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Can we learn from aviation: safety enhancements in transport by achieving human orientated resilient shipping environment

Osman Turan [a,*], Rafet Emek Kurt [a], Volkan Arslan [a], Sara Silvagni [b], Marco Ducci [b], Paul Liston [c], Jaan Maarten Schraagen [d], Ivy Fang [e], George Papadakis [f]

[a]*University of Strathclyde, 100 Montrose Street, Glasgow G4 0LZ,* United Kingdom,
[b] *Deep Blue Srl, Piazza Buenos Aires 20, 00198 Rome – Italy*
[c]*Trinity College, University of Dublin, Dublin 2, Ireland*
[d]*TNO, Kampweg 5, NL-3769 DE Soesterberg, The Netherlands*
[e]*Lloyd's Register, Southampton Boldrewood Innovation Campus, Burgess Road, Southampton, SO16 7QF United Kingdom*
[f]*A.P.&A. Ltd. London, United Kingdom*

Abstract

It is well reported in the literature that more than 80% of shipping accidents are attributed to Human/organisational Error. Maritime community has realised that despite all the increased safety standards and technological developments, accidents are still occurring and the systems are not resilient to errors at various levels. The FP7 SEAHORSE project focuses on safety in marine transport by addressing human and organisational factors through transfer of well proven practices and methodologies from air transport to marine transport in an effective, collaborative and innovative manner. This will be primarily achieved by introducing the principles of resilience engineering in an integrated framework which will result in multi-level resilience that linking individuals, team, multi-party teams and organisations in ship operation that ultimately enhancing shipping safety.

This paper presents similarities and gaps between two transport sectors while establishing the principles of transfer of skills, technology from aviation to maritime, which includes but not limited to rules, standard operating procedures, safety culture, just culture and mandatory safety reporting methodologies. The paper further present the feasible areas for transfer, experience gained during the transfer of technology/skills from air to marine while outlining the resilience framework adapted to maritime transport.

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* Corresponding author. Tel.: +44-141-5483211.
E-mail address: o.turan@strath.ac.uk

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1. Introduction

Currently while an increase in the transportation of goods worldwide by sea has been recorded, a general decrease in the number of crew on-board has been observed over a number of years. Due to system automation, operational streamlining and financial constraints extra demands have been placed on the smaller crew which has the potential to lead to situations conducive to human error and accidents. The modern seaman is expected to be multi-disciplined with a high level of technical skills, have broader deck officer responsibilities, manoeuvre the vessel he/she is working on at short notice and be prepared to work long hours with very limited days off and outside social contact. These working conditions and this environment are proven not only to be making seafaring a less attractive career option but more worryingly causing accidents.

It is well reported in the literature that more than 80% of shipping accidents are attributed to Human Error. Marine accidents are the result of error chains rather than single events (Swift, 2004). Traditionally safety has been addressed both by designers and regulatory bodies such as the International Maritime Organisation (IMO) through structural, mechanical, electrical and technological solutions with the aim of minimising damage and prevention of loss of life and ships/floating structures. Maritime community has realised that despite all the increased safety standards and technological developments, accidents are still occurring and the system is not resilient to errors at various levels. Furthermore, it has been often ignored that the human element of the maritime system has not been evolving in the same way that technology is developing; with the physical capabilities and the limitations of the human being overlooked.

The air transport sector, which is in many ways similar to the marine sector have been facing similar human and organisational factors that affect operational safety. However the airline industry has been managing these issues by approaching the same problem systematically and developing much more advanced methodologies and techniques that can be adapted to the marine industry while utilising the experience of air transport.

