Future Maritime Transport Systems and Integrated Planning

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Abstract: Transport systems are becoming increasingly interconnected, automated, and complex, from a human centred approach to digital connectivity. This involves new opportunities but also implies new vulnerabilities. This paper present maritime transport challenges when implementing automated vessels, and especially how this may affect cooperation between organisations. Moreover, the inclusion of vessels with different levels of automation (LoA) will change the interactions between technology (vessels), managers and operators. The purpose is to identify how socio-technical perspectives represented by the Integrated planning (IPL) concept and resilience perspectives can be beneficial when implementing autonomy. Cooperation in a future maritime transport system (MTS) including autonomous vessels will frequently be between unequal actors, involving both conventional and automated vessels and several control centres. Resilience engineering (RE) may contribute to a paradigm shift towards a more proactive perspective. It is important ensuring that new ways of working, regulations and standards are in accordance with practice between strategical, tactical, and operational levels. The paper presents the IPL related to an ongoing Norwegian project for preparation and management of potential brittleness and risks, uncertainties and unknowns when executing transport operations. Particular attention is on integrated planning both between different actors and at different management levels.

Keywords: Integrated planning, Autonomy, Maritime, Transport system, Resilience, Ecosystem

1. Introduction

The capacity of transport supply chains has increased dramatically. One trend is bigger vessels in combination with faster transitions to land-based modes and interconnection to terminals (Rodrigue, 2020). The biggest container vessels could transport up to 8.000 TEUs (Twenty-foot equivalent units) in the mid 1990's. Today this is more than 20.000 TEUs. Economy driven development shifts cost and environmental footprint per transported unit downwards (Notteboom, et al, 2022), it has also increased complexity, dependencies and vulnerability of the Maritime Transport System (MTS) due to increased cargo volumes.

Moreover, the increase in transport capacity also involves more actors. Disruptions of chains may provide far-reaching disturbances, e.g. the container vessel Ever Given blocking the Suez-canal in March 2021 resulting in temporarily stopping more than 400 vessels from passing through (Lee & Wong, 2021). After the channel opened up, due to terminal lack capacity to handle all new demands at the same time, transport was delayed even further.

Developing new MTS with autonomous solutions should learn from conventional shipping experiences when developing new rules and technologies, in addition to building resilience into the MTS by identifying critical elements and developing plans to handle changes and disruptions. Automation of supply chains should be based on understanding traffic and collaboration practices from conventional vessels.

The purpose of this paper is to identify how integrated planning and management concepts can be beneficial when implementing autonomy. Traditional planning normally considers only one transport element, as one vessel or one specific operation. A vessel sailing schedules (voyage plan) and sailing status is seldom connected and proper integrated with the whole transport system. Bringing resilience into planning is important, focusing on both technical, human and organisational levels.

Figure 1 illustrates the complexity of stakeholders involved today, including operational interaction with authorities, and main nautical operations supporting the vessel. Future shipping (autonomous) must understand how the system is organised today, e.g. exchange of mandatory services information, and navigational and operational information exchange with stakeholders and ICT systems.

