Are Safe and Resilient Systems less Effective and Productive?

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During the last 50 years, people have become considerably more physical and virtually connected due to a more modern and mobile world, and new technologies for collaboration and communication, such as mobile phones, satellites and internet. Next era will likely be the introduction of autonomy that is still in its start phase. By increased global mobility and transport, people and transport solutions expect to be more efficient and productive. At the same time, the development implies challenges due to continuous technological and context changes, resulting in potential new risks and accidents. However, are safety and effectiveness two poles at the same dimension, meaning that increasing one means decreasing the other? Or - Is it possible to increase productivity and effectivity and at the same time maintaining safety? The purpose of this paper is to increase the awareness of adequate planning in order to improve resilience/safety and effectivity. Planning is important to cope with opportunities and challenges, and theoretical perspectives on planning and management may be useful. The paper uses scenarios from autonomous shipping to illustrate increased system complexity and interrelations between components.

Keywords: Resilience, Effectivity, Safety, Transport, Productivity, Automation

1. Introduction

During the last 50 years, people have become considerably more physical and virtually connected due to new technology and mobility. By increased global mobility and increased transport, people expect to be efficient and productive. At the same time, the development implies challenges due to continuous technological and context changes, resulting in potential new risks and accidents.

Introduction of new technology may have several impacts, e.g. safety, economy, sustainability or climate. At the same time, new technology will result in new types of incidents coursed by technology but can also avert accident. However, it totally will lead in increased safety (Hoem, Fjørtoft and Rødseth, 2019). This paper uses scenarios from maritime transport to illustrate theoretical perspectives and challenges associated with the implication of new technology (autonomy). Autonomous vessels can be without people on board, and thus less exposed to humans when accidents occur. However, humans and crew on a vessel have also averted many accidents, that seldom can be found in statistics materials.

The purpose of this paper is to increase the awareness of adequate planning in order to improve resilience/safety and effectivity.

2. Planning in a changing world

2.1 Time phases and focus areas

Planning covers multiple time dimensions, from long term proactive planning and anticipation, to real-time reactive responses to a current event. In this paper we divide the total planning period in three phases or stages:

Planning phase	Time perspective
1. Strategic	1 – 5 years
2. Tactical	14 days up to 1 year
3. Operational	Today and until 14 days in front

Each planning phase correspond to different management levels. However, the levels should have a strong link to assure that the plans are sufficiently connected. Table 1 lists some focus areas representing associated goals and constraints. The table helps understanding where safe and resilient systems can be counted for.

2.3 Conflicting goals – Economic pressure challenge safety

Several authors refer to an increasing conflict between safety and other goals – especially effectivity. This often includes conflicts between strategical, tactical, and operational goals and decisions, where short-time profit may challenge long-time objectives like safety. Organisations

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must handle efficiency pressures in a context with increasingly complexity and interconnections.

Table 1. Planning levels – Focus areas and constraints.

	Controllable constraints	**Uncontrollable constraints**
Strategic	Strategic partnership, Life cycle management, Priority between operations, Resource needs (people, competence, equipment, facilities, vessel, logistics)	Market and financial issues, Infrastructure and Governmental decisions, Laws and enforcement
Tactical	Critical resource (People, Equipment, Vessels), Transport strategy and demand, Schedules, Risk and safety evaluation (HSE)	Market changes/ fluctuations, Technology failures, Infrastructure and Laws and enforcement
Operational	Resource management, Stowage, Daily production and distribution plans, Status reports and scheduling, Risk and safety evaluation (HSE)	Weather, Strikes, Damages, Traffic, Deviations, 3rd part failures, Changes in demand

The goal conflict influence choices and performances both at political, business and individual levels (Rasmussen (1997). He argues that effectivity and cost figures will be prioritized over safety, and where companies' decision makers will focus on economic incentives of on short term functional and survival criteria rather than long term criteria like welfare, safety and environmental impact. Further, since ships were increasingly operated by banks and investors rather than shipping professionals, the aim of commercial companies appears to have changed from serving a substance matter, toward a narrow focus on financial operations.

