Risk-based analysis and design for remote pilotage operations in Finnish fairways

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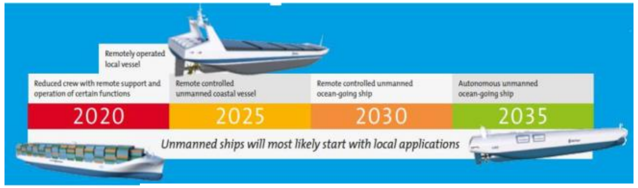
CMSRF webinar on 23.4.2024

Smart shipping-related research in Finland over the last 8 years



ECAMARIS

Enablers and Concepts for Automated Maritime Solutions

GYROSCOPE

SMART CITY FERRIES

DIMECC Program
SEA4VALUE – Fairway

2016	2017	2018	2020	2021	2023	2024
Advanced Autonomous Waterborne Applications Initiative **(AAWA)**	Design for Value **(D4V)**	Smart City Ferries **(Älyvesi)**	**Sea for Value (S4V)**	Autonomous Shipping Education Network **(AutoMARE)**	Enablers and Concepts for Automated Solutions **(ECAMARIS)**	Risks and opportunities of digital solutions in sustainable transition to carbon-neutral marine logistics **(GYROSCOPE)**

Focus: Development of technologies that enable autonomous ship operations
Scope: Ships and the autonomous maritime ecosystem (e.g. smart fairways)

Sea for Value – Fairway program (2020-23)

DIMECC Program
SEA4VALUE – Fairway

Remote pilotage in an intelligent fairway

Industrial partner links:

Research partner links:

Funding partners:

Ship pilotage

When a ship arrives in **congested or shallow areas**, experienced navigators on local waters, known as pilots, go onboard the ship to provide expert navigational guidance.

A **lower number of accidents** has been recorded **in ships with pilots** compared to ships without pilots.

Source: Matthew Barra

Source: Safety4Sea

Challenges

- **Complex and critical operation** as it occurs in congested areas with high collision and grounding risks.
- Risky for pilots as several accidents occur when pilots are getting on and off the ship.
- Pilotage services invest a lot of resources in providing this service.

Sandy Hook Pilot Dies in Boarding Accident

An undated file image of Maersk Kensington (courtesy Manuel Hernández Lafuente / MyShip)

Marine Pilot Survives Pilot Ladder Accident at Port of Durban

Durban harbor (file image)

BY THE MARITIME EXECUTIVE 04-29-2020 01:20:32

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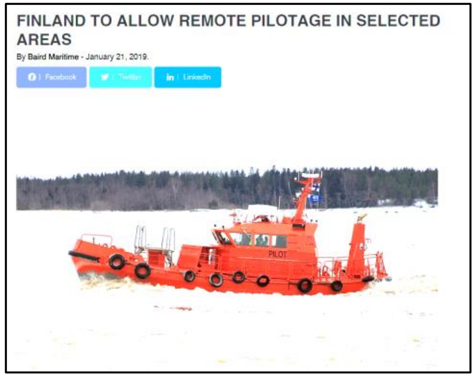
Remote pilotage: a novel form of pilotage

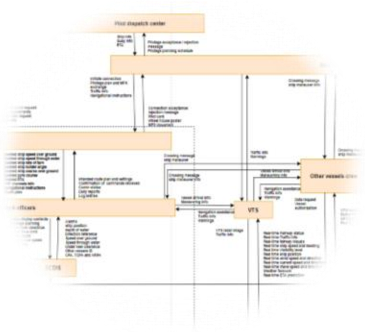
Source: Dimecc


FINLAND TO ALLOW REMOTE PILOTAGE IN SELECTED AREAS

By Baird Maritime - January 21, 2019

Facebook | Twitter | LinkedIn

Source: Baird Maritime



- Instead of pilots boarding the ship, in remote pilotage, the remote pilot will support the ship crew remotely from a shore control center.
- The **Finnish pilotage act** was amended in 2019 and again in 2023 to **allow remote pilotage** services in Finland.