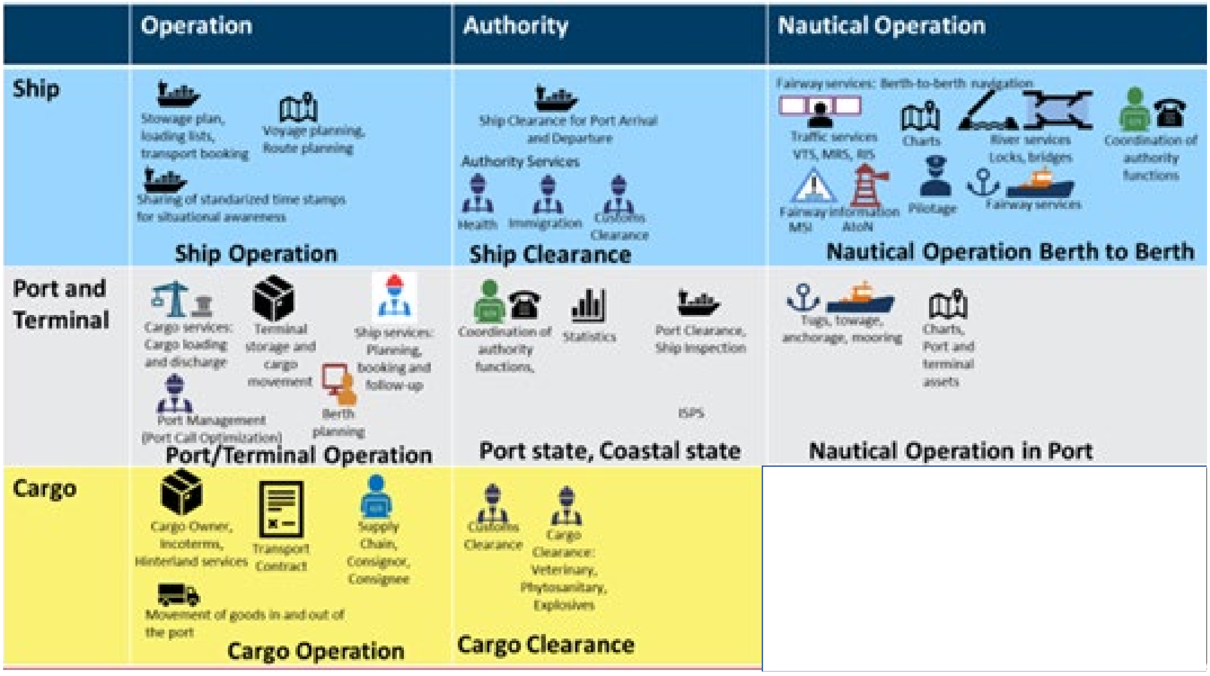

Figure 1: Collaboration between ship, port and terminal, and cargo. (Rødseth, et al., 2020)

International Maritime Organisation (IMO, 2021) describes defined levels of autonomy related to future maritime transport operations:

1. *Degree One: Ship with automated processes and decision support:* Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.
2. *Degree Two: Remotely controlled ship with seafarers on board:* The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
3. *Degree Three: Remotely controlled ship without seafarers on board:* The ship is operated from another location, no seafarers on board.
4. *Degree Four: Fully autonomous ship:* The operating system of the ship can make decisions and determine actions by itself.

2. Integrated Planning (IPL)

The Integrated Planning (IPL) is based on experiences from petroleum industry, reported in Ramstad, Halvorsen and Holte (2012). Capabilities and enablers in Table 1 are described later in this chapter.

Table 1: IPL enablers and capabilities (Ramstad, Halvorsen, Holte, 2012)

Enablers	Capabilities			
	Competence	Commitment	Collaboration	Continues learning
ICT	Available tools Utilizing tools Potentials in tools	Utilizing defined tools Following and updating info Involvement in design process	Integration and harmonization Aggregated and filtered info Collaboration platform	Time, arenas, focus
Roles and work processes	Holistic understanding Planning competence Change competence	Compliance and accountability Common goals Reciprocity	Defined in work processes Role descriptions specific on collaboration	Local interpretation Experience transfer and mentoring
Arenas for plan collaboration	Know the arenas Competence one use The planner as facilitator	Commitment participation Prepared and involved Joint problem solving	Defined goals and participation Regular and structured collaborative	Broad participation

The concept includes a model and methodological structure for IPL. The IPL concept is based socio-technical theory and represents a holistic perspective on planning, emphasizing the interplay between planning horizons, between organizational units, and among cross-organisational partners.