A new trend today is that cargo owners are investing in own ships, that are breaking traditional way of operating. Norwegian examples are that the fertilizer company Yara owns the autonomous vessels Yara Birkeland and the food distributors ASKO invested in two autonomous vessels. Commercial success in a competitive environment implies exploration of the benefit from operating at the fringes of the unusual, accepted practice.

Catastrophes like Chernobyl were caused by a systematic mitigation of organisational behaviour toward accident under the influence of pressure towards cost-effectiveness (and not by human errors) (Rasmussen, Ibid). He emphasizes that established practice during critical situations implies the risk of crossing the limits of safe practices and the boundaries of acceptable performance. Aiming at productive targets, the individual actor must give priority to cost effectiveness, workload, or risk of failure.

2.4 *Actors at different management levels*

The socio-technical system controlling safety and economy includes several levels ranging from legislation, over managers and work planners, to system operators. Based on Rasmussen (1997) model of six levels (listed in parenthesis), this paper classifies management actors on three levels:

Planning level	**Actors and control actions**
1. Strategic (top)	Government (1); *Legal systems make explicit priorities of conflicting goals*
2. Tactical	Regulators/Associations (2), Authorities and industrial associations, unions and interest organisations; *Interpret and implement control activities*
3. Operational (bottom)	Company (3), Management (4), Staff (5), Work (6), Front-line operators and company stuff; *Make the rules operational by interpreting and implementing in the context of a particular company*

From a port to port perspective, several systems and actors are involved in sailing a vessel for conventional shipping. Figure 1 illustrates the complexity of collaboration between actors; ICT systems needing information, traffic systems, governance issues, and different stakeholders involved or responsible for the systems.

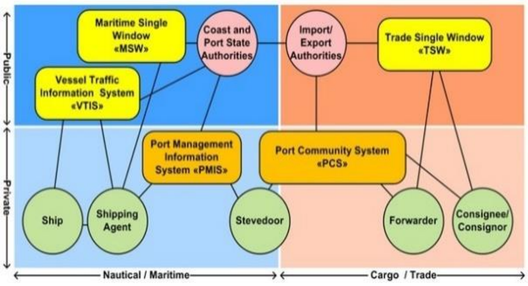

Figure 1. Systems and actors involved in sailing a vessel from port to port.

Each group have different plans, both on strategic, tactical and operational level. However, the whole transport system must be taken into consideration to be both safe and lead to more effectivity. When introducing autonomy, the picture will almost be the same, but the decision processes will be somewhat different. This will be described in more in section 4.

3. Theoretical planning and management

3.1 *Reactive and proactive approaches*

Theoretical perspectives are changing over time. In safety science, three main approaches have dominated the last century (Hale and Hovden, 1998). From an early emphasis on technology after the industrial revolution, the focus from the 1950ths shifted to human factors and human failures, and then from the 1990ths turning into highlighting organisational factors and safety management. Further, an emerging, general trend is an increased emphasize on general systems and the interrelation between different sub-systems and parts.

In addition to consider what goes wrong, safety has recently also comprised why things go right. Hollnagel (2013) respectively calls them Safety I and Safety II. Here we will summarize some of the differences. *Safety I (reactive)* have dominated traditional approaches and defines safety as a condition where the number of adverse outcomes is as low as possible. Measures are based on past incidents and aversive outcomes. Hence, the objective is to "avoid things that go wrong" and to handle potential failures and misses. *Safety II (proactive)* has become even more reported in safety studies and literature. Safety II essentially means adopting a resilience engineering (RE) perspective. The objective is to "ensure that things go right". This imply the need for studying normal situations, everyday activities and the ability to succeed under varying conditions. Hollnagel (ibid) emphasizes that humans can adjust what they do to match the varying conditions of work. Accordingly, humans may be considered a resource and a strength, instead of a potential problem causing failures.