Additional challenges:and *requirement:*

- Embedded software and advanced new technology (prone to software and design errors) .
- Higher number of interactions between components (which can result in unsafe interactions).
- *The **Pilotage act** specifies that a comprehensive risk management study is necessary to enable remote pilotage services in Finland.*

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Aim of the Risk Analysis of RP

- Develop a description of the system (concept of operation) to understand what are the system components and how it functions

- Conduct risk management of Remote pilotage operation using Formal Safety Assessment Framework

- Integrate suitable methods for executing each step of the FSA

Initial Formal Safety Assessment

Scope: Intelligent fairway and remote piloting operations

Step 1 System description	System requirements System components System design solution Hazard identification
Step 2 Risk analysis	Risk criteria Risk estimation Risk evaluation
Step 3 Risk control options	Risk mitigation actions Feasibility study Initial selection of RCOs
Step 4 CBA	Implementation cost Economical benefit Evaluation of mitigation capability
Step 5 SRMS	Management strategy Stakeholder roles and responsibilities Documentation

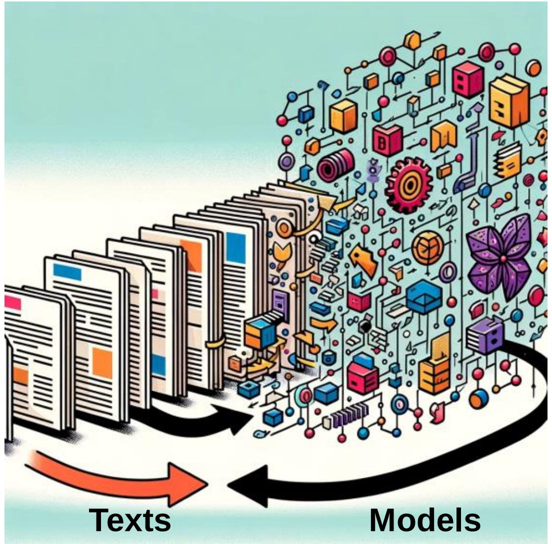
Step 1
Remote pilotage system description

From text-based system description to model-based system description (1)

- **Formal Safety Assessment** based studies has been **criticized** for their **ambiguous system description.**
- **Model-based System Engineering** can **reduce this ambiguity** by utilizing models and minimizing the texts.
- **Challenging to adopt** because various modeling methods exist.
- The suitability of modeling methods depends on:
  - The system scope: What kind of system is being considered and how complex is it?
  - The purpose of the modeling – What is it being used for?
  - The end-users – Who will be using the models?

FSA steps

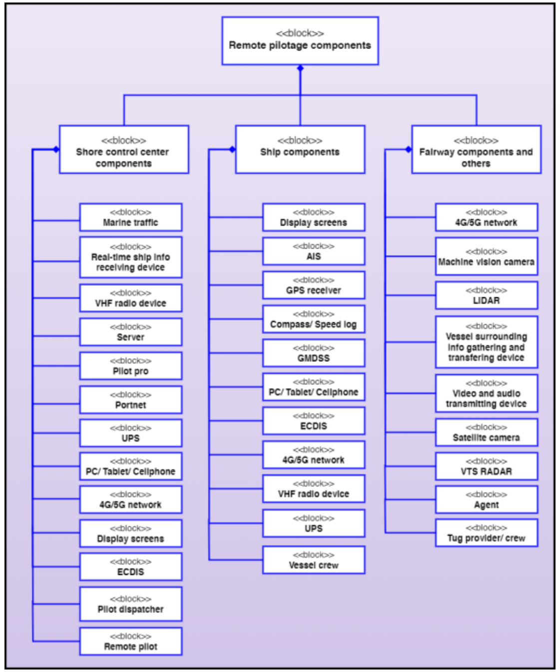
Step 0: Goal, scope and system definition

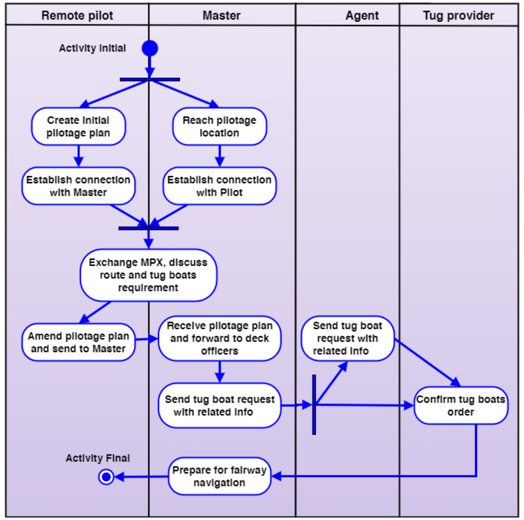


Source: bing.ai

From text-based system description to model-based system description (2)

