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3rd European STAMP Workshop, STAMP EU 2015

## Towards STAMP based dynamic safety management of eco-socio-technical maritime transport system

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### Abstract

Under an increasing maritime transport in the Baltic Sea, and especially in the Gulf of Finland, the possibility of environmental harm and accidents due to shipping pressure is growing. To counteract increasing risks, adequate measures for accident prevention and mitigation of environmental consequences are critically important. The Gulf of Finland Mandatory Ship Reporting System (GOFREP) is a the complex socio-technical maritime transport safety management system that has been in efficient operation since 2004 and it is open to further improvement and development. However, environmental safety is not explicitly covered by the GOFREP so far. According to our working hypothesis, the Systems Theoretic Accident Models and Processes (STAMP) can be extended beyond the area of socio-technical system safety into realm of complex eco-socio-technical systems safety. This paper attempts to demonstrate the conceptual potential of STAMP based on adaptive management of the Maritime Spatial Planning processes and integrated safety management of eco-socio-technical maritime transport system.

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**Keywords:** Systems Theoretic Accident Models and Processes (STAMP); eco-socio-technical maritime transport system; Baltic Sea; dynamic safety management; Maritime Spatial Planning

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## 1. Introduction

Improving society's ability to manage environmental risks emerging from increasing maritime transport activities is important for ensuring sustainable use of biological diversity based ecosystem services. While maritime transport is of vital economic importance to the Baltic Sea Area, challenging winter navigation conditions pose additional hazards to ships operating in these waters.

There is a growing body of publications on probabilistic risk analysis of maritime transport including the Gulf of Finland sea area [1, 2, 3, 4]. At the same time, the systems theory based approaches to maritime transport system safety have attracted less attention. The Gulf of Finland Mandatory Ship Reporting System (GOFREP) - the complex socio-technical maritime transport safety management system - has been in efficient operation since 2004 and it is open to further improvement and development [5]. However, environmental safety is not explicitly covered by the GOFREP at this time.

Following Zalesny et al. [6] and according to our working hypothesis, the Systems Theoretic Accident Models and Processes (STAMP) [7] can be extended beyond the area of socio-technical system safety into realm of complex eco-socio-technical systems safety. This paper demonstrates the conceptual potential of STAMP based adaptive management of the Maritime Spatial Planning processes and integrated safety management of eco-socio-technical maritime transport system.

## 2. The background: hierarchical regulatory levels of maritime transport safety management

Global to local regulatory levels of the maritime navigation and environment safety management system (Fig. 1) reflect the basic systems theory idea of hierarchical levels. Constraints or lack of constraints at the higher levels control or allow lower-level behavior while safety itself is treated as an emergent property at each of these levels [7].

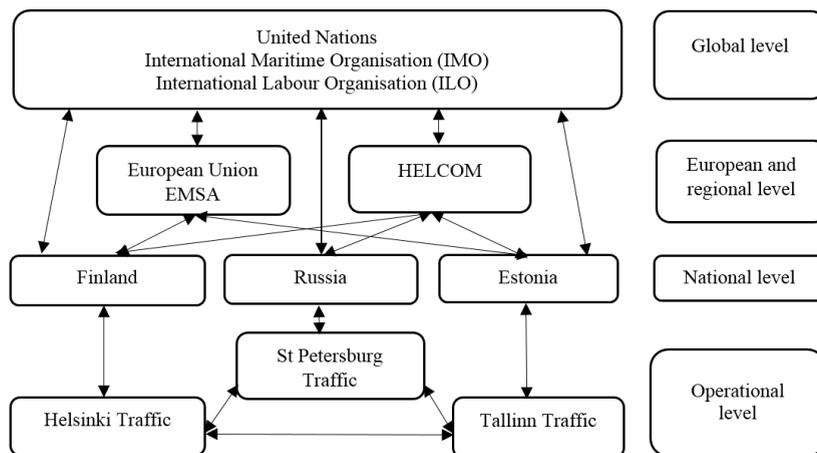


Fig. 1. Hierarchical regulatory levels of maritime transport safety from global to local (Arrows represent the bi-directional information flow between the regulatory levels), (modified from [8]).

