Aalto University
School of Engineering

A STAMP-based approach for designing maritime safety management systems

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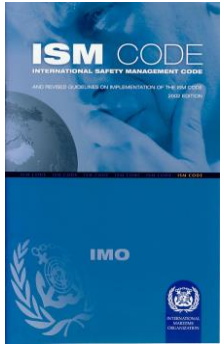
Background

Maritime navigational operations are complex and difficult to manage (1). For this reason, the IMO attempts to ensure the safety of maritime operations through regulatory demands.

The design and implementation of SMS influenced by a limited approach which focuses on fulfilling the demands of maritime regulations(2).

This creates the lack of adequate processes for designing and implementing SMS which can represent and improve the management of safety critical organizations (3)



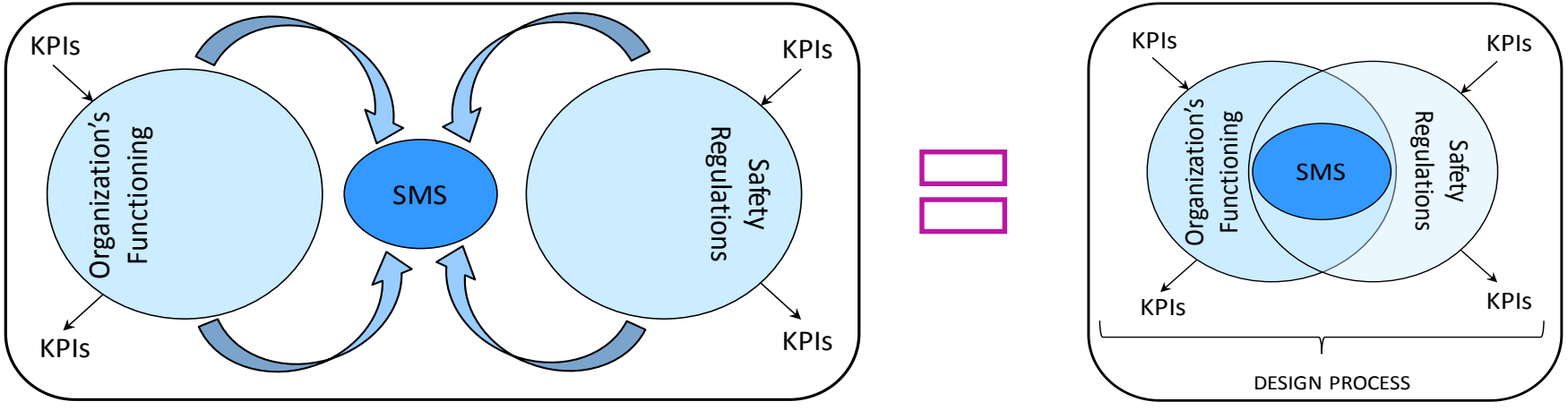
(1) Hetherington, C., Flin, R., Mearns, K., 2006. Safety in shipping: The human element. J. Safety Res. 37, 401–411
(2) Schröder-Hinrichs, J.-U., Hollnagel, E., Baldauf, M., Hofmann, S., Kataria, A., 2013. Maritime human factors and IMO policy. Marit. Policy Manag. 40, 243–260
(3) Leveson, N., 2011. Engineering a Safer World: Systems Thinking Applied to Safety. MIT Press

Aim

Elaboration of an integrated system and safety engineering process for designing SMS. A process which can give answer to the following questions:

- How maritime organizations can systematically design SMS which can represent and constantly improve the management of safety?
- How to define safety requirements and controls which are capable of ensuring the functioning of a SMS at all levels?
- What mechanisms can be implemented to efficiently monitor, review and guide the functioning of SMS?