2.1 From traditional planning to integrated planning

Table 2 presents some key IPL principles compared to more traditional planning approach. Describing planning as an activity is the function of selecting enterprise objectives and establishing policies, procedures, and programs necessary for achieving them (Kerzner, 2013), while planning in an operational environment is usually understood as creating a predetermined course of action within a forecasted environment. Since increased digitalization opens for improved efficiency across different actors, the resulting increased complexity of operational systems requires proactive and robust planning. Critical interdependencies between activities and actors must be coordinated through increased interaction, information sharing and collaboration between stakeholders.

Compared to traditional planning, the IPL concept is particularly useful when focusing on the entire operational system, especially interfaces and interdependencies of activities and resources across organizational boundaries. The aim is to avoid "silo planning" resulting in inefficient and unexpected disruptions in transport operations and increased cost for the total system (Ramstad, et al, 2014).

Table 2: Comparison of key IPL principles and more traditional planning principles (Ramstad, et al., 2014)

Categories	Integrated Planning	Traditional Planning
Planning activity	Proactive, robust (and agile)	Reactive
Integration	Between organizational disciplines and planning horizons (strategic, tactical and operational), and across organizations and locations	Limited integration and involvement, largely dependent on organizations and physical location
Collaboration	Multidisciplinary collaboration at designed coordination arenas	Expert planning, single discipline
Competence	Knowledge about the operational system, dependencies, consequences	Limited knowledge and focus on dependencies and consequences of changes in plans to the total operational system
Commitment	Commitment to IPL planning processes and plans	Commitment to single discipline plans
Learning, improvements	Analysis and sharing of experiences across units & disciplines	Learnings within disciplines/siloes

2.2 The four IPL Capabilities – Cultivating IPL practices

Human and organizational capabilities shall ensure sustained implementation and improvement of IPL practices. Continuous attention and focused leadership are needed for cultivation, and thus contribute to establish an organizational culture that builds and maintains sustainable practices.

1. *Competence* is defined as "to know how to do things", including knowledge and skills to perform work tasks. Designed IPL work processes involve professionals and decision-makers in all domains and at different levels. Defining necessary competence and expectations related to key roles in IPL (planner, leaders, task responsible) is vital; general planning competence (knowledge about work processes and implementation of them in a local context, knowledge of ICT tools), in addition to operational experience. The planners have a key role as facilitator to ensure inclusion of competent participants in arenas for cross-domain collaboration. Virtual and face-to-face meeting require communicative skills.
2. *Commitment* relates to organizational practices and individual as well as collective orientations towards defined roles and processes, i.e. objectives and processes to reach them. Joint commitment to an overall goal is an important part of IPL practices. Furter, involvement, participation and trust in the IPL development process are essential for commitment to established integrated transport systems and plans, and compliance with defined organizational roles and responsibilities. All necessary roles need to

commit to participating in collaborative arenas, and to arrive prepared and ready for active dialogue and discussions about prioritizations, i.e. organizational culture and ambition towards a common goal. Decisions at the operational level require practical expertise and planning that also consider changing contextual and situated demands.

3. *Collaboration* is a process in which different entities share information, resources, and responsibilities to jointly plan, implement, and evaluate a program of activities to achieve a common goal. Since transport operations involve numerous participants, roles and services, collaboration is a key asset for achieving efficient operations. When establishing integrated plans, collaboration often goes across organizational and geographical boundaries. Harmonised ICT tools are essential, including access to integrated data systems, real-time information, and adapted details to the individual recipient needs. Shared ICT systems should visualise roles in established transport plans as well as for situational awareness along a transport chain. In addition to arenas, collaboration requires willingness and ability among organisation members. Creating a constructive collaboration climate and interaction across boundaries require open communication, trust, dialogue, and positive conflict and deviation negotiations.
4. *Continuous learning* is understood as organizational learning and applicable changes in planning practices based on social learning, collective reflections, and experience sharing. Plan coordination arenas may function as efficient learning arenas in a collective learning process across boundaries. These should be based on open communication, actively participation, involvement by all disciplines, and willingness for collaboration. Integrated plans can function as common reference for communication, reflections, and shared understanding of demands/possibilities along a transport chain.