At the highest level, the United Nations Convention on the Law of the Sea (UNCLOS) establishes fundamental rules governing all uses of the oceans and their resources and provides the framework for further development of specific areas of the law of the sea. Responsibility for maritime issues is delegated to International Maritime Organization (IMO) and International Labor Organization (ILO) provided that IMO is the agency responsible for shipping, environment and security, and ILO for the laws governing maritime personnel.

IMO focuses on the development of a comprehensive regulatory framework for shipping with a remit including safety, environmental concerns, legal matters, technical cooperation, maritime security and the efficiency of shipping including the major conventions: 1) International Regulations for Preventing Collisions at Sea (COLREGs), 2) the

International Convention for the Prevention of Pollution from Ships (MARPOL) covering accidental and operational oil pollution and pollution by chemicals, goods in packaged form, sewage, garbage and air pollution, 3) International Safety Management (ISM) Code, 4) the International Convention on Standards of Training, Certification and Watch keeping for Seafarers (STCW), and 5) the International Ship and Port Facility Security (ISPS) Code, as an amendment to the Safety of Life at Sea (SOLAS) Convention on minimum security arrangements for ships, ports and government agencies prescribing responsibilities to governments, shipping companies, shipboard personnel, and port/facility personnel.

ILO focuses on the promotion of the maritime labor standards resulting in the adoption of codes of practice and guidelines addressing the seafarers' issues. The Maritime Labor Convention sets minimum requirements for seafarers to work on a ship and contains provisions on conditions of employment.

IMO's vision is to eliminate all adverse environmental impacts from ships by developing regulations that apply universally to all ships. In order to address the increasing focus on environmental issues IMO established its Marine Environmental Protection Committee to consider any matter concerned with marine pollution from ships. This resulted in the adoption of 21 IMO treaty instruments directly related to environmental protection, including the major conventions, which are considered as the environmental safety regulatory constraints enforced generally at the national level.

Outside the MARPOL regulations, the IMO Assembly has adopted Guidelines for the designation of Particularly Sensitive Sea Areas (PSSAs), which are deemed to require a higher degree of protection because of their particular significance for ecological, socioeconomic or scientific reasons, and because they may be vulnerable to damage by international maritime activities. The Baltic Sea was designated as a PSSA at the 53<sup>rd</sup> session of the IMO Marine Environment Protection Committee in July 2005 [9].

At the European Union level, the role of European Maritime Safety Agency (EMSA) is to assist the Commission and the member states in the implementation of the maritime safety legislation and to act as a forum for co-operation between the European Union members and institutions [8].

The Baltic Sea Area has some of the densest maritime traffic in the world. During recent decades, the traffic in the area has not only increased but the nature of the traffic has also changed rapidly. One tendency is the increase in the transportation of oil and other harmful substances by ships, which also increases the potential for water pollution. A spill could have disastrous effects on the vulnerable nature of the area such as fish spawning areas and breeding, nursery and resting areas for birds and marine mammals.

At the Baltic Sea Region level, the Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area (1974) covers the whole of the Baltic Sea area, including inland waters as well as the water of the sea itself and the sea-bed. The governing body of the Convention is the Helsinki Commission - Baltic Marine Environment Protection Commission (HELCOM).

HELCOM Baltic Sea Action Plan (BSAP) adopted by all the coastal states and the EU in 2007 is an ambitious program to restore the good ecological status of the Baltic marine environment by 2021. According to the BSAP, the maritime traffic and offshore activities should be carried out in an environmentally friendly way while accidents and the consequent harm to the marine environment is minimized and the maritime activities cause no harm to the marine environment.

### **3. STAMP based management of Maritime Spatial Planning processes**

The EU Directive established a framework for maritime spatial planning [10] and defines objectives of maritime spatial planning (MSP) as follows “When establishing and implementing maritime spatial planning, Member States shall consider economic, social and environmental aspects to support sustainable development and growth in the maritime sector, applying an ecosystem-based approach, and to promote the coexistence of relevant activities and uses. Through their maritime spatial plans, Member States shall aim to contribute to the sustainable development of energy sectors at sea, of maritime transport, and of the fisheries and aquaculture sectors, and to the preservation, protection and improvement of the environment, including resilience to climate change impacts. In addition, Member States may pursue other objectives such as the promotion of sustainable tourism and the sustainable extraction of raw materials.”