3.2 Measurement and indicators

In accordance with more complex and interrelations, the need for measuring and coping with foreseen and unforeseen events increase.

(1) Planning depend on data quality. Planning quality - and coordination between different levels and actors - relies on basic data and available information. Aas (2008) defines logistics planning as balancing the availability of information and problem-solving capacity**.** *Information availability* is defined as collecting, structuring and presenting information regarding the need at the installation for transport capacity, the transport resources available and weather conditions/forecasts. *Problem solving capability* is to process all relevant information and transform it into logistic plans, loading and unloading plans.

Supply chain management is the integration of business processes for co-ordination of activities and processes within and between organizations in the supply chain (Cooper, Lambert and Pagh, 1997). This term may be used also for coordination within autonomous transport, between the different stakeholders involved.

(2) Resilience and economy indicators. The primarily reason to an imbalance between economic and safety goals, is that fewer proactive metrics are available relative to the data an organization can compile to build reactive metrics (Woods et al, 2015).

In addition, several factors discount using proactive metrics when they conflict with more short-term and more definitive reactive ones. The authors introduce a framework to analyse economy-safety trade-offs, comprising two indicator dimensions - Safety–Economy and Reactive–Proactive - used to identify what the organizations pay attention to (monitor, assess, investigate) and factors that may conflict or reinforce each other.

Most organisations use reactive, lagging indicators based on past experiences and statistics of accidents and incidents. In addition, Wood et al (ibid) suggest a new paradigm, and argue to use proactive, leading indicators that may anticipate and warn of areas of possible increased safety risks and to be able to act in advance of potential danger. A proactive approach tends to look for patterns and relationships that can help recognize anomalies early. Organisations should develop and use proactive indexes, tools and models to discover and handle scenarios where safety indicators come into conflict with short-term economic and productivity pressures.

There focus will differ doing strategic, tactic or operational planning, and it is a need to coordinate them. The reactive strategies are maybe more significant in the long-time planning, and opposite to short-time operational planning. Even if building an accurate representation of an organizations' indicators is hard, the value of mapping indicators is promising as a basis for discussion and reflection.

(3) The development of *early warning indicators* should rest on sound theoretical foundation, because organizational factors' effect on safety/risk is by no means well understood (Øien, Utne and Herrera, 2011). Usually accidents are not caused by a single factor, but pattern of events. Based on resilience engineering (RE), they put light on the potential of early warning (often labelled predictive) indicators. They are classified as indirect indicators and can measure the performance of functional units within an organization, such as operation, maintenance and training. Reactive (lagging) indicators identify and report on incidents and learning from mistakes, while active (leading) indicators provides feedback on performance before an accident or incident occurs. Leading indicators address the need to predict and act before an unwanted event.

The indicators may be used as a basis of decisions in face of productivity/safety trade-offs, to create foresight, anticipate opportunities and changing risks before failures occur. Regulators, managing and operating safety may be important when efficiency is failing to the status of critical constrains, while utility managers efficiency seems to be more important regarding safety. Performance indicators should be established for six functional areas: (1) Management, organization, and administration, (2) Design of facility and processes, (3) Training and qualification, (4) Operation, (5) Maintenance and (6) Emergency preparedness planning.