2.3 The three IPL Enablers – Designing infrastructure for IPL practices

The IPL enablers are based on Argyris (1992) regarding organisational contributing capabilities, e.g. role and responsibility structure, information system, and procedures.

1. *ICT solutions* are important for coordinating activities across planning levels. Planning levels are categorized at *strategic* (long-term, 2-5 years), *tactical* (mid-term, 6-24 months), and *operational* (short-term up to 3 months). The transport system complexity makes this demanding due to i.e. operations involving numerous actors (across organizational domains and companies), high risk operations, varying information integrity, and constantly changing environment. Further, information integrity and automatic transfer of real time data are absolute necessity to create integrated plans trusted by all stakeholders. Thus, ICT tools need to 'make the invisible visible'. Relevant and harmonized planning tools for implementation of IPL are related to: Real-time information for short-term planning; Aggregation of data, information processing and sharing; Visualization of plan interdependencies and consequences of plan changes; Collaboration surfaces, facilitating communication and collaboration across organizational, professional, and geographical boundaries.
2. *Roles and processes* supporting implementation of IPL practices should be easy to identify in digital work processes descriptions. Focus on both horizontal and vertical functions and coordination are recommended to establish common premises for decision making and prioritizing of resources, tasks, and actions. Important roles are the planner, the task responsible and the leadership.
3. *Arenas for plan collaboration*. Complexity of prioritization and coordination requires a forum for: interpretation and communication of plan data, development of shared understanding of interdependencies, structured and facilitated coordination across domains, collective learning and continuous improvement, and coordination of conflicts and deviations between parties.

3. Theoretical perspectives

3.1 Sosio-technical theory – Planning

As organisations are becoming more interrelated and complex, system theories are focusing both on the individual organisation and the relation between organisations. The IPL concept is based on a socio-technical approach to organisational learning. Planning supports decision making, facilitating identification of alternative future activities and selection of most appropriate activity considering all available factors. The challenge is to represent reality as simple as possible but as detailed as necessary, without ignoring any serious real-world constraints. A holistic understanding of operations contributes to increase system agility and thus ability to exploit opportunities in change and plan deviation.

Plans can be regarded as tools for coordination and communication, creating the basis for a common understanding of the situation. Planning as a *'resource for action*' (Gautherau and Hollnagel, 2005) indicates a discrepancy between *predicted and actual* performance (Ramstad, Halvorsen and Holte, 2012). Continuous deviation or change management is seen as an integral part of operational planning.

The IPL concept makes visible interdependencies across planning levels, vertically, as well as within each planning level, horizontally. IPL does not only integrate activity plans vertically across planning levels, but also integrates operational plans across domains at operational level. IPL affects the entire value chain of operations and coordination of activities. Operational practice is based on coordination between several organizational units with their own sets of goals and constraints. IPL is concerned with unify all stakeholder plans and consider how they mutually affect each other.

3.2 The Ecosystem – The system of interest

To transform the IPL concept to autonomous shipping, it is vital to define significant stakeholders and system of interest. Even though the ecosystem is a subtle and complex concept, Pickett and Cadenasso (2002) argue that it may simplify the complexity of other ecological concepts, and that three key dimensions make the concept both complex and broadly useful.