- ➢ A **decision-making framework** for selecting a suitable modeling language is provided.
  - ➢ End-users are involved throughout the selection process.
  - ➢ Different comparison criteria are applied depending on the modeling purpose and the type of system.
- ➢ The framework was applied to remote pilotage and the **System Modeling Language** was selected.
- ➢ Diagrams describing the remote pilotage operation were developed.



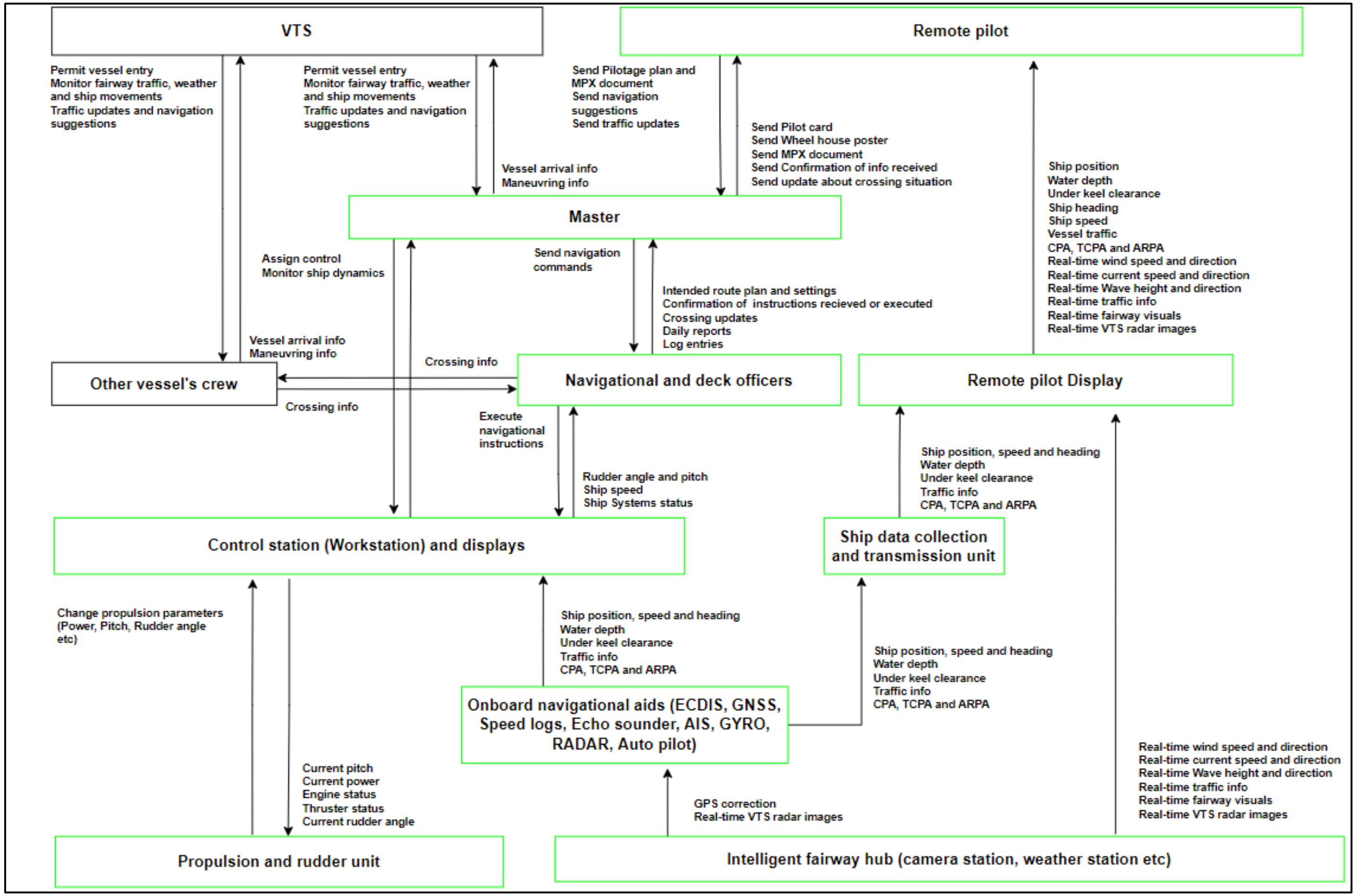


Step 2-4
Remote pilotage risk management

Hazard analysis

- Advanced hazard analysis method (STPA) for complex socio-technical systems, which considers safety a dynamic control problem rather than a failure prevention problem.

- Analyze all interactions in RPO to identify unsafe situations



Summary of RPO Hazard analysis (1)

-Six types of losses considered

L-1: Loss of life or injury to people
L-2: Loss of or damage of own ship and cargo
L-3: Loss of or damage of external objects
L-4: Loss of mission
L-5: Loss of environment
L-6: Loss of customer satisfaction

-Five System-level hazards considered

H-1: Ship violate minimum separation standards in route (L-1, L-2, L-3, L-4, L-5, L-6)
H-2: Ship does not maintain safe under keel clearance (L-2, L-4, L-5, L-6)
H-3: Ship leaves designated route (L-1, L-2, L-3, L-4, L-5, L-6)
H-4: Lack of communication initiation between remote pilotage stakeholders during remote pilotage (L-4, L-6)
H-5: Lack of information sharing between remote pilotage stakeholders during remote pilotage (L-1, L-2, L-3, L-4, L-5, L-6)

-More than 150 Unsafe actions identified

UCA1: Remote pilot does not initiate the communication with master prior to the pilotage. (H-4, H-5)
UCA12: Remote pilot provides wrong, unclear or missing info in pilotage plan and is followed by the vessel crew (H-1, H-2, H-3)
UCA103: Navigational crew provides rudder angle too late during pilotage operation (H-1, H-3)
UCA104: Navigational crew provides rudder angle via AP without providing correct settings to AP during pilotage (H-1, H3)
…

Summary of RPO Hazard analysis (2)

- **800+ unsafe scenarios were identified, which were group into 3 major categories and 50+ sub-categories:**