(4) Adjusting plans to real-time operations. Azadeh and Zarrin (2016) have developed a framework for productivity assessment, including a RE perspective. They clarify the distinction between productivity, efficiency and effectiveness. Productivity is determined by looking at the obtained production (effectiveness) versus the invested effort for reaching the result (efficiency). Hence, efficiency correspond to planning at the operational and tactical level, whereas effectiveness is associated with strategical planning

4. Scenarios – Autonomous shipping

The main goal of an Autonomous System (AS) is to define and describe needed infrastructure and organization to conduct safe and effective autonomous transport operations. This is not only about one vessel but concerns the whole transport system. The autonomous systems should avert more accidents than introducing. More automation is expected to remove some accidents caused by human error due to e.g. fatigue, workload and lack of attention (Hoem, Fjørtoft and Rødseth (2019). However, some new ones are also assumed to appear**.**

4.2 Resilience perspectives related to planning and management

Introducing new technology like autonomous shipping will change the way of working. To handle new threats, unfamiliar events and accident types, planning and management should develop and rely on proactive measures and methods. Additional indicators are needs to the traditional including foresight indicators handling both foreseen and unforeseen events.

Three types of resilience of a system are relevant to planning: *emotional* (character of a person/ organization/community), *technological* (features making it able to recover and gain functionality, when exposed to external pressure) and *social or ecological* (capability to change, adapt to new scenarios without losing functionality when exposed to external influence). Proactive safety is important when introducing autonomous systems, building awareness both regards external (as weather) as well as intern (as own capabilities, engine power) factors.

The sustained experience of modern societies depends on safe and efficient functioning of multiple systems, functions and specialized services (Hollnagel, 2013). The growth of capability brings rapid changes to society as new opportunities arise, complexities growth and new threats emerge (Woods, 2020). Resilience may represent a new paradigm for continuous adaptability, and it could be based on research on resilient performance of human adaptive systems.

When studying safety and economy, RE addresses the gap and distance between WAI (Work-as-Imagined) and WAD (Work-as-actually-Done). These correspond to the planning levels; WAI representing the strategic and tactical levels and WAD corresponding to the operational level. WAI is described in laws, regulations and standards.

In addition to questionnaire surveys, in-depth knowledge about WAD requires using methods like interviews, observations, storytelling and simulations. The results may be used to identify and act upon the ability or potential to adjust activities, resources, tactics and strategies in the face of potential events, variations, demands with diverse degree of uncertainty and to regulate processes relative to targets and constraints.

4.3 Coping with uncertainty

A system is resilient if it can adjust its functions prior to, during or following changes and disturbances, and the system sustain required operations under expected and unexpected conditions (Hollnagel, 2011). The iterative loop will be detection, analysis, action and control, as presented in Figure 2. Firstly, the *detection* should identify if an operation is going as planned or whether there are obstacles leading to an unwanted situation. This can either be based on technology, human observations, or information from external sources such as sensors on board the vessel or in the infrastructure.

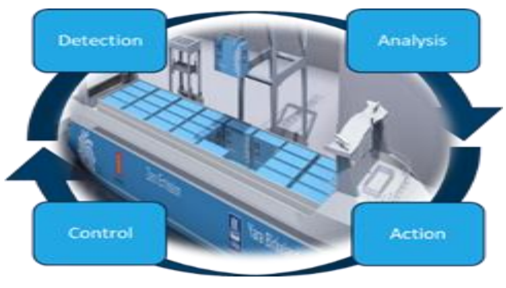

Figure 2. Management and decision cycle

The next will be to *analysis* the detection and define the operational state a vessel should be placed in depending on the vulnerability of the detection. This can be analysed based on the ship capability, forecast, risk level, and awareness to the sailing vessel surroundings, such as other traffic or vulnerable infrastructure. The *action* to be taken depends on the previous analysis, in addition to understand if the technology or the autonomous system can handle the situation itself or if humans must be called-up and take control. This again depends on the availability to both infrastructure, such as communication and sensor data to get awareness and to do remote operations, and the time calculation to achieve resilience or come back to normal operations as planned. The *control* stage will reflect on the hand-over control loop and human operator - technology relations.

4.3 Challenges operating future autonomous systems

Future transport sectors will be characterized by increased digitalisation, automation and electrification. One system will likely have to interact with several others, in an open infrastructure. Technology is likely to change the way of working. The infrastructure is supporting future digital applications with a higher degree of connectivity, more data available for analysis and awareness, and more availability to real time data due to decreased sensor costs.

