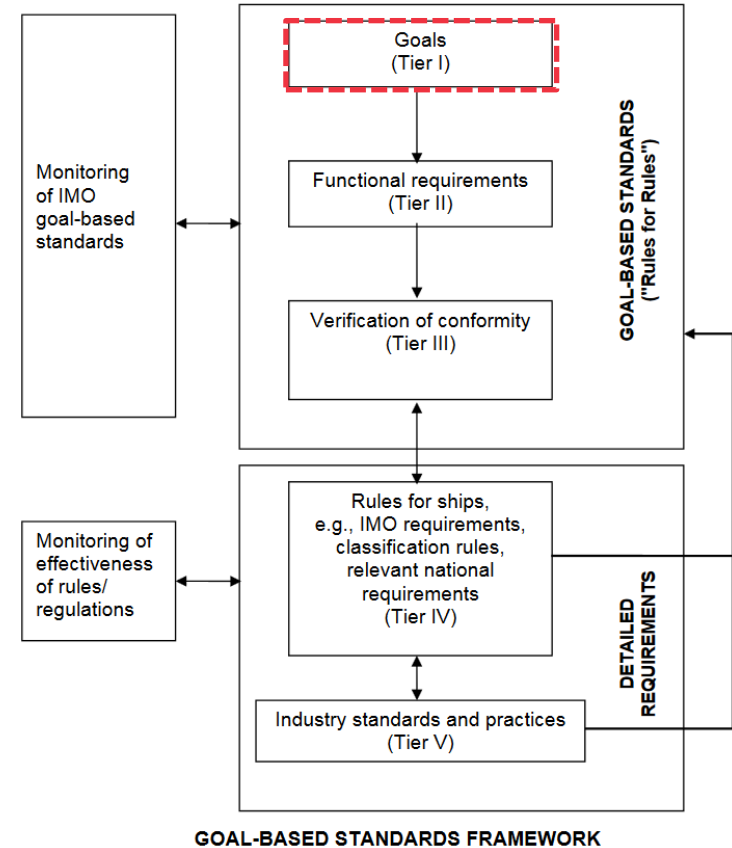
Goal-based standards (GBS)

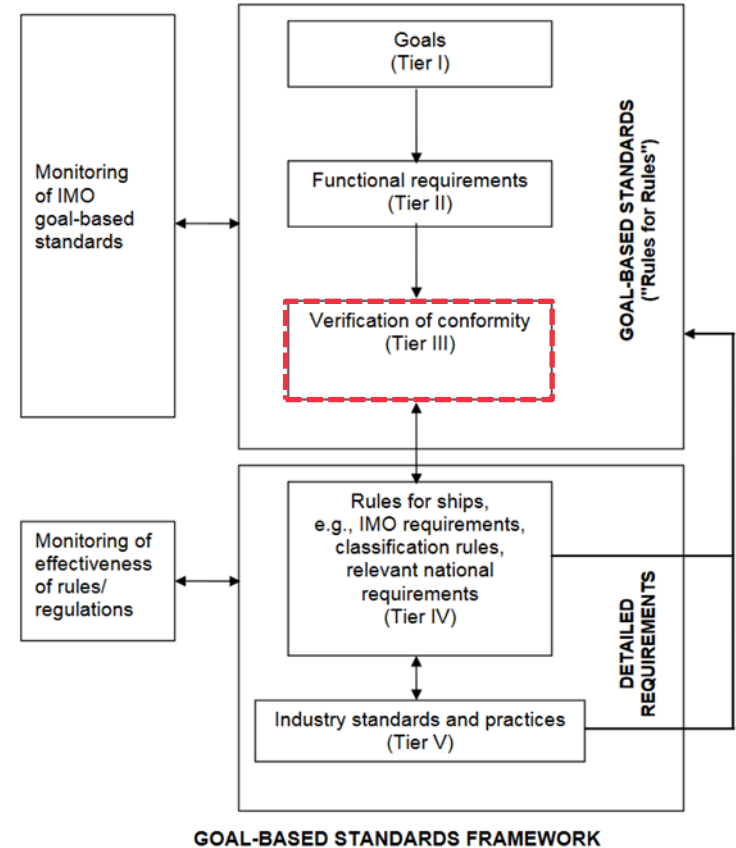## Tier II: Functional requirements (FRs)