The EU Marine Strategy Framework Directive (MSFD) [11] requires from Member States to establish and implement monitoring programs in order to assess the environmental status of marine waters. Such monitoring programs include the indicative lists of characteristics, pressures and impacts, thus enabling to assess the achievement of established environmental targets. The qualitative descriptors for determining Good Environmental Status according to MSFD are listed in Table 1. The right column classifies the descriptors according to the presence of corresponding pressure or state criteria/attributes within the descriptor according to the Driver-Pressure-State-Impact-Response (DPSIR) framework.

Table 1. The qualitative descriptors for determining Good Environmental Status (according to MSFD [12]).

MSFD descriptor	Short name	DPSIR Classification
Biological diversity	D1	State
Non-indigenous species	D2	Pressure/state
Commercially exploited fish and shellfish	D3	Pressure/state
Marine food webs	D4	State
Human-induced eutrophication	D5	Pressure/state
Sea floor integrity	D6	Pressure/state
Hydrographical conditions	D7	Pressure/state
Concentrations of contaminants	D8	Pressure
Contaminants in fish and other seafood	D9	Pressure
Marine litter	D10	Pressure
Energy, including underwater noise	D11	Pressure

It is stated that “Over the past decade marine spatial planning (MSP) has been recognized as a way to meet multiple objectives – ecological, economic, and social – within an increasingly crowded ocean. It can provide legal certainty and predictability for public and private investment while protecting natural resources like fish and fisheries.” [13]. Marine spatial planning (MSP) is a continuous, adaptive process that should consider performance monitoring and evaluation as essential elements of the overall management process [14]. However, although according to Ehler [13] an adaptive approach requires monitoring and evaluation of the performance of marine spatial plans, little research has been conducted on how such performance monitoring and evaluation can lead to meaningful results and whether current MSP initiatives have the essential features (e.g., measurable objectives) to allow it.

The new Estonian Planning Act was published on 26.02.2015 and provides the legal basis for the planning of Estonian coastal zone and the marine waters under the Estonian jurisdiction, including the Estonian Exclusive Economic Zone in the Baltic Sea (i.e. the area beyond and adjacent to the territorial sea). The recently published Estonian Planning Act legally supports also the full implementation of the Directive 2014/89/EU that established a framework for maritime spatial planning. Accordingly, the integrated planning of the spatial development of Estonian coastal zone and the marine waters under Estonian jurisdiction will be initiated in 2016.

According to this in-progress study, the STAMP standard control loop based adaptive management approach proved to be instrumental in structuring the preparatory processes of actual MSP in Estonia, including the transboundary issues. First, the implementation of the STAMP standard control loop fits well into the methodology of performance monitoring and evaluation of MSP [13] by structuring the processes of commonly used periodical performance monitoring and evaluation of plans with an aim to adapt the next cycle of MSP. Second, as suggested by this research, the STAMP standard control loop can be used as a basis for continuous performance monitoring and evaluation of the MSP adaptive management processes.

The planning preparatory processes are framed under the the EU MARE/2014/22 project “Towards coherence and cross-border solutions in Baltic Maritime Spatial Plans (Baltic SCOPE)”. The main focus of the SCOPE project is on the development of appropriate indicators and criteria that could be applied during the evaluation of the MSP processes and outcomes. These indicators will be embedded into a STAMP standard control loop, thus leading to a suitable monitoring and evaluation process, including recommendations for appropriate timing of evaluation.

Practical implementation of the STAMP concept enables planners and the stakeholders to integrate the monitoring and evaluation functions directly into the actual maritime spatial planning processes. The feedback stream of the standard control loop channels the available environmental and socio-economic information to the national planning agencies/authorities and the associated stakeholder groups (Fig. 2).

Societal environmental, socio-economic goals, objectives and targets specified through a political process as well as the quality management objectives of the planning process are serving as the “process model” for the planners and the relevant stakeholders. Building on the “process model” based analysis of the feedback stream information, the changes in management objectives and management actions accompanied with reallocation of resources to management actions are decided and the planning process continues.