Application of increasingly autonomous (IA) systems are driven by the expectation that such systems will return significant benefits in terms of safety, reliability, efficiency, affordability and/or previously unattainable missions' capabilities (National Research Council, 2014). Even though the report covers civil aviation, it is relevant to all transport. IA systems may potentially bring revolutionary changes in capabilities and operations. Rather than fully autonomous aircraft (not requiring a pilot), the focus is primarily on autopiloted and remotely piloted (nonautonomous) unmanned aircraft.

IA capabilities create a more complex system, with new interdependencies and new relationships among various operational elements (Ibid, 2014). This will likely reduce the resilience of the system because disturbances in one portion of the system could, in certain circumstances, cause the performance of the entire system to degrade precipitously.

Hoem, Fjørtoft and Rødseth (2019) have listed main factors distinguishing an autonomous ship from a conventional ship and the potential for increase or decrease of incidents. Differences imply increased importance of an improved planning when operating autonomous vessels.

Statistics usually show a very high percentage of accidents caused by human mistakes, but do not mention how many accidents humans have avoided (e.g. EMSA 2018). One driver for introducing autonomy (technology) in shipping is to reduce the total number of accidents. This requires reliability of technical systems onboard and it is necessary to add new technical barriers, e.g. by using increased redundancy. Main difference in operation will be a closer collaboration between technology and humans in control. The humans involved will have other functions, and the way of working will change.

4.4 Actors in autonomous shipping

Planning of Maritime Transport System (MTS) should see integrated transport systems together. Considering the complexity, good planning is probably even more important within autonomous operations than for conventional shipping.

Figure 3 illustrates the relations between actors in the autonomous transport systems The vessel itself (MASS), the vessel-technology interaction, as well as interaction between different stakeholders (Fjørtoft and Haugen, 2019).

Figure 3 The Autonomous Transport System

Several technical systems and equipment, both on board a vessel and from the land-based infrastructure, can be used to build awareness to a MASS operation. To be a resilient system, several control centres are significant for exchange of information both with conventional vessels and other users in an area where the MASS is operating.

Safety and effectivity of introducing autonomy depend on focused and open information exchange. This is critical to get a total and real-time picture of traffic changes. Of course, the security element of being to open must be considered.

(1) The autonomous vessels (MASS) will have to interact with sensors and systems when staying in a port, or on its way from port to port. For example, it must "talk" with the sensors in the port when berthing or leaving the port. In the fairway, the transport between ports, it must interact with other vessels, get weather data and navigational aids from external sources, and interact with the different traffic centres along its journey. It must also report real-time information to the Shore Control centre (SCC) operating the vessel. Thus, a MASS must consider different internal

(capacity, ballast, technical condition, power production, etc) and external (fairway conditions, weather, traffic, digital infrastructure etc) factors.

(2) The port and land-based infrastructure. The MASS will interact some differently with the port infrastructure than present practice. Hence, planning and operation will change. In some projects (e.g. IMAT) one of the objectives for autonomous operations is to build both awareness for operation, as well as resilience to the MASS from the land-based infrastructure. This can be cameras, radars or sensors along the fairway.

A MASS should correspond and interact with ports with high technological maturity. When sailing in, sensors at a MASS must talk with sensors at the port and along the infrastructure. When entering and docking, robots on a vessel must interact with robots at the terminal.

A vessel without humans onboard need a different operational profile than manned. Planners and managers must assure that the vessel capacities and condition are as required, and further take consideration of the need for longer time period in ports due to technical maintenance.

The operational planning phase should consider and ensure new or changed resources and supplies to the vessel. It is likely that a maintenance team will be organised as a local task force, that are doing required work during a port stay.

The maintenance window is likely to be longer and periodic service intervals must have a higher frequency than today. Maintenance work done by the crew members today are often done when the vessel is sailing between ports.