- FRs provide the criteria to be satisfied in order to meet the goals
  - *The FRs should cover all functions/areas necessary to meet the goal, and be developed based on experience, an assessment of existing regulations, and/or systematic analysis of relevant hazards*

GOAL-BASED STANDARDS FRAMEWORK

Goal-based standards (GBS)

## Tier III: Verification of conformity

- Instruments necessary for demonstrating and verifying that the associated rules and regulations for ships conform to the goals and functional requirements

- The verification process should be transparent and result in a consistent outcome irrespective of the evaluator
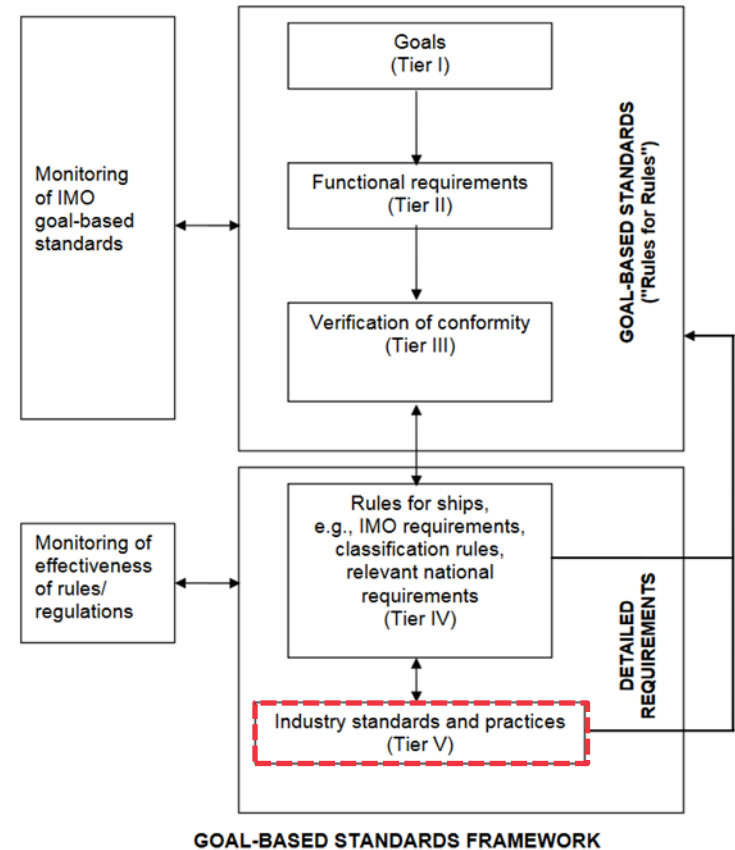

GOAL-BASED STANDARDS FRAMEWORK

Goal-based standards (GBS)