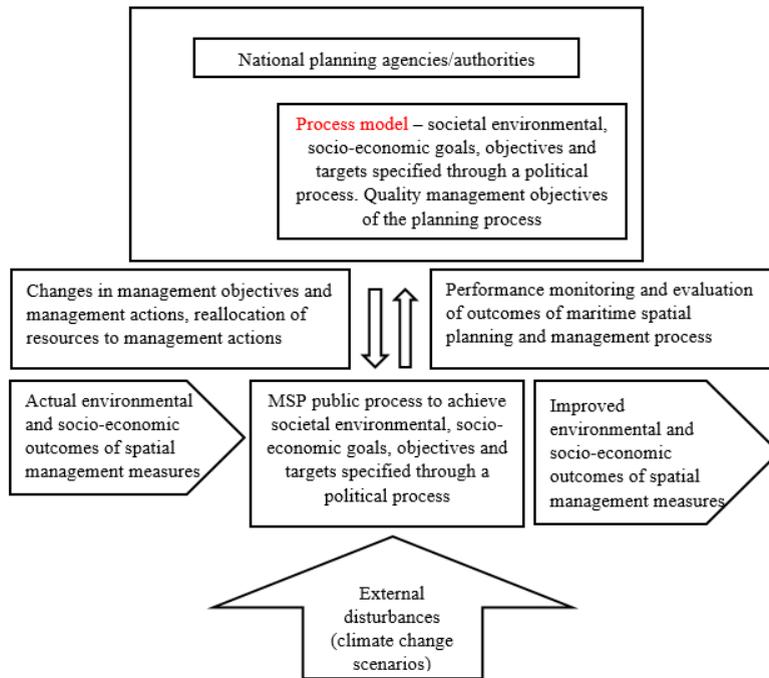


Fig. 2. STAMP standard control loop based Maritime Spatial Planning process management system (modified from [7])

According to Ehler [13] the “Management actions are the heart of any management plan. They are the collective actions that will be implemented to achieve the management goals and objectives of the plan. Management actions should be the focus of performance monitoring and evaluation.” Management allocates resources on the basis of feedback from the system and is therefore a key part of the system. Management decision making and resulting decision making biases must be taken into account during a STAMP analysis.

Particularly regarding the maritime transport safety management, it is stated that the Maritime Spatial Planning (MSP) is becoming an increasingly important issue for the shipping sector over the next few years [15]. The maritime professionals need to engage with other users of waterways space, from both a sea and shore perspective, and to take part in international, regional, national and local MSP debates, to ensure that the needs of the shipping sector are taken into full consideration and that the sector understands the needs of other marine users and resources. It is added that the essential characteristics of an MSP include that it is ecosystem-based, integrated, place-based or area-based, adaptive, strategic, anticipatory and participatory, and it should be based on sound science and be an iterative process. An MSP has the potential to address the impacts of all activities in a specific place, so that marine ecosystems can be productive, resilient to change, and accommodate appropriate, responsible economic activities.

It is further emphasized that there are some issues of critical importance to be considered by shipping industry when engaging in an MSP process: 1) when considering the rerouting of shipping lanes or the placement of MSP limitations on sea space (e.g., aquaculture and offshore energy installations) the maneuvering characteristics of vessels must be considered both for normal and abnormal conditions, 2) the constraint should be observed so that four ships should safely be able to pass each other in a shipping lane and a distance between overtaking and meeting vessels of two ship's lengths should be normally maintained as a minimum passing distance, 3) anything that might obscure visibility or radar conspicuity (i.e. a physical object, electronic interference or even light pollution, either at sea or on the shoreline) must be taken into account when assessing the impact on shipping by other marine users under an MSP plan, 4) enforcement of isolation zones for different ocean users such as commercial shipping, fishing and leisure craft in cases of increased traffic density in increasingly constricted water space, 5) in addition to navigational safety risks, assessment of the the impact rerouting may have on the environment and commercial operations.