The SEAHORSE project addresses human factors and safety in marine transport by transferring the well proven practices and methodologies from air transport to marine transport in an effective, collaborative and innovative manner. This is to be primarily achieved by introducing the principles of resilience engineering and smart procedures methodology in an integrated framework which will result in multi-level resilience that linking individuals, team, multi-party teams and organisations in ship operation that ultimately enhancing shipping safety. The resilience will be realised by

- Identifying the key human/organisational factors, which lead to operational successes and failures in marine and air transport and perform gap analysis in marine practices in comparison to air industry;
- Investigate how errors and non-standard practices were managed successfully in air transport and check the feasibility of applying best practices and resilience concept adopted in air transport for marine to improve human/organisational errors and safety
- Develop the Technology Transfer Framework from air to marine for successful implementation
- Introduce a smart procedure methodology in marine operations to manage non-standard procedures carried out on board ships to enhance overall resilience.
- Develop and validate a multi-level resilience model which encompasses individual, team, multi-party and organisational resilience that linked and integrated.

Seahorse concepts takes into account a) The crew needs and limitations that may affect their resilience with regards to navigation/operation of the ships (competency, physical & cognitive limits, attitudes, team composition), b) System design, equipment and procedures which promote/add/remove, by designing resilient systems and behaviour; c) Shared situational awareness, leadership, organisational drift, insufficient/non-existing safety culture, team work.

This paper presents project outputs so far by presenting the comparative state-of-art analysis between air and marine transport modes, occurrence analysis, gap analysis and scope of transfer in sections 2, 3,4 and 5 respectively. Workarounds in maritime sector and Multilevel Resilience Framework are presented in sections 6 and 7.

2. Comparative state-of-the-art between air and marine transport

2.1. Stakeholders

The review of stakeholders highlighted the fact that the two transport sectors are very different. Both have a strong emphasis on safety but there are differences in how safety is managed and negotiated by the main actors. The maritime sector, in the category of secondary users, contrasts strongly with the aviation sector. The maritime sector has a much more broad and varied category of secondary users. The aviation sector has ATM, maintenance and airport services to manage in terms of secondary stakeholders. But the maritime sector has not just the maritime equivalent of ATM (VTS), or maintenance and the port but stakeholders such as agents, towage companies, pilot companies, stevedoring, ship owners, etc. all of whom have inputs to the safety and reliability of the operation.. Safety and efficiency are often opposing forces and compromises often have to be made. Negotiation safety with so many stakeholders with varied agendas, as happens in the maritime sector, is a task which is complicated by training and regulatory issues.

2.2. Training

The aviation sector can be broadly said to have better systems and procedures in place to oversee, assess and ensure the currency of personnel training. One particular example is Human Factor (HF) training. HF training in the maritime sector is only mandated for certain grades of staff. While most of the same topics are covered in aviation HF training as in maritime, the fact that only certain grades receive the training means that its potential impact on the system functioning is decreased. The aviation sector is assisted in managing training by regulations which state the AMC (Acceptable Means of Compliance) whereby the regulators state what they view as an acceptable means of implementing the regulations and rules. Similarly, while the aviation sector struggles to effectively assess and evaluate training it does have in place systems to do this and is trying to improve. The maritime sector however, seems to not have attempted this yet.

2.3. Regulations

Both the maritime and aviation sectors are highly regulated industries but it is clear that oversight and the interpretation and implementation of regulations are an area where the maritime sector could learn from the aviation sector. The lack of a mandatory quality approval system for Flag States is creating a big safety discrepancy between the potential and actual safety of the maritime system. While the maritime sector seems to tolerate this systemic safety ‘workaround’ the aviation system is far less tolerant of safety ‘fudges’. Indeed the EU and US aviation safety regulators have the power to ban airlines that fail to meet their stringent safety requirement from even entering European airspace. This ‘blacklist’ is publicly available and regularly updated. It is clear that aviation, as a safety critical transport sector, has to be ‘seen’ to be safe (in addition to actually ‘being’ safe) and can derive commercial value from being ‘seen’ by the travelling public as safe but the regulations are far more reaching and stringent in terms of holding operators to account. Oversight of safety is one key area where the maritime sector could achieve key gains in learning from aviation – not just in terms of enforcing regulations but in assisting organizations in understanding how to meet safety requirements (such as the aviation AMC approach) and in terms of supporting organizations to implement and monitor the effectiveness of safety initiatives.