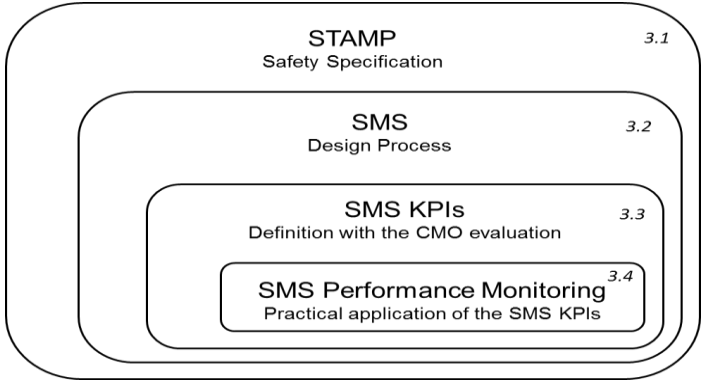
Safety management perspective



Elements influencing and interacting in the function of SMS

Methodology

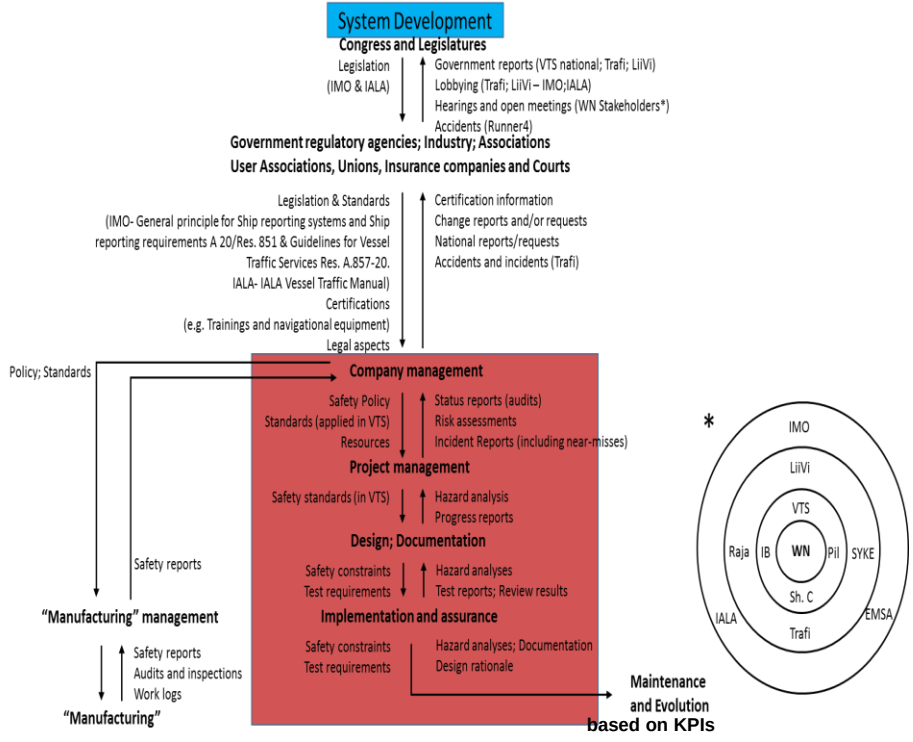
Methodology



	Environment	Operator	System and components	Verification and validation
Level 0: Program management	Management plans, safety plan, safety management procedures and safety plans			
Level 1: System purpose	Assumptions and constraints	Responsibilities Requirements	Goals, requirements, design, constraints and limitations	Preliminary Hazard analysis
Level 2: System principles	External interfaces	Task analysis and allocation, Controls and Displays	Logic principles, functional decomposition and allocation	Validation plan and System Hazard analysis
Level 3: System architecture	Environment models	Operator Task models and HCI models	Blackbox functional models and Interface specifications	Analysis plans and results, Subsystem Hazard analysis
Level 4: Design representation		Human – Computer Interface Design	Software and hardware design aspects	Test plans and results
Level 5: Physical representation		Guided User Interface design, physical control design	Software code, hardware assembly instructions	Test plans and results
Level 6: System operations	Audit procedures	Operator manuals, Maintenance and training materials	Error reports, and change request.	**Performance monitoring (KPIS)**

Safety Intent Specification

CASE STUDY:
VTS Finland



VTS Socio-technical structure

Proposed process for designing SMS

Level	Task
0	Review of the current practices for managing the function of the organization
1	Define system goals and constraints • Define accidents • Hazard identification • Preliminary hazard analysis • Environmental assumptions • Initial restrictions of the SMS • SMS requirements • Link between the requirements and detected hazards • High-level safety constraints of the SMS
2	Integrated principles for the function of the SMS under design • Interface • Hazard analysis and validation of the requirements
3 – 5*	Architectural design and functional allocation • Mapping of the elements in the SMS System design and physical representation. • Assessing of the SMS design and physical representation
6	Review of the actual performance of the designed SMS • Elaboration of auditing procedure • Review of personnel skills (training provision) and safety management (internal audit) • Definition of the KPIs for the SMS • Monitoring the performance of the SMS

Case Study:
VTS Finland

Aalto University
School of Engineering

Case study: VTS Finland

VTS Finland provides services for monitoring, communicating and reporting any event or issue related to the maritime traffic.