1. *Meaning* (definition) – is associated with physical environment in a specific place and is applicable to any case where organisms and physical processes interact in some spatial area. The system can be of any size but has an explicit spatial extent with specified boundaries. Further, ecosystems may change regarding composition, content, and duration, and may include humans and their artefacts.
2. *Model*s (applied in concrete or specific situations) – Describe the content and processes necessary for operationalize usable tools. Ecosystem models encompass a wide range of perspectives, and may be verbal, graphical, diagrammatic, physical, og quantitative. The focus may vary from e.g. energy, nutrients, and organisms. All models specify the nature of complexities, locations, and include interactions. The steps needed to establish the domain of a model (Pickett and Cadenasso, ibid): (a) Identify the components (e.g. biological, social, or geophysical entities) of the model, (b) State the spatial and temporal scale addressed, (c) Delimit the physical boundaries of the system, (e) Articulate the connections among the components (e.g. directly, tight coupled, hierarchical), and (f) Identify the constraints on system behaviour. Dynamic ecosystem models focusing on resilience appear to be especially appropriate for human ecosystems and the assessment of sustainability.
3. *Metaphors* – may be the ecosystem as e.g. a machine or an organism. Behavioural metaphors include ecosystems as resilient structures or ecosystems as fragile structures. One major benefit of the ecosystem concept is its ability to reflect a wide array of processes, values, and kinds of interactions. In addition, the models may indicate outputs into socially valuable terms (as ecological footprint, safety/ resilience).

3.3 Resilience

Ecosystem resilience. Resilience thinking emerged out of dissatisfaction with models of ecosystem dynamics in ecological science in the 1970s (Cote and Nightingale, 2012). Resilience thinking proposes a systems approach to human-environment relations that fits well with attempts to predict or model social-ecological change. However, the authors propose to include dynamics of societal change in definitions and analysis of *resilience in socio-ecological systems (SES)*, e.g. social sciences perspectives on *agency*, *power,* and *knowledge*. Sociocultural contexts and power will help to capture underlying heterogeneities across different social-ecological systems dynamics. Further, a move towards *situated systems* and cultural and political categories of specific contexts, helps capture more realistic options available to specific SES to respond to change and variability.

Resilience Engineering (RE) uses a variety of definitions (Woods, 2015), including resilience as (1) *rebound* from trauma and return to equilibrium; (2) synonym for *robustness*; (3) *graceful extensibility* (opposite of brittleness) when surprise challenges boundaries; (4) *network architectures* that can sustain the ability to adapt to future surprises as conditions evolve. Woods distinguish resilience and robustness. While robustness refers to being able to deal well with *known unknowns*, resilience refers to being able to deal well with *unknown unknowns* and handle troubles that were not foreseeable. Two latest definitions have recently emerged due to challenges regarding how systems may adapt to manage increased complexity, e.g. risk of brittleness and failure when events push the system up to and beyond its boundaries for handling changing disturbances and variations.

Arenas for collaboration enable stakeholders to reflect on how goals are being managed. The concept of *polycentric governance architecture* (PGA) is lately introduced in RE to increase the knowledge of how networks cooperate, adapt to future challenges and how it is possible to facilitate adaptive responses as a challenge unfolds (Woods, 2020).

Due to complexity, there will always be gaps between network partners' perspectives on goals and cooperation. All systems pursue multiple goals that interact and can conflict (Wood and Branlat, 2011). Critical properties of polycentric systems mentioned; Reciprocity, commitment to build common ground and to align goals across centres and levels, ability to shift forms of coordination across centres, anticipate bottlenecks ahead, and how initiative is delegated and regulated. Further, they notice two critical challenges: Regulation of interactions across centres, in addition to underlying architectural principles leading to resilience in polycentric systems. PGA principles may contribute to manage human adaptive systems to recognize signs of operating on the limits and how to have the capacity to move as conditions change.

4. Integrated planning when implementing autonomous vessels in MTS

4.1 The MARMAN project

MARMAN (Maritime Resilience Management of an Integrated Transport System) project aims to explore what forms of regulatory, managerial, and operational competencies will be needed when faced with increased connectivity and automation. The project (2021 – 2024) focuses on implementation and application of vessels with different levels of automation. Maritime resilience management is based on a socio-technical approach and is adapted to integrated planning area. In the resilience area, scientific insights and operational practices is seen in concert to prepare for normal variability of practice, expected and unexpected events.