2.4. Challenges

In relation to current challenges there are areas of convergence and divergence between the two sectors. Both the maritime and aviation interviewees have stated those paperwork and task loads are very important challenges for their operations. In the aviation sector workload has sometimes been decreased due to automation on the flight deck, whereas in the maritime sector the paperwork on the bridge is reported to increase the workload. Paperwork in the aviation sector is also an issue but here the challenges with paperwork relate to inaccurate documentation, illegible data cards and out of date maintenance data. Similarly both sectors see challenges related to the organisational context – specifically the lack of resources in the aviation sector which has an impact on competence (insufficient training) or task performance (lack of equipment, inadequate facilities etc.), though the industry is trying to manage this through audit plans and regular reporting. In the maritime sector one issue is the compartmentalisation of safety where it is viewed as separate from the operation and not related to everyday work. This leads to the notion that safety is somebody else’s problem and results in a diffusion of responsibility for safety. Meanwhile there is convergence in relation to multicultural crews. The maritime sector cites this as a significant challenge whereas the aviation sector states that it is not a safety challenge as standard operating procedures constitute a good solution for avoiding possible issues that can come up due to multicultural issues. Clearly the strong professional culture of pilots, or maintenance personnel, and their common (standardized) training produces a more consistent basis for a common professional culture than exists in the maritime sector. Finally, the issue of resources is again one of the greatest issues in aviation. The lack of resources can most of the times lead to a lack of knowledge (not enough trainings), inadequate facilities, lack of equipment and lack of personnel. The main results can be safety issues and quality issues. Some measures taken by the airline industry are the monitoring through an audit plan in order to improve possible inadequacy of resources and the regular reporting of the personnel to their managers.

3. Occurrence Analysis

"Occurrence Analysis" provides an overview of accidents and incidents which commonly occur in the maritime and aviation industry and therefore contributes to the overall aims of the SEAHORSE project by highlighting the key areas where failures occur and helps form the basis for developing an understanding about whether there is a way of adopting best practices to improve safety. The analysis of accident and incident data was conducted by using publicly available occurrence data, data from the end-users of the consortium, other stakeholders and reviews of other occurrences analysis, particularly in the aviation industry. Particular attention was given to human errors, operating procedures and organisational issues. Further interviews and expert opinions were collated to confirm the findings as well as to provide deeper insight into the dynamics of failure.

3.1. Occurrence reporting procedures

Aviation: Aviation has a standardised mandatory occurrence reporting system as International Civil Aviation Authority, ICAO Annex 13 (Chapter 8) requires States to establish mandatory incident reporting systems to gather information on actual or potential safety deficiencies. This requirement is supplemented by further ICAO requirements which require aviation companies to have in place formal processes to collect, analyse and act upon feedback on hazards and risks in operations in order to support the implementation of mandated safety management systems. In Europe mandatory occurrence reporting, which has existed since 2003 (Directive 2003/42/EC), was supplemented in 2007 with implementing rules establishing a Central European Repository of information on civil aviation occurrences (Regulation (EC) 1321/2007). It contains all occurrences collected by EU Member States, and rules on the dissemination of the information stored in the European Central Repository (Regulation (EC) 1330/2007). In process of Mandatory Occurrence Reporting (MOR) activity, Aviation industry is using same taxonomy and procedure. MORs received by the CAA are all coded under the ECCAIRS data definition standards which use the ICAO ADREP Taxonomy.

Maritime: The maritime sector has not reached the maturity level of aviation despite the efforts within the IMO, and different authorities use different taxonomies to guide the collection of data. Additionally there are significant variations in the standards of reporting. This creates a significant problem with regards to the creation of a single maritime occurrence reporting taxonomy as well as a centralised database. The European Maritime Safety Agency (EMSA) is currently making efforts to create a centralised database using a standardised taxonomy to gather data but this objective may not be easily realised given the safety maturity level of the maritime sector and the dominant safety culture that exists. This is one of the key areas as a potential topic for the transfer of best practices from aviation to enhance occurrence reporting in the maritime sector

3.2. Availability and similarity of data

In aviation reports of single accidents are publicly available in Agency databases (e.g. NTSB-AAR, European Central Repository). However, more in depth information on the contributing factors is classified and only accessible by authorized national agencies to ensure anonymity and confidentiality.