#### 4. STAMP based integrated safety management of maritime traffic and port operations

As the IMO [16] defines “The mandatory ship reporting system in the Gulf of Finland covers the international waters in the Gulf of Finland. In addition, Estonia and Finland have implemented mandatory ship reporting systems to their national water areas outside VTS areas. These reporting systems provide same services and make same requirements to shipping as the system operating in the international waters. The mandatory ship reporting system and the Estonian and Finnish national mandatory ship reporting systems are together referred as the GOFREP and their area of coverage respectively as the GOFREP area” (Fig. 3).

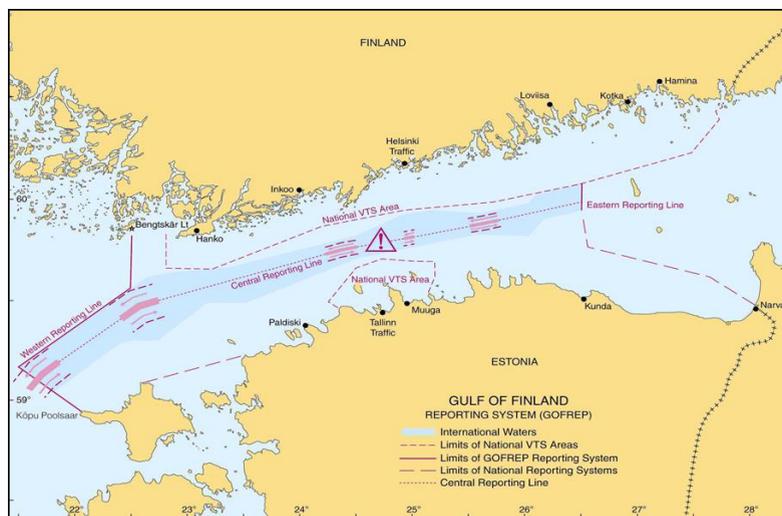


Fig. 3. The GOFREP geographical coverage.

According to the IMO [17] ships of 300 gross tonnages and over are required to participate in the GOFREP system while ships under 300 gross tonnages should make reports in circumstances where they 1) are not under command or are anchored in the Traffic Separation Scheme (TSS), 2) are restricted in their ability to maneuver, and 3) have defective navigational aids. A short report is given to the appropriate Traffic Center when entering its area, every time a vessel is crossing the reporting line and a full report is given on departure from the ports in the Gulf of Finland or at the latest when entering the GOFREP area.

A ship is required to give a short position report by voice or by Automatic Identification System (AIS) when entering the mandatory ship reporting area, whereas the full report may be submitted by voice or by non-verbal means. Ships that are registered in domestic traffic and navigate exclusively inside the inner territorial waters are not required

to make a full report when departing from a port in the Gulf of Finland. The language used for communication is English, using the IMO Standard Marine Communication Phrases, where necessary.

The GOFREP is the maritime traffic control system jointly managed by the Finnish Transport Agency, Estonian Maritime Administration and the Federal Agency for Maritime and River Transport of Russian Federation. The system is based on the activities of the GOFREP Traffic Centers of Estonia (Tallinn Traffic), Finland (Helsinki Traffic) and the Russian Federation VTMS Centre in Petrodvorets (Saint Petersburg Traffic). Each authority provides information to shipping about specific and urgent situations that could cause conflicting traffic movements, as well information concerning safety of navigation, for instance information about weather, ice, water level, navigational problems or other hazards [16].

The GOFREP functions are performed using 1) radar and Automatic Identification System (AIS) surveillance of traffic in the Ship Reporting System (SRS) area with a particular attention to the development of conflicts in vessel traffic and detection of COLREGs contraventions, 2) radio communication, and 3) the maintenance of direct and separate communication links between the GOFREP Traffic Centers for coordination, information update and exchange. During the period when the Gulf of Finland is covered by ice, ships reporting to the center will receive information on the recommended route through the ice and/or are requested to contact the national coordinating icebreaker for further instructions. The icebreakers provide the optimal route to the ships that are fit for winter navigation taking into account the ice situation and fulfilling the national ice class regulations [17].

The GOFREP Traffic Center operator is able to observe the controlled maritime traffic process through the radar and AIS surveillance of traffic in the Ship Reporting System (SRS) area, relate each observation to the process model, and actuate the process if the vessels under control proceed against the COLREGs requirements.