4.2 IPL - The Maritime Transport Ecosystem

The first step in creating an IPL concept is to *define relevant stakeholders and functions*, including interrelations and collaboration. Collaboration in large scale, complex, socio-technical systems may be considered as systems-of-systems (Relling, Praetorius and Hareide, 2019). The authors describe the MTS as collaborative, integrated and context dependent due to geographical locations and development over time.

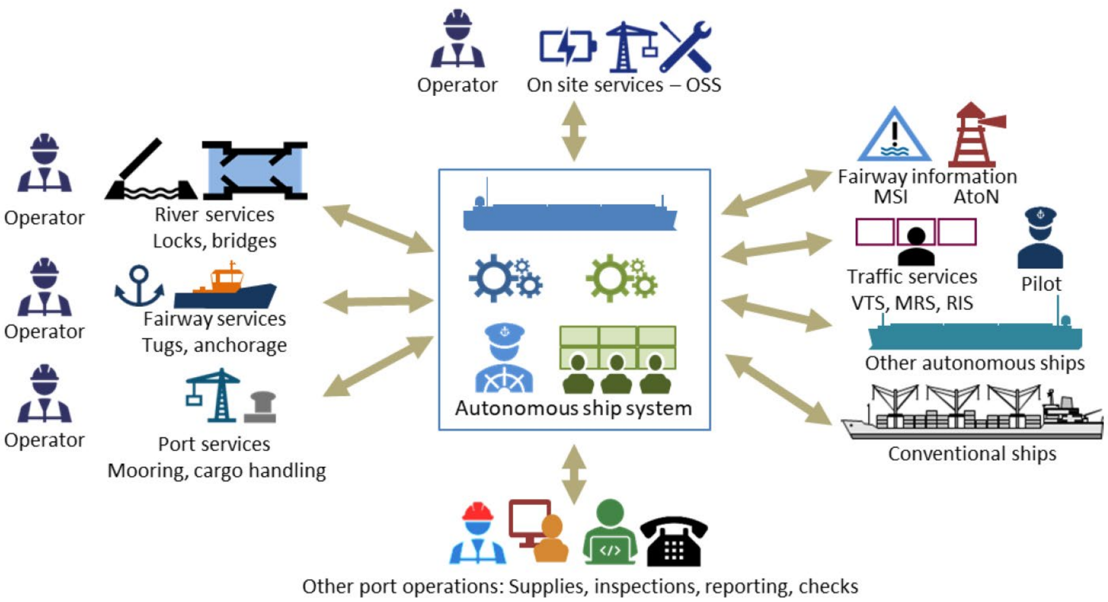

Figure 2: The physical context of the autonomous ship (Rødseth, et al., 2020)

Main components and key actors in the physical context of the autonomous ship systems is presented in the EU project AUTOSHIP (Rødseth, et al., 2020).

1. *The physical autonomous ship system* depending on Levels of Autonomy (LoA), required crew and related onboard systems catering for secure and efficient autonomous operations. Further, necessary remote operations centres (ROC) of the ship management organisation handle daily operation of the ship, including exchange information with other ROCs or a Vessel Traffic Service, VTS.

2. *Conventional ships*: Pilots, bridge personnel and related ship management organisation, representing a significant challenge in terms of interaction.
3. *Other autonomous ships:* Covers onboard ship systems providing interface between crew and lower sub-systems onboard. Also requiring operational standards and protocols for safe and predicable navigation and manoeuvring behaviour.
4. *Ship crew:* Depending on degree of automation, crew may be onboard during parts or the entire journey.
5. *Vessel Traffic Services (VTS):* Providing operational support and coordination of maritime activity for the operational area in question.
6. *Local Monitoring Centre (LMC).* Similar function as VTS, but with an explicit focus on the local port and service providers, possibly also with the responsibility to manage and operate the exchange of information. A local centre will have good local information needed for planning, a real-time overview and follow-up information used by each SCC, or directly by Maritime Autonomous Surface Ships (MASS). In some cases, an LMC solution can be autonomous, or computer based itself, with no humans in the loop.
7. *Port and fairway services:* Supports navigation and manoeuvring of ships, including shipmaster, maritime pilot, tug master and operator of VTS.
8. *Port and land-based infrastructure.* MASS is expected to interact differently with the port infrastructure as opposed to present practice. Hence, planning and operation will also change. Land-based infrastructure – as cameras, radars and sensors along the fairway - are intended to ensure situational awareness for safe and efficient operation of MASS, as well as resilience.
9. *Context actors* as a variety of shipowners, the International Maritime Organisation (IMO), Flag States, Classification societies, also cover organisations and stakeholders affecting decisions.