The SEAHORSE Consortium managed to obtain a comprehensive accident review from the UK CAA containing important information on human and organisational factors which could be considered comparable to the MAIB database used for the maritime analysis. A direct like-for-like comparison across categories and/or levels of human and organisational factors was not possible due to the fact that the CAA and the MAIB use different frameworks to categorise accidents and incidents. Aviation and maritime are two transport sectors with different levels of safety maturity and it stands to reason that they have emerged using different classification schemes for accident and incident data. So, while a direct comparison cannot be made, the data were sufficiently rich to give us insights into the incidence of human and organisational issues in the maritime sector as compared to aviation.

3.3. Occurrence Analysis

Maritime: According to the European Transport safety Council, passenger fatality rates in shipping are 14.8 passengers per 100 million passenger hours and 0.46 per 100 million passenger kilometres. The data obtained from the MAIB (Maritime Accident Investigation Branch) was analysed under three levels: Underlying accident factor category, underlying accident factor and underlying accident sub-factor. It was found that the majority of the factors leading to accident is related to the human factor category (74% of the underlying main factors) while 26% are listed under the technical category. For each accident there are more than one root cause recorded in the MAIB database. Therefore, it is very common that the number of accident sub-factors is higher than the actual number of accidents. This confirms the view in the maritime and aviation domains that accidents are results of a chain of events rather than a single point failure.

Under the human factors category, when underlying accident factors are analysed it can be seen that over 50% of the underlying accident factors under the human factors category are related to 'people' and their poor performance. The second largest group is 'system-crew factors' (15%). 'System-company and organisation' percentage is 9%, which is followed by 'working environment' (8%) and 'system-equipment' (8%). All safety-related issues on board are directly influenced by the company that the vessel belongs to. Therefore management factors are recognised as extremely important and should form a core element of the resilience framework.

When the underlying sub-factors under the 'people' category are analysed it reveals that inattention was found as the cause of the majority of the accidents reported. Inattention results as the main cause leading to human error (19%) while perception of risk (9.3%) is the second most frequent underlying sub-factor of 'people' related to marine accidents. 8.8% of human errors are caused by inadequate communication or situational awareness and 8.1% of human related errors are caused by perception abilities. 6% are caused by complacency and 5.8% by the competence of people. Under the 'system-crew' factor, 42% of the underlying sub-factors are related to inadequate procedures which may be misleading or may give insufficient information. This is followed by lack of communication or coordination between crew members with 18%. These occurrence analyses clearly highlight the gaps in various areas, which are related to human and organisational issues.

Aviation: The Global Fatal Accident Review 2002 to 2011 was carried out to provide a ten-year overview of worldwide fatal accidents involving large jet and turboprop aeroplanes engaged in passenger, cargo and ferry/positioning flights (CAA, 2013). There were a total of 250 worldwide fatal accidents, which resulted in 7,148 fatalities to passengers and crewmembers on-board the aircraft. The proportion of aircraft occupants killed in these fatal accidents was 70% which indicates that, on average, 30% of occupants survived. The overall fatal accident rate for the ten-year period from 2002 to 2011 was 0.6 fatal accidents per million flights flown or 0.4 when expressed as per million hours flown. The corresponding on-board fatality rate for the same period was 22.0 fatalities per million flights flown or 12.7 when expressed as per million hours flown. According to European Transport safety Council, passenger fatality rates in aviation is 0.035 per 100 million passenger kilometres. Factors related to the human element are by far the main explanatory factor, in view of the data submitted to the UK CAA´s Mandatory Occurrence Reporting (MOR).