    Category 1 (C1) : Issues related to Hardware and Software

        C1.1 - VHF failure

        C1.2 – Cellphone /Tablet

    Category 2 (C2): Issues related to Human factors

        C2.1- Distraction

        C2.2- Lack of skills/competence

    Category 3 (C3): Issues related to incomplete, incorrect, unclear or lack of data

        C3.1- Issues with data related to ship info

        C3.3- Issues with data related to ship dynamics

UCA1: Remote pilot does not initiate the communication with master prior to the pilotage. (H-4, H-5)

Causal Scenario 1 (S1): The remote pilot does not initiate the communication because he doesn't receive the required ship information to initiate the communication from pilot dispatch center (C3)

Causal Scenario 2 (S2): The remote pilot does not initiate the communication because of fatigue due to work overload (C2)

…

Safety related to equipment

GYRO	RADAR	AIS	GPS
Engines	Fairway infrastructures	Lights onboard	Cloud services
Displays	Sound signaling device	Integrated alarm system	Communication device
Autopilot device	ECHO sounder	ECDIS	Rudder and helm
Data transmission unit	Networking equipment	Thruster and propulsion unit	

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Safety/Security related to information exchange

Ship dynamic data	Ship info	Fairway traffic info
Ship systems info	Weather info	Water depth info
Communications info	Quay info	Tugboat info
Crossing info		

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Safety related to human factors

Lack of skills /competence	Fatigue	Stress	Distraction
High level of task complexity	Lack of trust	Lack of checklists/ guidelines	Lack of standard phrases
Lack of seamanship	Language barrier	Wrong assumption	Poor situational awareness

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Safety related to human factors

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Skills related to remote pilot : Navigational suggestions, pilotage planning, establishing connection and sending info, suggesting emergency procedures, communication skills, situational awareness, handling new equipment e.t.c.