Tier IV: Rules and regulations

- Detailed requirements to meet the goals and functional requirements

GOAL-BASED STANDARDS FRAMEWORK
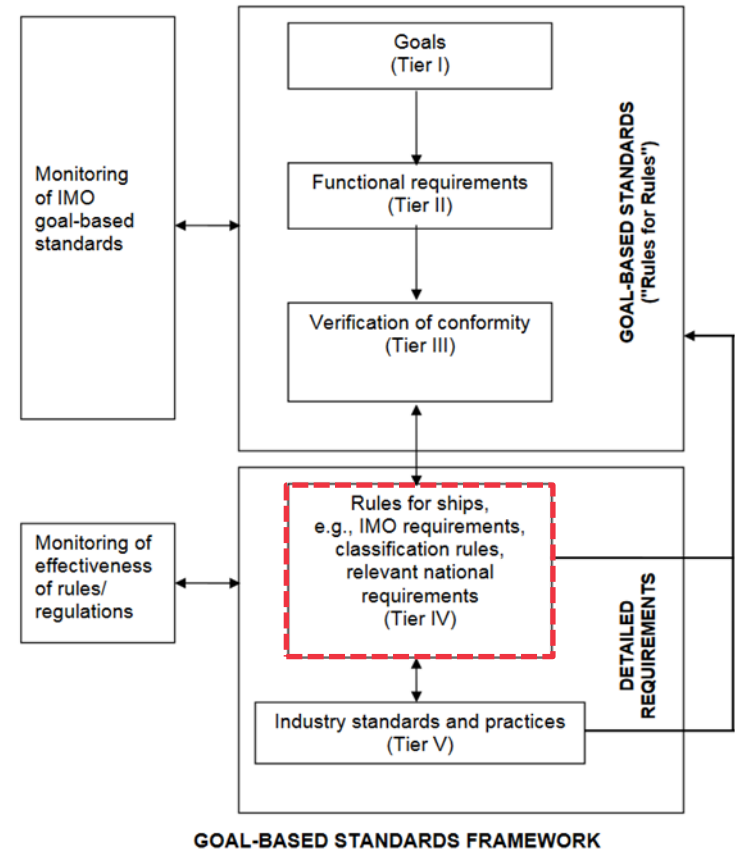
Goal-based standards (GBS)

Tier V: Industry practices and standards

- Industry standards, codes of practice and safety and quality systems for shipbuilding, ship operation, maintenance, training, etc.,

- These may be incorporated into or referenced in the rules/regulations

GOAL-BASED STANDARDS FRAMEWORK

Goal-based standards (GBS)

Monitoring

- Continuous evaluation the effectiveness of Tier I–V
- Identification of risks not addressed in the present rules and regulations

GOAL-BASED STANDARDS FRAMEWORK
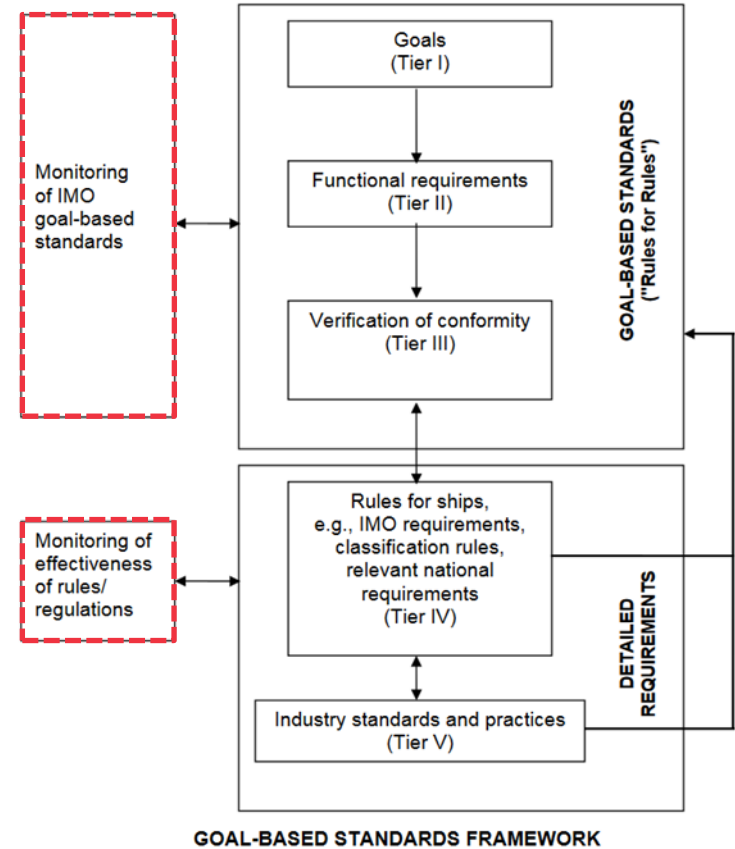
Example structure of a goal-based regulation

Preamble
The International Code of...
General
...
Introduction
This part of the Code contains the...
Definitions
…
Application
Goals
The goal of this Code is to...
Functional requirements
In order to achieve its goal, this Code...