VTS areas:

- Bothnia VTS
- West Coast VTS
- Archipelago VTS
- Hanko VTS
- Helsinki VTS
- Kotka VTS
- Saima VTS

VTS centres:

- Gulf of Finland VTS
- Western Finland VTS
- Saima VTS

VTS Finland (services provided)

Information: traffic conditions in the areas and the condition of the aids to navigation and channels.

Navigational assistance: the vessel's position and bearings/courses over ground. It is provided at open sea, and from the open sea to the vicinity of pilot boarding places and also outer anchorages. It is only advisory and normative, the *master* is the final responsible for manoeuvring the vessel.

Traffic organization: this is given to prevent dangerous meeting, crossing and overtaking situations and congestion. For this, VTS separates the traffic in terms of time or distance according to the situation and circumstances.

Results

Output (Level 0)

Review of the current practices for managing the function of the organization:

- The structured VTS Finland Quality Management Systems is the basis for the designing of the SMS.

Process	IALA Guideline
Routine processes	
A. Identification of ships entering the area	1056; 1111; 1089; 1105; 1083; 1102;1071; V-127; V-103
B. Identification of ships leaving port	1089; 1083; 1102; 1071; V-127
C. Provision of VTS *The process is activated when the process 1 or 2 started*	1089; V-127
D. Gulf of Finland Reporting System (GOFREP) *It includes the reporting of deviations*	1018; V-127

Output (Level 1)

18 main accidents

Accident type	Accident	Navigational season
Internal	1. Fire on the VTS centre	Both seasons
	2. Blackout in the VTS centre	Both seasons
External	3. Collision ship-to-ship 3.1 In meeting 3.2 Passing 3.3 Crossing 3.4 In pilot assistance.	Both seasons
	4. Collision with a fixed object	Both seasons

26 identified hazards

Hazard	Accident
A.1 Electrical equipment without proper maintenance A.2 Flammable material no properly controlled A.3 Lighting during storm affecting electrical equipment A.4 Fire in neighbouring building and/or office	1
B.1 Power grid failure B.2 Electrical equipment without proper maintenance	2
C.1 Radar equipment without proper maintenance C.2 Image system (AIS) outdated and/or without proper maintenance C.3 Communication equipment (radio, telephone, and IT) without proper maintenance C.4 Weather causing failures (lighting storms, winter storms, heavy rain, strong winds..)	F1

Preliminary Hazard analysis

Hazard	Severity				Likelihood
	H	T	E	P	
A.1	3	1	2	4	Low
A.2	3	1	2	4	Low
A.3	2	1	2	3	Low
A.4	3	1	2	3	Low
B.1	1	1	1	2	Medium
B.2	2	1	1	2	Low
C.1	1	3	1	2	Low
C.2	1	3	1	1	Low
C.3	1	2	1	1	Low
C.4	1	2	1	2	Medium

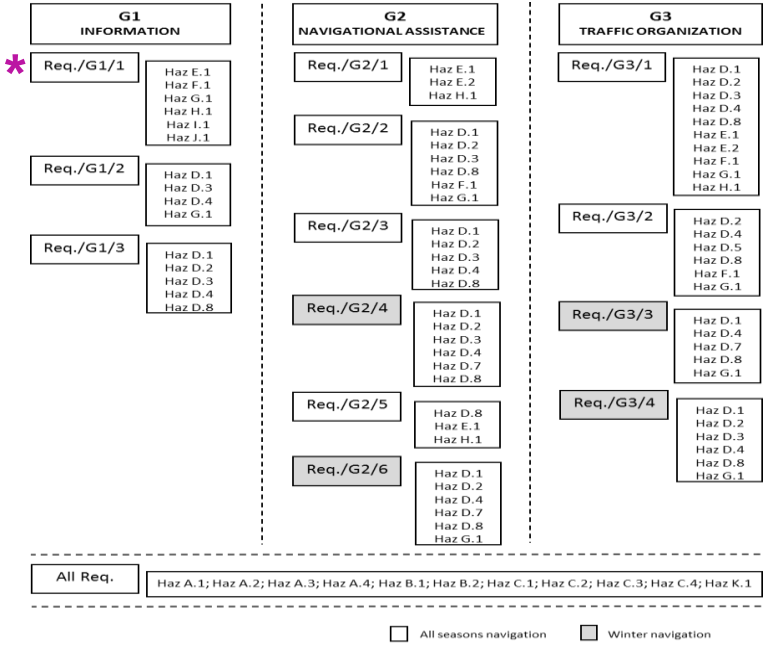
Severity Level	H Human	T Traffic operations	E Environment	P Property
4	Loos of life	Traffic operations discontinued	Catastrophic affectations to the environment	VTS centre/ ship loss
3	Severe injury or illness	Major affectations to the operations	Major affectations to the environment	VTS centre/ ship major damage
2	Minor injury or illness	Minor affectations to the operations	Minor affectations to the environment	VTS centre/ ship minor damage
1	Insignificant injury or illness	Insignificant affectations to the operations	Insignificant affectations to the environment	VTS centre/ ship insignificant damage