Skills related to Master and navigation crew: Vessel navigation, communication skills, executing emergency procedures e.t.c

Risk control measures:

- Selection of ship and fairway
- Simulation practices for remote pilotage
- Experienced and skilled pilots / crew
- Half-Duplex or Duplex communication
- Certification of Remote pilots and its validity
- Training for remote pilots and ship crew.
- Emergency procedures for remote pilotage (changing to conventional pilotage in case of major issues)
- Increased situational awareness (Installation of more camera stations in fairway, assess other technologies)
- …..

Risk matrix

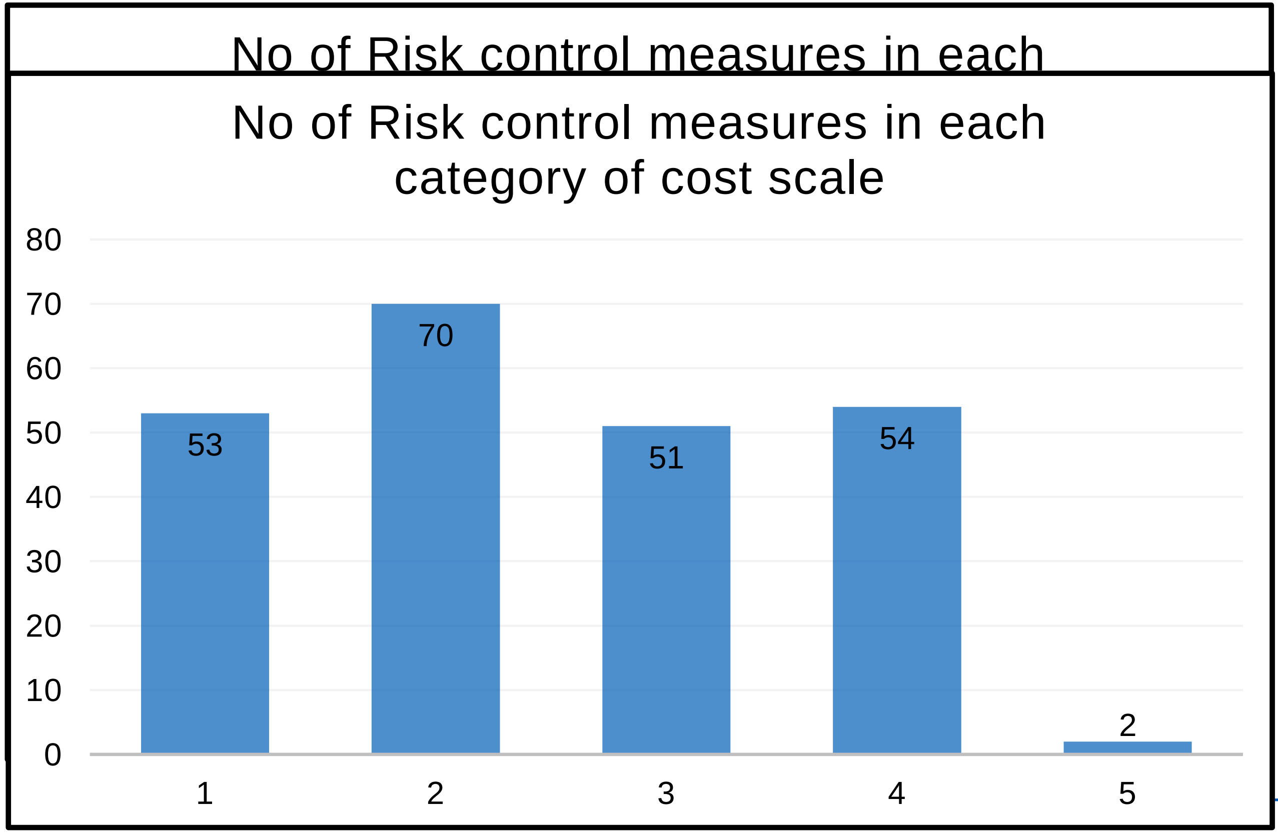
Risk matrix		Severity			
		Minor	Significant	Severe	Catastrophic
Frequency	Extremely remote	0	1	0	2
	Remote	6	10	7	2
	Reasonably probable	1	0	13	2
	Frequent	0	1	3	1