Regulation A-1
Goals
The goal of this regulation is to...
Functional requirements
To achieve the above mentioned goals, the following FRs...
Regulations/requirements
In order to comply with the functional requirement of…

Regulation A-2
Goals
The goal of this regulation is to...
Functional requirements
To achieve the above mentioned goals, the following FRs...
Regulations/requirements
In order to comply with the functional requirement of**…**

Goal/risk-based maritime regulations

Important goal/risk based maritime regulations include

- Goal-based standards (GBS)
- Formal safety assessment
- Safety equivalence
- Probabilistic damage stability
- Probabilistic oil outflow performance
- Polar Code

Formal safety assessment (FSA)

An approach for the determination of new or modified rules at IMO using risk analyses and cost benefit assessments

- Transparent and systematic comparison of various risk control options
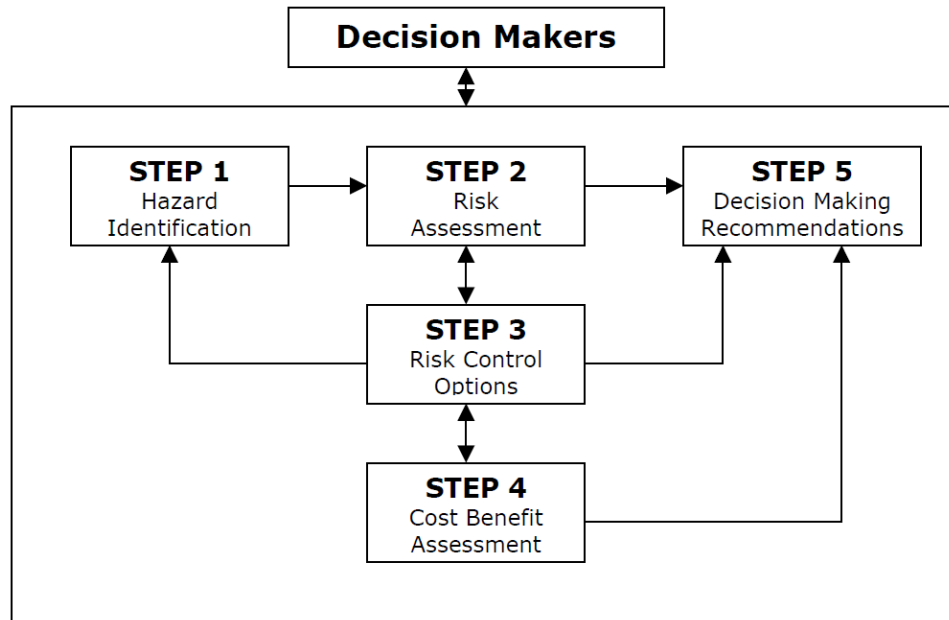
"FSA is a structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property by using risk analysis and cost benefit assessment" (IMO)
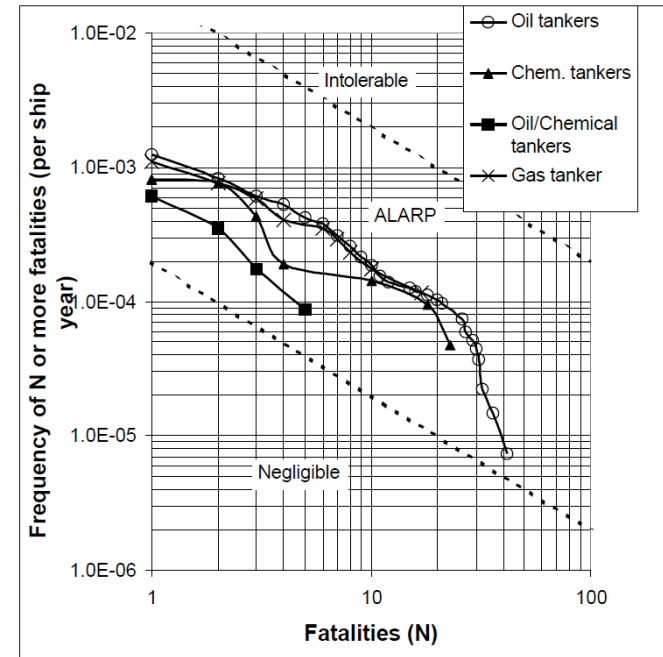
Formal safety assessment (FSA)