Output (Level 1)

Assumptions and constraints

Hazard D.2. VTS provide inappropriate navigational assistance to the vessels in the area.	
Assumption	Safety Constraints (SC)
EA/D.2/1 (List of information) EA/D.2/2 (Communication restrictions) EA/D.2/3 (International guidelines) EA/D.2/4 (Training)	SC. The IALA guidelines and recommendations are implemented in the functioning of all the VTS centres. This includes: • Acquisition of appropriate technology to provide VTS all year around (including wintertime). • The cooperation with all relevant stakeholders in the provision of navigational assistance • The safety and business strategy targets stated by VTS Finland and Finnish maritime authorities SC. VTS Finland executes periodical reviews for the testing the skills of the personnel of the centres. SC. The operators are trained to be efficient when providing navigational assistance. Demanded basic training by IALA is provided to operators and supervisors. The training is strengthened by having exercises in simulated environments which are evaluated by training experts.

Requirements of the SMS



*	Req./G1/1	15 minutes before entering a VTS area, vessels must provide its basic information (vessel name, location, destination, intended route and vessel general condition) to VTS centre.

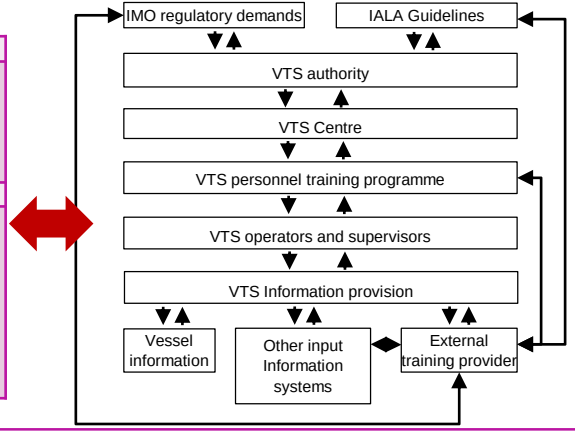
Output (Level 2)

Definition of the practical functioning of the requirements

Req./G2/2. A vessel approaching to a point of contingency must be informed about the situation and recommendations (guidance) should be provided.	
Interface	Radio is the most common mean used to inform about contingencies in the planned route. In case communication by radio is not possible, other alternatives must be used. The requirement could have connection with other organization such as: pilots, icebreakers, SAR services, shipping company and any organisation affected by the vessel logistics chain.
Controls and displays	Contingencies are reported by radio to VTS centres. This enables the marking and displaying of the areas of contingency within VTS monitoring system.
Logic principles	Once contingencies are reported, marked and displayed in the VTS monitoring system, VTS operators inform the potential risk to other vessels approaching the area and provide recommendations about how to proceed.