Estimated risk levels

Low risk level – 18 categories
Medium risk level – 9 categories
High risk level – 22 categories

- The estimated risk levels are before the implementation of risk control measures
- The successful implementation of risk control measures is expected to lower the risk levels

Preliminary Cost-benefit analysis of Risk Control measures

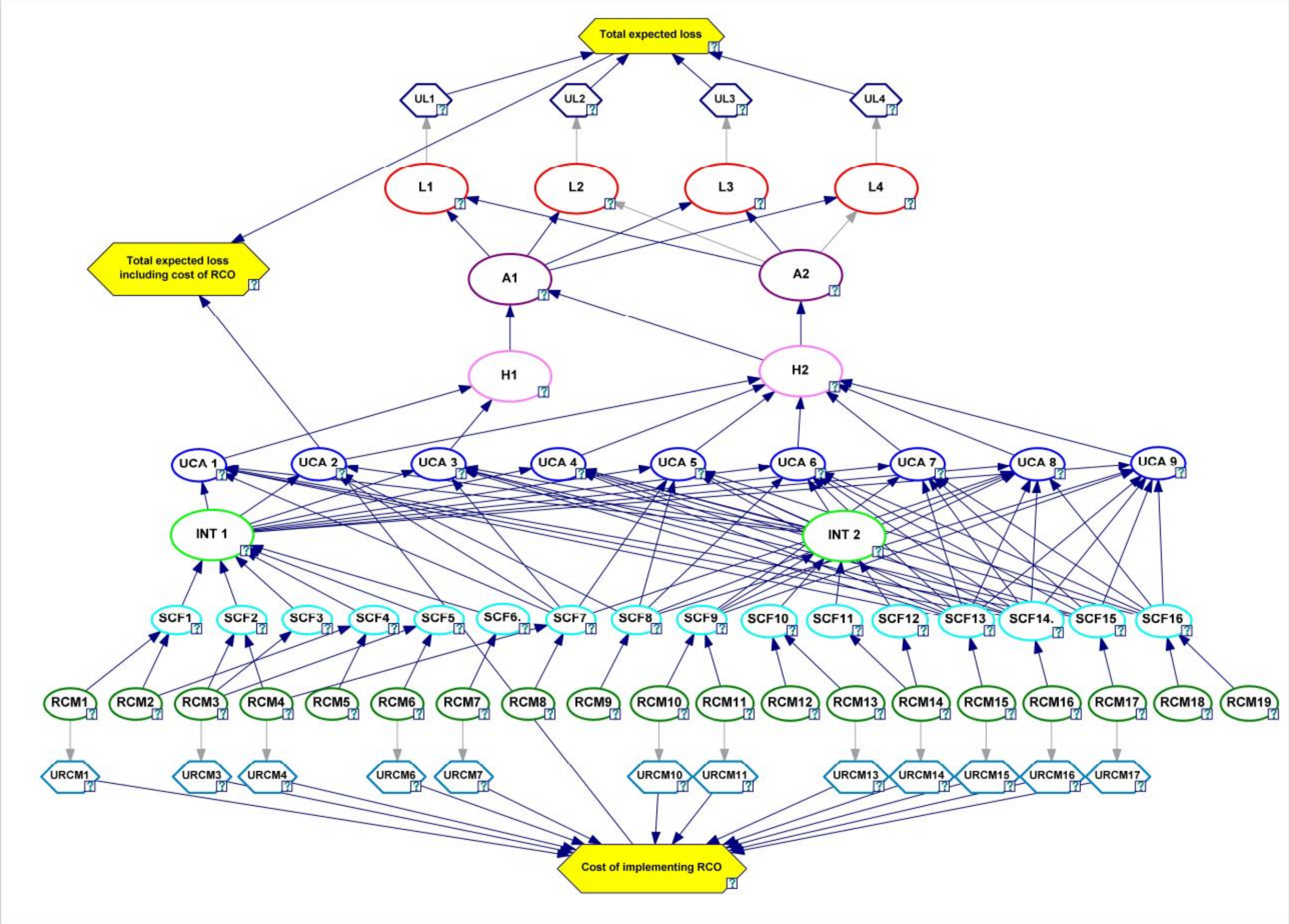


Scale for cost of Risk Control Options	
Cost	**Approx. Cost (in €)**
1- No direct cost	0
2- Low cost	1 – 9,999
3- Average cost	10,000-99,999
4- High cost	100,000 – 1 mil
5- Very high cost	Above 1 mil