The Traffic Center operator intervenes in a collision risk situation, when according to the COLREGs rules, the give-way vessel should have already taken action to avoid collision. The operator timely contacts the give-way vessel when it is obvious that the proximity to the stand-on vessel might lead to a collision that cannot be avoided by the actions of the give-way vessel alone. However, the operator does not give advice on maneuvering actions, leaving the master with the freedom to choose the appropriate actions to be taken.

Maritime traffic high level hazards and the corresponding COLREGs requirements/constraints in the GOFREP mandatory ship reporting area are presented in the Table 2.

Table 2. Maritime traffic high level hazards and the COLREGs requirements/constraints.

High level hazards	COLREGs requirements/constraints
Vessel is violating the safe speed limits appropriate to the prevailing circumstances and conditions.	Every vessel shall at all times proceed at a safe speed so that she can take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions.
A pair of controlled vessels violate minimum separation standards.	Every vessel shall use all available means appropriate to the prevailing circumstances and conditions to determine if risk of collision exists. If there is any doubt such risk shall be deemed to exist. Any action to avoid collision shall be taken and, if the circumstances of the case admit, be positive, made in ample time and with due regard to the observance of good seamanship.
Vessel is violating the Traffic Separation Scheme requirements.	A vessel using a traffic separation scheme shall: 1) proceed in the appropriate traffic lane in the general direction of traffic flow for that lane, 2) so far as practicable keep clear of a traffic separation line or separation zone, 3) normally join or leave a traffic lane at the termination of the lane, but when joining or leaving from either side shall do so at as small an angle to the general direction of traffic flow as practicable, 4) a vessel shall, so far as practicable, avoid crossing traffic lanes but if obliged to do so shall cross on a heading as nearly as practicable at right angles to the general direction of traffic flow.

In situations where the give-way vessel does not react to the operator's warning or seems to pay no attention to it, the operator uses the message markers to deliver the message “comply with the International Regulations for

Preventing Collision at Sea”. The Traffic Center operator informs the vessel about the situation when it is noticed that a vessel in the monitoring area is in danger to run aground.

It is stated that the primary objective of the GOFREP system is to facilitate the exchange of information between the ship station and the shore station, and support the safe navigation and protection of the marine environment according to the COLREGS requirements [17]. All means are used to encourage and promote the full participation of ships required to submit reports under the SOLAS regulation. If reports are not submitted and the offending ship can be positively identified, information is passed to the relevant Flag State Authorities for investigation and possible prosecution in accordance with national legislation.

Furthermore, if a ship participating in the mandatory ship reporting system fails to appear on the radar screen or fails to communicate with the Authority or an emergency is reported, the Maritime Rescue Coordination Centers (MRCCs) or Maritime Rescue Sub-Centers (MRSCs) in the area are responsible for initiating a search for the ship in accordance with the rules laid down for the search and rescue services, including the involvement of other participating ships known to be in that particular area.

European Maritime Safety Agency (EMSA) operates and manages a suite of systems which receive, process, and distribute information on vessel traffic reports (LRIT, SafeSeaNet), satellite monitoring (CleanSeaNet), and Port State Control (Thetis). Long-Range Identification and Tracking (LRIT) is a mandatory international system to track ships around the world. Member States and the EMSA operate SafeSeaNet, the vessel traffic monitoring and information system covering the waters in and around Europe. The specific system acts as a platform for maritime data exchange, linking together maritime authorities across the continent. SafeSeaNet as a vessel traffic monitoring and information system is established in order to enhance the maritime safety, port and maritime security, marine environment protection, and the efficiency of maritime traffic and maritime transport. CleanSeaNet provides a state-of-the-art oil spill monitoring service which supplements existing surveillance systems at national or regional level, strengthens member state responses to illegal discharges, and supports response operations to accidental spills. The STAMP standard control loop is used to present maritime traffic and port operations environmental safety management system (Fig. 4).