Different risk acceptance criteria

- The max accepted individual risk
- The max accepted societal risk
- The max expenditure to avoid a statistical fatality in accordance with the principle of As Low As Reasonably Practicable (ALARP)
  - *Not static, approx. USD 1.5-3 million*

Societal risk

Figures: Papanikolaou et al., 2009
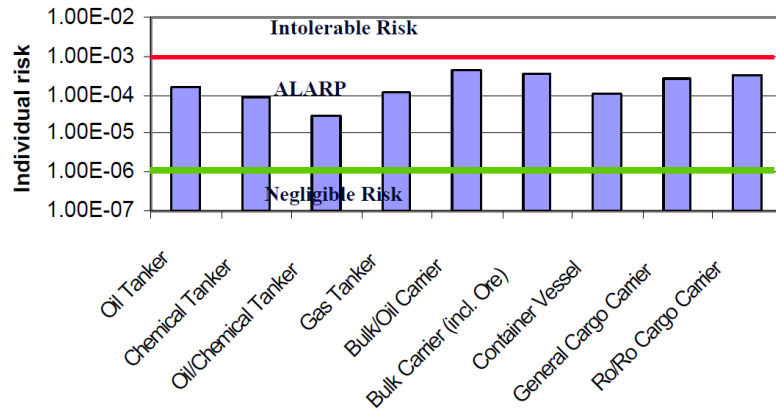
Formal safety assessment (FSA)

The acceptable individual risk depends on if the risk is taken voluntarily or involuntarily

- Risk acceptance criteria proposed by Norway
  - *Max tolerable risk for crew members:* 10^{-3} *per year*
  - *Max tolerable risk for passengers:* 10^{-4} *per year*

Costs connected to managing individual and societal risks are expressed in terms of the <u>Cost of Averting a Fatality (CAF)</u>

- CAF = cost per-life-saved, value of life
- CAF values will depend on geographic location, local economy, type of activity, and public tolerance of risk

$$\text{GrossCAF} = \frac{\Delta C}{\Delta R}$$

and

$$\text{NetCAF} = \frac{\Delta C - \Delta B}{\Delta R}$$

Where,

ΔC is the cost per RCO

ΔB is the economic benefit per ship from the implementation of RCO (this might include pollution prevention)

ΔR is the risk reduction per ship, in term of fatalities averted, implied by RCO.

Formal safety assessment (FSA)

Limited application of FSA

- Probably because the FSA process is highly technical and complex, taking approx. 1 year to complete

FSA has to date not been applied on environmental risk control measures

- No agreed on environmental risk measures or criteria

Goal/risk-based maritime regulations

Important goal/risk based maritime regulations include

- Goal-based standards (GBS)
- Formal safety assessment
- Safety equivalence
- Probabilistic damage stability
- Probabilistic oil outflow performance
- Polar Code

Safety equivalence

General principle

- Any solution may deviate from the prescriptive requirements if the alternative design meet the intent of the goal and functional requirements concerned and provide an equivalent level of safety as the prescriptive design

To prove equivalency, a design must be analyzed, evaluated, and approved in accordance with IMO guidelines