Scale for effectiveness of Risk Control Options	
Effectiveness	**Reduction**
1- Very low effectiveness	1-20%
2- Low effectiveness	20-40%
3- Medium effectiveness	40-60%
4- High effectiveness	60-80%
5- Very high effectiveness	80-100%

Cost-benefit analysis of RPO using Influence diagrams

- An Influence diagram of RPO has been developed to assist the decision-makers in the selection of Risk Control Options
- The diagram is focused on critical risk nodes and can estimate the total expected benefit by calculating the benefit due to risk reduction and the cost of implementation
- Some important measures in the selected RCO were redundancy of data collection and transmission unit, standardization of language, and requirements such as certification and minimum crew size.



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Step 5
Defining the basis for the Risk and Safety Management Strategy of Remote Pilotage

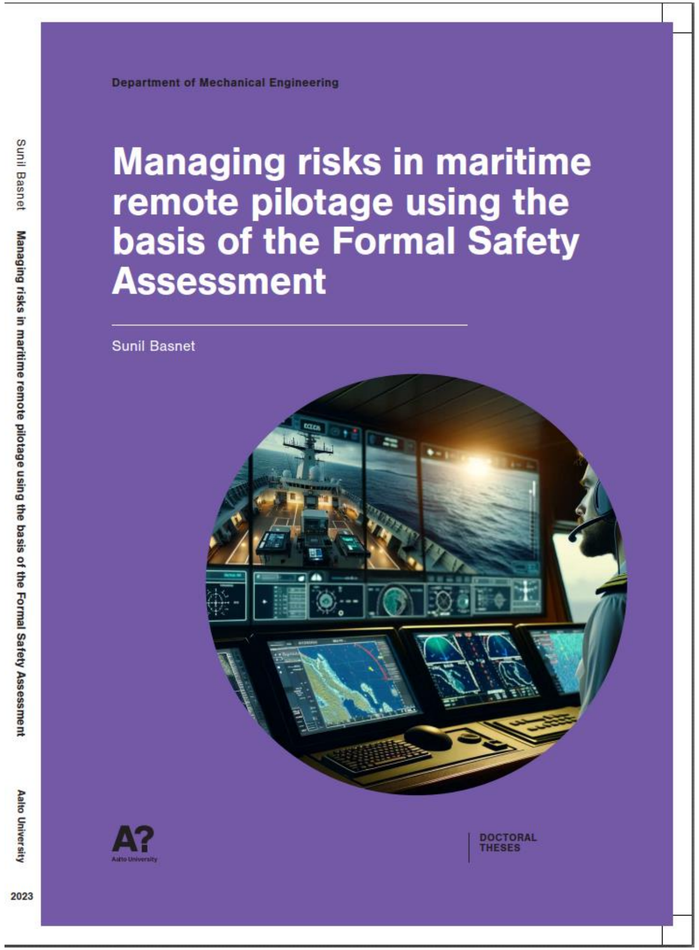
Work concluded and next steps

- 50+ loss causal factors were identified in RPO risk analysis requiring risk control options.
- The risk management strategy defined with the RCOs should be used as the foundation for the definition of a structured management system to continue the design and future operations of remote pilotage in Finland
- The output of this work supports the definition of safety requirements related to remote pilotage (preliminary abstract level requirements exist already in the pilotage act)
- Remote pilotage was demonstrated in Finland in 2022. The results of this study were utilized in the demonstration.
- For the next iterations, the scope of the analysis should be expanded to a higher level (management and authorities).
- At this moment an initiative was submitted to the EU to continue the work in Finland and other EU countries

All details of the study

Please see the following D.Sc. Thesis:

https://aaltodoc.aalto.fi/server/api/core/bitstreams/88a9a04d-302c-42ce-bb06-f81fb31e5c29/content



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Thank you!

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