Re-defining the requirements

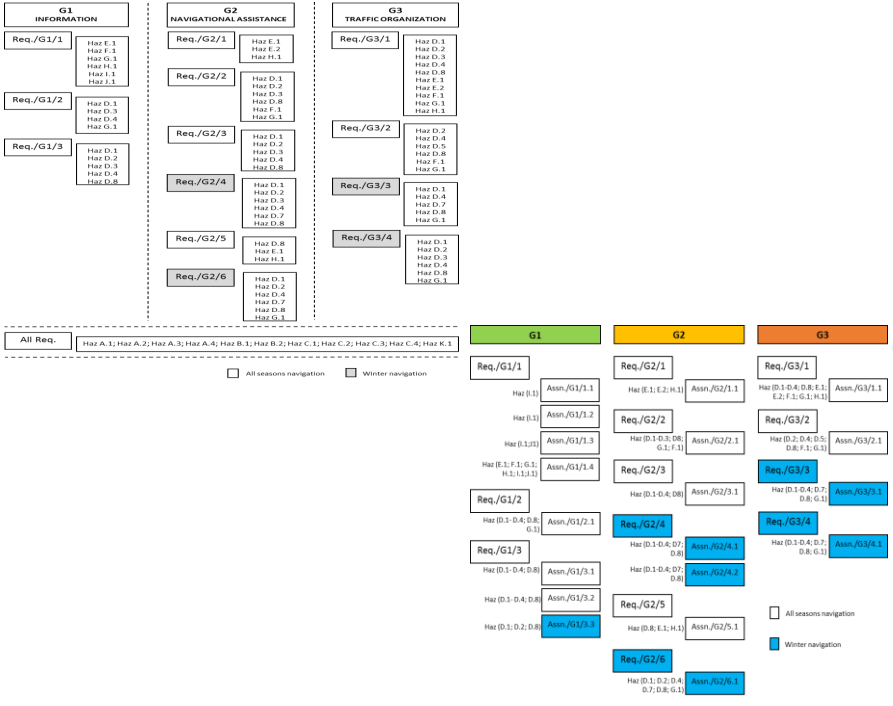
Detecting potentially Unsafe Controlled Actions (UCAs)
UCA 1. The training provided for VTS personnel does not consider the demands and guidelines of the existing normative. UCA 2. The training provided does not match the needs and common characteristics of an actual service provision. UCA 3. The training does not efficiently consider the actual scope and limitations on the provision of navigational assistance. UCA 4. The training does not efficiently consider the common input from relevant information systems such as pilots, icebreakers, SAR services
Redefine of the safety constraint
SC. The operators are trained to be efficient when navigational assistance. Demanded basic training by IALA is provided for operators and supervisors. The training is strengthened by having exercises in simulated environments which are evaluated by training experts. This includes: - Demanded basic training in IMO regulations (e.g. SCTW) and IALA guidelines are included in the training offered. - The training programme efficiently covers the specifications of the actual scope and limitation in the provision of navigational assistance by VTS Finland. - Trainers incorporate the actual characteristics on the exchange of information between VTS centres and vessels, including the understanding about the common conflicts during communication.



STPA process

Output (Level 3-5)

Analysis of the architectural design, system functional allocation and system physical representation



Requirements of the SMS to be evaluated and reviewed with the navigation monitoring system provider

1. General review of the requirements for the functioning of the SMS VTS Finland

Requirement	Hazards	Status and support evidence
Req./G1/1 Req./G1/2 Req./G1/3 Req./G2/1 Req./G2/2 Req./G2/3 Req./G2/4 Req./G2/5 Req./G2/6 Req./G3/1 Req./G3/3 Req./G3/4	A.1; A.3; B.1; B.2; C.1; C.2; C.4; D.1-4; E.1; E.2; F.1; G.1; H.1; K.1	Are the requirements informed and detailed explained to the provider? Are the assumptions and hazards explained and reviewed with the provider? - Documents of reference: Are the requirements fulfilled by the provider? - Exceptions: Are the general aspects of the monitoring system improved after reviewing the requirements with the provider? - Provide a documented action:

2. The VTS Finland monitoring system must follow the demands in international regulations which are adapted to the requirements.

Regulation	Req.	Condition evaluated
IALA Guideline 1056	Radar	Are the requirements of the regulation fulfilled?

Output (Level 6)

- A defined internal audit procedure for the SMS

- SWOT analysis of the skills of VTS operators and supervisors

Strengths: - Strong background in maritime navigation - Practical experience in actual ship operations - Experience in the actual functioning of VTS - Strong knowledge of maritime contexts - Strong knowledge of the functioning of the equipment and technologies - Fast processing of the information in different contexts	**Weaknesses:** - Usage of the message markers - Language proficiency and communication
Opportunities: - Improve the use of message markers by implementing exercises in simulated environments - Improve the efficiency of communication internally and externally - Creating more interactive exercises which include VTS environment and ship simulators - Provide training for executing appropriate risk analysis	**Threats:** - Experience influences the involvement of the VTS operators when using the message markers (assuming how the operator would act in the same context) - Internally VTS operators speak local language. The communication with vessels is English. This sometimes causes problems in the fluency of the communication when internal and external communication are combined. - The mandatory reporting of extraordinary events is demanded in VTS centres. Reporting after a finalized work schedule may compromise the quality of the reports.