- "Guidelines for the approval of alternative and equivalents as provided for in various IMO instruments", MSC.1/Circ.1455
- Related challenges
  - *How to assess and compare the safety performance of the prescriptive solution with that of an alternative solution?*

Safety equivalent designs can also be referred to as "alternative designs"
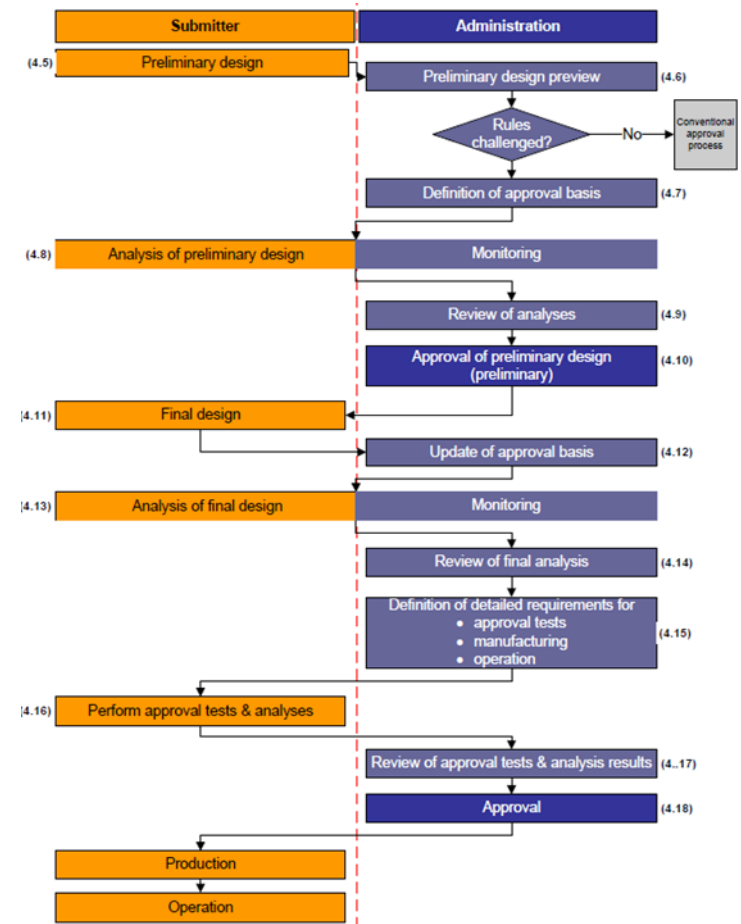
Safety equivalence

Application example

- Alternative design and arrangements for fire safety
  - *Prescriptive rule*
    - Max allowed length of fire zone: 40 m
  - *Application of the principle of safety equivalence enables large open public spaces*
  - *Equivalency demonstrated by numerical fire simulations + evacuation simulations*

Photo: Color line

Space (i)

Frequency of fire ignition event in space i | fire escalation from space of fire origin | Loss of human life injuries/fatalities

$f(i)$ | $P_i(E|f)$ | $pdf(N)$

$\Delta Risk_i$

Figure: Papanikolaou et al., 2009

Aalto-yliopisto
Insinööritieteiden
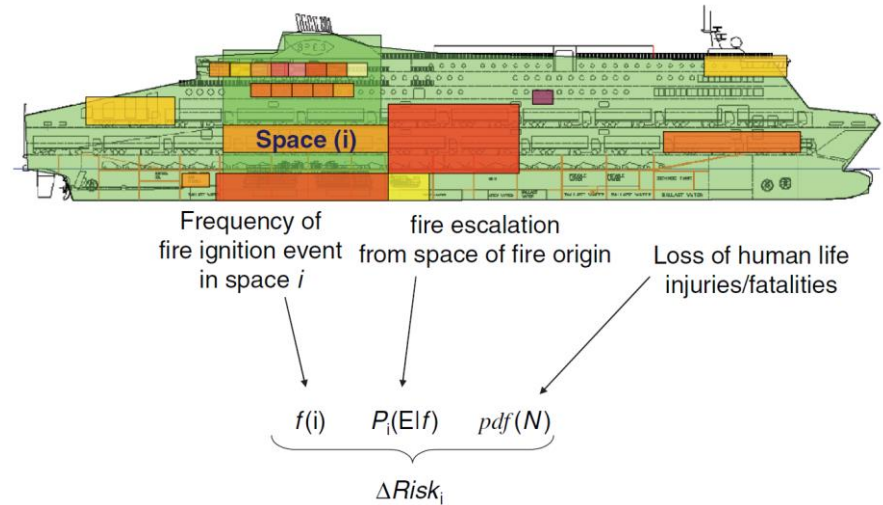korkeakoulu