The IPL concept includes strategical, tactical, and operational *management levels*. Relling, Praetorius and Hareide (2019) exemplifies actors in a Norwegian MTS at six level: Governmental level (Ministry of Transportation – MoT); Regulators and associations (MoT and the Norwegian Coastal Administration – NCA); Company (NCA and Department of Maritime Safety); Management (VTS managers of individual VTS centre); Staff (crew on duty); and Front-line operators and company staff (individual VTS-operators).

IPL Capabilities, Enablers and scenarios in a future MTS are presented in Table 3. Resilience perspectives are significant when operationalising these. MASS will increase complexity and influence interrelations, implying a need for handling both normal variability of performance and operations, and foreseen scenarios and unforeseen events. Cooperation is expected to be between unequal actors and imply new interactions between humans (managers, operators), technology (e.g. vessels), and digital infrastructure. Increasing dependence on information systems, and increasingly sharing of control of systems with automation, are creating a considerable potential for loss of information and control leading to new types of “human errors” (Leveson 2012).

The operational planning phase should consider and ensure new or changed resources and supplies to the vessel. While maintenance today is often done when sailing between ports, maintenance teams will likely be organised as local task forces doing required work during a port stay.

The planning of a voyage must include loading/unloading, docking, and transport between locations. SCC planning cover tactical and operational level of MASS operations, including daily dialogue with ports, conventional vessels, and other SCCs and stakeholders. This requires new awareness regarding, e.g. communication MASS and SCC, navigation, context, regulations, emergency, and mandatory reporting of the vessel journey.

Table 3: IPL capabilities to ensure a resilient MTS when implementing autonomous vessels

Autonomous and resilient transport systems	
Competence	An autonomous transport sector will change current the competence requirements. In addition to good seamanship counting for navigation, future operations will have more integrated human-machine interfaces. Human operators must rely more on technology and have the competence to understand why the technology takes decisions, e.g. Explainable Artificial Intelligence (XAI) where humans should understand the reasons for an action. Thus, more integrated ICT solutions are required, enabling seamless exchange of real-time and updated information. Autonomous shipping also expects to change the competence from "*how can I use the technology"* to "*what can the technology do for me".* Future competence will be more on how to operate the technology as well as how to support when required.