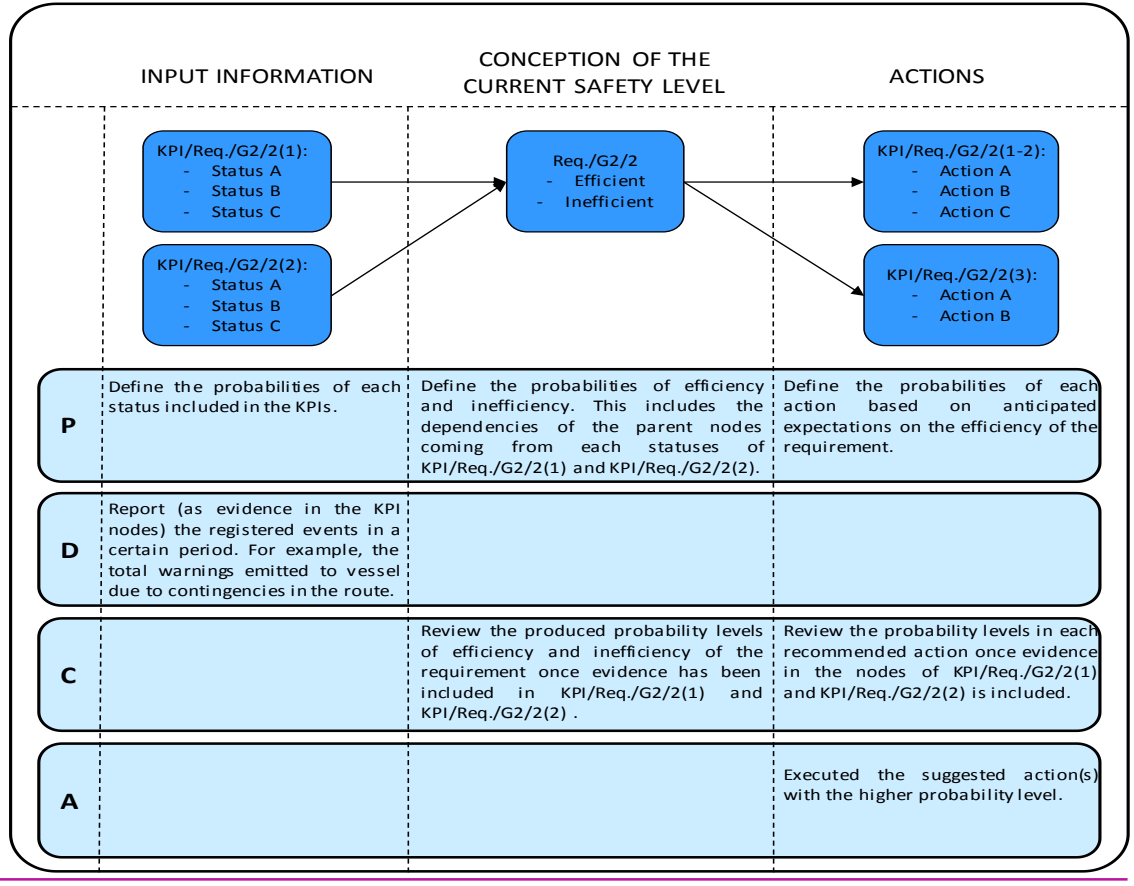
Output (Level 6)

- 31 KPIs for monitoring, measuring and guiding the performance of the designed SMS for VTS Finland

KPIs per requirement
1. KPI/Req./G1/1(1): Percentage of vessel reporting when entering a VTS area (if possible classified by VTS areas) (Monitor KPI) 2. KPI/Req./G1/1(2): Actions developed to improve the vessel reporting (in each VTS area) (Drive KPI) 3. KPI/Req./G1/1(3): The initial status of vessels when entering VTS areas is commonly (Outcome KPI)
4. KPI/Req./G1/2(1): Percentage of efficiency of the VTS monitoring system to represent (portray) ship routes? (Monitor KPI) 5. KPI/Req./G1/2(2): Reported malfunctions compromising AIS? (Outcome KPI)
6. KPI/Req./G1/3(1): Efficiency of the actions made by VTS to ensure vessels listen to the VHF channels? (Monitor KPI) 7. KPI/Req./G1/3(2): Actions developed to improve the information sharing in VTS (Drive KPI)
8. KPI/Req./G2/1(1): Reported speed violations occurred in VTS areas (Monitor KPI) 9. KPI/Req./G2/1(2): Actions made by VTS to efficiently inform about existing restricted areas? (Drive KPI)
10……..