Goal/risk-based maritime regulations

Important goal/risk based maritime regulations include

- Goal-based standards (GBS)
- Formal safety assessment
- Safety equivalence
- Probabilistic damage stability
- Probabilistic oil outflow performance
- Polar Code

Propabilistic damage stability

Objective: to ensure sufficient damage stability

- A ship's ability to survive various flooding scenarios is quantified in terms of the subdivision index A (degree of subdivision)

$$A = \sum (p_i s_i), A \geq R$$

p_i = the probability that the compartment or group of compartments under consideration may be flooded

s_i = the probability of survival after flooding of the compartment or group of compartments in question (calculated based on a ship's GZ curve for the damage scenario in question)

R = minimum required subdivision

- Determined based on real-life accidents

- Different designs with the same index value are considered equally safe

- R is determined based on ships whose damage stability is considered satisfactory → Not related to any specific level of safety risk (!)

- Operational aspects (active measures) not considered

Aalto-yliopisto
Insinööritieteiden
korkeakoulu

Goal/risk-based maritime regulations

Important goal/risk based maritime regulations include

- Goal-based standards (GBS)
- Formal safety assessment
- Safety equivalence
- Probabilistic damage stability
- Probabilistic oil outflow performance
- Polar Code

Propabilistic oil outflow performance

Objective: to limit accidental oil outflow

- A ship's ability to limit an oil outflow is quantified in terms of a measure referred to as <u>oil outflow performance</u>
  - *Also referred to as <u>pollution prevention index</u>*
- Determined based on a probabilistic approach utilizing damage statistics of real-life incidents
  - *Related calculations are complex and extensive and therefore carried out using dedicated software tools*
- Weakness: the index does not relate to any explicit level of environmental risk
  - *The IMO has not agreed on any environmental risk measures or criteria*

Goal/risk-based maritime regulations

Important goal/risk based maritime regulations include

- Goal-based standards (GBS)
- Formal safety assessment
- Safety equivalence
- Probabilistic damage stability
- Probabilistic oil outflow performance
- Polar Code

Polar Code

The International Code for Ships Operating in Polar Waters (Polar Code)