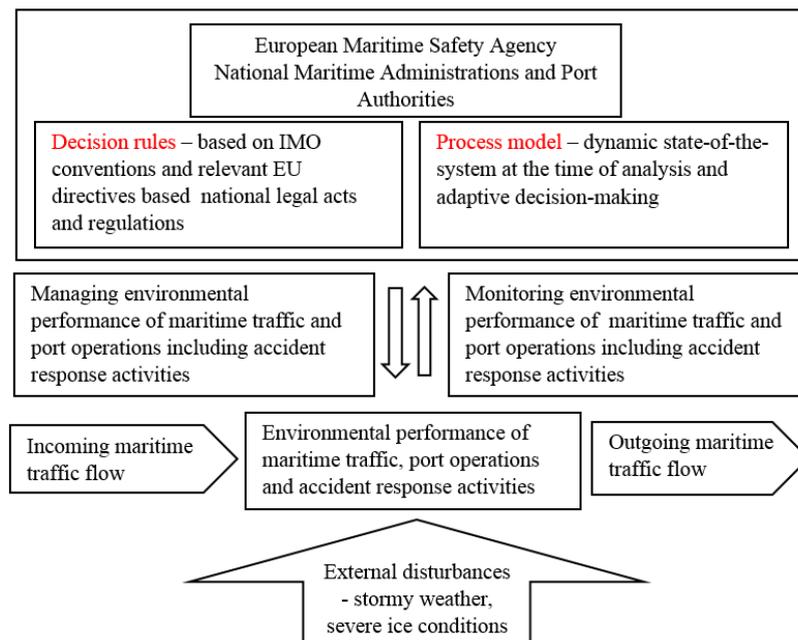


Fig. 4. STAMP standard control loop based maritime traffic and port operations integrated safety management system (modified from [7]).

The EMSA acts as a controller of the maritime processes in waterways. Environmental performance emerges from these processes. The controller sends “signals” (decisions, resources, standards, etc.) to manage the processes. The

EMSA gets feedback from these processes through monitoring in order to adjust operations and update the EMSA's process model.

The services produced by the EMSA systems are shared with Member States and the Commission and supplement and enhance national capacity for vessel traffic monitoring, Port State Control, and maritime pollution preparedness and response. It is important to add that services are offered directly to EU Member States and organizations, sparing them the cost and complexity of buying and managing the underlying hardware and software, and hosting separate data integration systems. In relation to the navigational and environmental safety management in the GOFREP marine area, the objective is to eliminate the operation of sub-standard ships through a harmonized system of Port State Control by verifying that the competency of the master and officers on board, and the condition of the ship and its equipment comply with the requirements of international conventions (SOLAS, MARPOL etc.) and that the vessel is manned and operated in compliance with applicable international law.

## 5. Conclusions

The STAMP standard control loop based adaptive management concept proved to be instrumental in structuring the preparatory processes of actual MSP in Estonia, including the transboundary issues. Practical implementation of the STAMP concept enables planners and stakeholders to integrate the monitoring and evaluation functions directly into the actual maritime spatial planning processes. Based on the "process model" analysis of the feedback stream information, changes in management objectives and actions accompanied with reallocation of resources are decided and the planning process continues.

Implementation of the STAMP standard control loop fits well into the performance monitoring and evaluation of an MSP by structuring the processes of commonly used periodical performance monitoring and evaluation of plans with aim to adapt the next cycle of MSP. In addition, as suggested by this study, the STAMP standard control loop can be used as a basis for continuous performance monitoring and evaluation of the MSP adaptive management processes.

Based on this study, it is suggested to use the STAMP standard control loop as a basis for further development and implementation of the integrated safety management of maritime traffic and port operations. The integrated safety management of holistic eco-socio-technical system builds on the monitoring of environmental performance of maritime traffic and port operations including accident response activities, and on the feedback based appropriate corrective management actions.

The EMSA acts as a European controller of the maritime processes in waterways. Environmental performance emerges from these processes. The controller sends "signals" (decisions, resources, standards, etc.) to manage the processes. The EMSA gets feedback from these processes through monitoring in order to adjust operations and update the EMSA's process model. In addition, at the local Gulf of Finland level the maritime transport navigational safety is controlled and managed by the GOFREP Traffic Centers.

## Acknowledgements

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