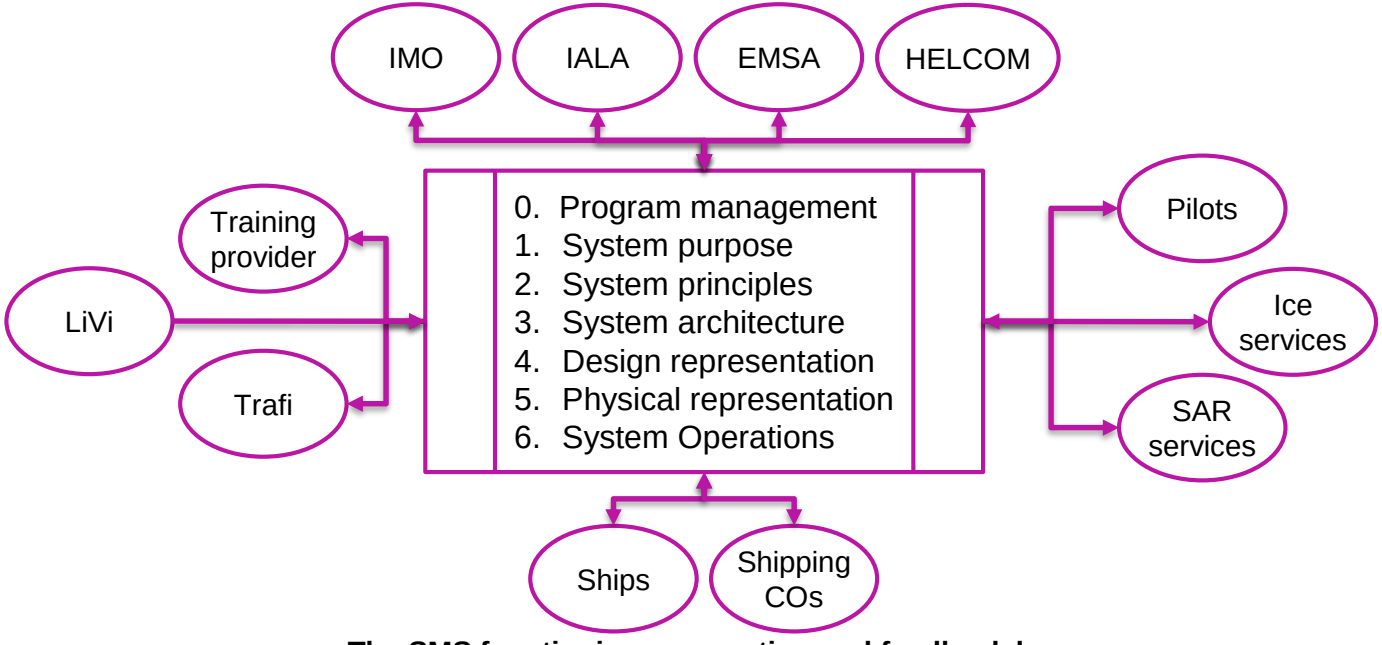
Output (Level 6)

VTS Finland
performance
monitoring tool



Conclusions

The proposed process seems to be proficient for adopting the actual safety practices of the organization and transferring these into the functioning of an organizational SMS. This enables a good flow of information with other stakeholders, improving cooperation and enabling harmonization of safety management practices.



The SMS functioning, connection and feedback loop

- The application of the process resulted in the design of 13 safety requirements utilized to manage the safety of ship traffic in Finnish sea areas all year around.

- Tools have been provided to review the safety performance of the SMS and to revise the objectives and general functioning of the SMS.

- The designed SMS can be utilized and maintained in a smoothly and systemically manner. This prevents making unpredicted and expensive modifications and adaptations afterwards.

- Process downsides: time and resources consuming. Particularly, for an industry heavily educated to operate fast regarding safety and where other approaches (e.g. PRA) are promoted in official guidelines.

Thank you

This study was carried within the Strategic and Operational risk management for wintertime maritime transportation system “BONUS STORMWINDS”