(3) Vessel Traffic Centre (VTC) and Local Monitoring Centre (LMC). The SCC operations by different stakeholders, must be planned and coordinated regarding the total marine traffic in an area. A VTC or LMC may give support and coordinate operations. The port or local service providers may have the responsibility to manage and operate the exchange or achievement 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 the MASS. In some cases, an LMC solution can be autonomous or computer based itself, with no humans in the loop.

(4) Shore Control Centre (SCC) will have an important role in the operation of a MASS vessel. An SCC can remotely operate a vessel and be the connection point with other conventional vessels, traffic centres or those requiring information from the vessel. An SCC will exchange information with other SCCs or a Vessel Traffic Service, VTS.

Our 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 planning of a voyage must be better than today, where both the loading and unloading, docking, and the transport between two locations are part of the plan. SCC planning at both tactical and operational level will be important, in addition to internal planning of the SCC organisation. A SCC must also have daily dialogue with ports and other stakeholders the MASS is meeting on its way, and with other SCC's as well as with conventional vessels. This requires new awareness, such as to the communication availability between MASS and SCC, navigational awareness, and awareness to environment, regulations, emergency and to the mandatory reporting of information following the vessel journey as examples.

5. Discussion

Several factors may help considering whether a transport system may be categorised as resilient systems and at the same time be effective and productive.

5.1 Performance, stress and challenges

In the context of increased complexity and interrelations, are humans a potential risk (and should be excluded) or safety resource (able to take safe decisions) when facing disturbances? Human operator's capability was studied in the MUNIN project, and the result indicates that MASS one operator can manage to be responsible of about six vessels, dependent on many concerns. The most important are probably the operational context. Sailing from A to B in open waters with low traffic will be easy to monitor and control. Docking or loading activities need more attention from an operator.

Several studies have used Yerkes-Dodson law, (from 1908) to explain the relation between performance and arousal/stress. As illustrated in **Error! Reference source not found.**, performance is related to physiological or mental arousal. Performance increases up to a point. However, when levels of arousal become too high, performance decreases. This implies that task where operators must handle more than six vessels are likely to cause high stress and thus weak performance.

Resilience theory emphasizes to study performance variability in everyday life. Thus, according to the inverted U-model, the performance in WAI (work as actually done) may vary from weak to strong dependent on the degree of arousal in the situation and context. Weak performance is associated with tasks of both low and high pressure. Further, different arousal levels are associated with different mental stages.

Coping with stress in challenging situations may be handled by using strategies implying positive or negative responses due to courses of actions and outcomes. Further, people may vary in their abilities to use a qualified coping strategy, depending on e.g., skills and task complexity. In our example, a docking task will bring about more operator stress (and increased probably of weak performance) than sailing in open sea.

Optimal experiences and performance are a result of balancing skills and challenges (Csikszentmihalyi, 1996). Optimal experiences result when the task challenge correspond to personal skills, and the task are manageable. Too challenging tasks compared to available skills, will result in anxiety (and weak performance). Likewise, too high skills compared to challenge may result in weak performance due to boredom.

Autonomous transport systems include interaction between several actors. Operator competence requirements are often high. However, several studies show that control centre operators often perform routine tasks. As a result, they are likely to experience boredom, and may be lacking to pay attention.

On the other hand, implementation of MASS may create new, sudden, and complex situations. These are unfamiliar to the RCC operators, and lacking skills should bring about high stress. Hence, the performances are expected to be weak.

Capability or competence is not only a question of formal education, but also includes practical skills acquired during work and underlying the ability of an expert to act quickly and effectively in the work context (Rasmussen, 1997). Further, knowledge of normal competence of co-operating agents is necessary to judge what information to communicate up, down or horizontally in the system. This particularly important facing fast changes.