- The first international regulatory framework mitigating arctic shipping related risks
  - *Enforced January 1, 2017*
  - *Concerns all ships in the Arctic as defined by the IMO*
- Goal-based
  - *Determines goals and functional requirements for various "systems"*
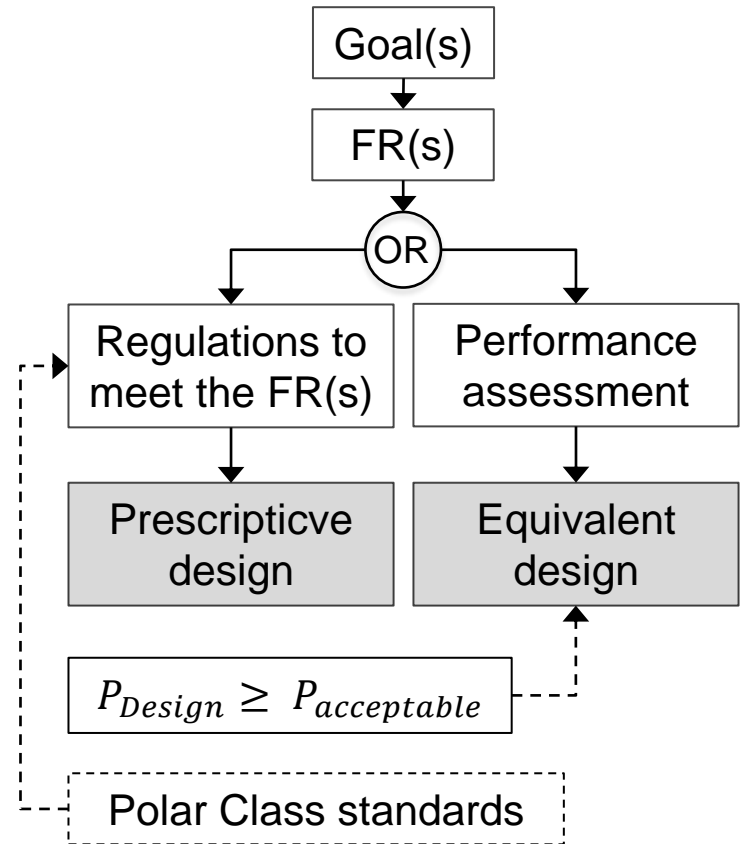
Polar Code

Objective: to ensure the same level of safety for ships, persons and the environment in polar waters as in other waters

- Supplements the SOLAS and MARPOL conventions to account for Arctic specific safety hazards such as
  - *Sea ice, icing, low temperatures, extended periods of darkness/daylight, high latitude, remoteness, lack of crew experience, lack of suitable emergency response equipment, severe weather conditions, sensitive environment,...*
- Determines regulations concerning the design, construction, equipment, operations, training, and pollution prevention
  - *Considers both <u>active and passive</u> risk prevention and mitigation*

Polar Code

A ship approved in accordance with the Polar Code will be issued a Polar Ship Certificate that classifies a ship as one of the following

- Category A
  - *For ships allowed to operate in at least medium thick first-year ice*
- Category B
  - *For ships allowed to operate in at least thin first-year ice*
- Category C
  - *For ships allowed to operate in ice conditions less severe than those included in Category A-B*

In addition to the ship category, the ice certificate determines detailed operational limits concerning for instance the minimum temperature and the worst ice conditions in which a ship can operate

End of lecture - Summary

Lecture summary

Goal/Risk-based ship design

- Determines design criteria in the function space in terms of design goals and functional requirements to meet the goals

- Turns passive compliance of prescriptive rules into active ownership of risks

- Extends the feasible design space → Allows innovative and optimized solutions

- Is associated with a high time and resource consumption and the risk of misleading safety assessments

- Can be part of a holistic design process

- Can and will co-exist with prescriptive regulations
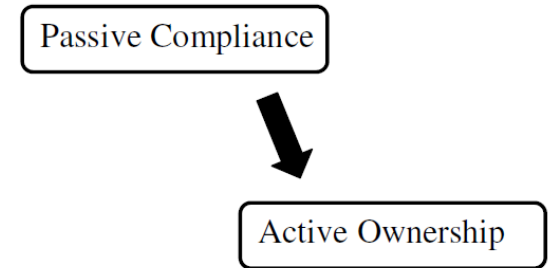 - *Application of prescriptive rules where appropriate*

Figure: Jenkins (2012)

Aalto-yliopisto
Insinööritieteiden
korkeakoulu

Learning logs and next lecture

- **Please return the fourth learning log by Sunday 2.10 at 23:59**

- **Next lecture is release as video on Monday 3.10. The fast quiz will be open from Tue 4.10 at 14:00 to Friday 7.10 at 16:00**

Time for the fast quiz

Instructions:

- The fast quiz is open after the finalization of Lecture 4 (so, now)
- The link to the quiz is:

- The link will close at 14:00
- The grading of the quiz is given before Lecture 05
- If you have any question, please let me know

Aalto-yliopisto
Insinööritieteiden
korkeakoulu