Autonomous and resilient transport systems	
	The introduction of ROCs, and possibly fewer crew onboard ships and terminals, new roles and related responsibilities must be defined – supported by clear and defined work process. Areas for collaboration must be accessible, enabling quick identification of possible conflicts of interest and unwanted consequences to changes of plans. In terms of resilience, robustness can be built into the system by defining actions to be performed in situations of automation shortfalls (Woods, 2015), emphasizing clearly defined roles and process, and ensuring required competence is built into the organization.
Commitment	As *trust* is a keyword, autonomous solutions will require a different approach for building trust between humans, organisations, and ICT. Trust is considered management, or responsibility of ensuring operations are compliant with plan, e.g. when MASS is about to be unloaded/loaded at a terminal, the process is likely a joint activity between terminal and vessel systems. To be an efficient operation, other ship-terminal operations must be considered in parallel, including defined roles and processes. In this context, arenas for collaboration are also important as enables for defining responsibility related to the plan and related sub-activities.
Collaboration	In autonomous shipping *collaboration* to achieve common goals will change from a human-to-system/computer collaboration and deciding action. One significant challenge is handling conflicts or deviations, e.g. MASS delay to port and inability to unload cargo according to pre-defined schedule. Collaboration *requirements*: seamless exchange of updated data/information across organisations, different ICT systems, defined roles and responsibility distributed across the system, and whom and how to collaborate.
Continuous learning	For autonomous systems, *continuously* learn from operation is one key successes, and the ability to make changes when new constraints occur. Both intelligent systems and involvement of humans must be counted for. Autonomy is still unmature. Knowledge is insufficient regarding generation of new accidents, technology challenging regulations, and simultaneous MASS and conventional practices. Lack of operational compliance of traffic rules at sea, the COLREG, challenge the development of new technology compliant with COLREG. Knowledge is missing on how the context will affect autonomy and commercial transport operations, and how to report potential difficulties and errors.
Resilience	The four *resilience principles* of Woods (2015) are highly relevant for all four Cs to build required resilience. Resilience as *rebound* should be applied when considering how to react to different actions and events, where stakeholders can use defined arenas to evaluate scenarios and make improvements e.g. how humans and automation should interact to improve operational resilience, and how clearly defined roles and processes may be established. *Robustness* can be built into the system by defining actions related to "What if" scenarios, and to plan work-process related to both expected and unexpected events. *Graceful extensibility* focuses on how different organizations and transport systems can cope with unexpected events and specifying required actions. *Network architecture* contributes resilient operations by defining specific network actions, evaluating functions and procedures for communication, and sharing of responsibilities. This may prove particularly important in defining situations which require cooperation between ship and ROC, or if normal communication links are disrupted and fallback opportunities are required.

5. Discussion – future maritime transport systems and integrated planning

Future maritime transport including autonomous ship will require new ways of working and new systems for IPL. The implementation of autonomy is likely to be done in steps, as example the vessel Yara Birkeland implementation will follow the levels of autonomy step-by-step. First, the vessel will be manned with navigators, next is partly remote-control centre operation, and finally the vessel technology will do the sailing.

Regards IPL, it is likely to follow same approach. First, humans in control and operators located where operations are executed, next is more remote planning but still in control by humans, and finally some of planning based on sensors and statuses along the transport chain, maybe automatic. As higher level, as more important it will be to understand decisions to enable humans to take control if required. Future maritime transport must therefore also be more integrated and connect organisations, humans, and technologies. Planning quality will be more important, and plans will be shared between stakeholders and systems at a higher degree than current practices. Mutually trust is important between systems and shared status during both planning, execution and follow-up after reaching the destination. Therefore, Commitment, Competence, Collaboration possibilities and Continuous learning will be extremely important for a successful execution.

Another significant element is how to build resilience into the system. Resilience is not only back-up system in case of technologies failure, it also addresses human knowledge regarding planning and execution of operations. Resilience should prepare for the unknown, but also use expertise and experiences from previous operations.

Following IPL, resilience should not only focus on one transport means, but ensure the total transport chain is integrated to meet challenges, and where all involved parties together solve these and select best possible solutions. The main success criteria is probably building trust between humans and organisations, to both technologies and data.

6. Conclusion

Increasingly complex and interconnected when implementing MASS into the MTS will require new ways of working, collaboration, and communication. Changes will affect management at the operational, tactical, and strategical level, in addition to the interactions between them.

The IPL concept, developed in the petroleum industry, may be beneficial when implementing MASS. The increased complexity is expected to increase the risk potential failure, and implementation of new technology in MTS may challenge the planning of changes in normal operations, foreseen deviations/catastrophes, in addition to unforeseen events. The development of an IPL concept for the MTS seems promising, and resilience perspectives may be beneficial when adapting the original IPL concept to MTS.

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