In sum, to be safe and efficient, the implementation of new technology (and procedures) should be accomplished by training and gradually developing skills according to challenges. The operator should first learn to handle easy tasks, and by gradually increasing challenges the skills increase.

5.2 Planning and management influenced by theoretical perspective

Safety management have changed during the years, partly influenced by new theoretical perspectives and empirical approach. Methods and measurement influence what kind of data you select and the interpretation of them, "What-You-Look-For-Is-What-You-Find" (Hollnagel, 2008). Further this influence planning and measures to achieve desired goals, according to the principle "What-You-Find-Is-What-You-Fix" (Lundberg et al., 2009). The appearance of and recently increased emphasize on RE, imply adding measurements to traditional safety science.

RE addresses the gap and distance between WAI (Work-as-Imagined) and WAD (Work-as-actually-Done). Reflection on the gap between expected results and actual results is closely connected to single-loop and double-loop learning (Argyris and Schön, 1996). Single-loop learning is connected to maintaining efficiency – "doing things right" according to existing values/ norms. (Related to WAD.) Double-loop learning is about "doing the right things", by questioning the existing values/norms. (Related to WAI.) This is important in a dynamic work environment.

5.3 Safety culture and goal conflicts

Goal conflicts may be illustrated by the distinction safety culture versus safety climate. It is important to distinguish between them (Transportation Research Board, 2016). *Safety climate* is the shared perception among members of an organization of the priority of acting safely based on shared assessments of the behaviours expected, rewarded, and supported by the organization and its supervisors and managers. The safety climate of an organization sends signals regarding underlying assumptions and values animating its safety culture.

Traits of a strong *safety culture* are that the entire organization makes safety a priority relative to business performance, effective practices and processes for safety permeate the organization across geography and hierarchical levels, leading (near misses) and lagging (incidents) indicators of safety performance are actively measured, and training of and investment in employees to deliver safe performance are continuous.

5.4 Resilience perspectives and effectivity

A resilience perspective emphasises the need for handling normal variability of performance and operations. This is in accordance with economic planning where effectivity and productivity are stressed. The goals in both perspectives are to handle anomalies and maintain normal operation.

When things go right there is no difference between the expected or planned, and the actual. When attention or initiates are related to handling normal variability in everyday situations – safety and efficacy are not conflicting.

"While day-to-day activities at the sharp end never are reactive only, the pressure in most work situations is to be efficient rather than thorough. This reduces the possibilities to be proactive" (Hollnagel, 2011). Proactive safety management requires that some planning effort is spent to think about what could possibly happen, to prepare appropriate responses, to allocate resources, and make contingency plans.

Proactive safety management must focus on how everyday performance usually goes well rather than on why it occasionally fails, in addition to actively try to improve the former rather than simply prevent the latter.

6. Conclusion

From our study we have seen that:

- Resilient systems do not need to be more effective. Planning and controlling safety based on RE may combine resilience and effectivity/ productivity goals. The challenge for both is to handle normal variations, surprises and changes in operational performance.
- RE is a suited approach when studying technological innovations (autonomy). A proactive approach is necessary, in addition to traditional, to cope with foreseen/unforeseen events.
- Implementation of MASS will increase the complexity and change actors' interrelations. RE indicate that increased planning quality will enhance both safety and effectiveness in critical, complex, or anomalous/ unexpected conditions.
- Further, 'humans in the loop' are needed at control centres and may be a safety resource. New ways of working and multiple agent interaction require specified training in order to maintain safe and efficient operations.

Some important elements that future studies of autonomous shipping should consider:

- RE – Development of emergency preparedness for unexpected and expected changes.
- Effectivity - The planning requirements will probably be more precise as closer you are to operation, from strategic to operational planning
- Proactive indicators are needed in addition to reactive, and they should be context specific.
- Planning at and coordination between different levels and actors are essential. Think integrated transport systems instead of modal focus.
- Explore the total effects of introducing MASS when it comes to resilience skills, and develop specific training of different actors and levels

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