- Over half of all fatal accidents (52%) involved an "Airline (human and organisational factors)" related primary causal group. Other causal groups are listed as environment (5%), aircraft system/components (5%), engine (4%) and maintenance (2%).
- The most frequently identified primary causal factor was "Flight Crew Handling/Skill – Flight handling" (14% of all fatal accidents).
- 66% of all fatal accidents involved at least one 'Airline' related causal factor. In addition to "Flight handling", "Omission of action or inappropriate action" (12%) was the joint most-commonly assigned causal factor.
- "Omission of action or inappropriate action" generally related to flight crew continuing their descent below the decision height or minimum descent/safety heights without visual reference, failing to fly a missed approach or omitting to set the correct aircraft configuration for take-off.
- Nearly 40% of all fatal accidents involved some kind of loss of control, making this the most frequent type of accident. Non-technical failures (for example flight crew failing to correctly respond to a warning) were the predominant cause of loss of control accidents.

4. Gap analysis between air and marine transport

The SEAHORSE gap analysis is related to the gaps that exist between maritime and aviation. In a workshop with maritime and aviation attendees the topics and sub-topics were discussed and a joint decision was made about the existence of otherwise of a gap. The criterion for stating that a gap exists was that the gap should have an impact on safety. It was not a statement of difference between the maritime and aviation systems.

Following the workshop a total of 44 gaps were identified which impact safety in the maritime sector (Table 1). This is the first such study clearly providing the gaps between the air and maritime transport with regards to safety.

Table 1. Gaps identified between Air and maritime sectors.

A-Stakeholders	E-Current Challenges
1. Standardisation	29. Application of workspace guidelines
2. Passenger focus	30. Fatigue (including physical fatigue)
3. Complicating role of ship owner	31. Multicultural/language issues
4. Fragmentation	32. Paperwork
5. VTS authority	
6. Transnational regulation	
7. Flag states	
8. Operationalisation of training regulations	
9. Standardisation of training	
B-Functional Demands	F-Human and Organizational Factors
10. Human Machine Interface	33. Advanced tackling of HOF issues
11. Crewmember procedures	
12. Language stills	
13. Maintenance during operation	
14. Command conflict (maintenance)	
15. Lack of certification	
16. Procedures vs qualification	
C-Training	G-Operational Demands
17. Maturity & capability of HF training	34. Standardisation
18. Maturity & capability of HF training	35. Experience and regulations
19. Reluctance to report	36. Input of captain to planning
20. Lack of standardised training	37. Lack of mandatory maneuvering advice
21. Limited use of simulations	38. Maturity & capability of reporting
D-Regulations	H-Socio-Economic Issues
22. Centralised Framework	39. Lack of proper rest hours
23. Flags of convenience	40. Length of time away
24. The finance and quality of seafarer/crew training	41. Social benefits
25. Scope of Personnel Licensing	42. Health and safety
26. Responsibilities in traffic control	43. Training costs
27. Standardisation	44. Social perception
28. The scope of regulations for maintenance	

4.1. Standardisation

Standardisation is one such gap – featuring as it does in the stakeholder topic. Aviation is far more standardised compared to maritime. Even just taking the example of vessels and aircraft, it is far easier to regulate, control and manage a system which has standardized vessels compared to one which has no easy means of comparison or predicting outcomes where variables are not standardized in any knowable way. In aviation, rank structure is informed by licenses as crew (flight crew and maintenance crew) have licenses for a particular aircraft 'type' (a particular 'brand' of aircraft series produced by a particular manufacturer) and their experience is represented by this license. In maritime, the rank structure within a ship's hierarchy is key and without a license related to particular vessel it renders rank structure particularly strong as a cultural artefact – and indeed rank structure often creates barriers to communication

4.2. Commercialisation of safety

Maritime is predominantly a cargo transport sector (though this is changing). Aviation is predominantly a passenger transport sector. While the human factors discipline has continually failed to demonstrate the monetary impact or benefit of safety initiatives in aviation, safety continues to be a driver for technological and organisational improvement. That is to say, without evidence of improvements to efficiency (even though most safety experts legitimately suggest that improving safety will concomitantly improve safety) aviation companies are still willing to invest in safety initiatives. This is because not only does safety have a commercial value in aviation but also airlines want to be seen to do 'safety'. Airlines want to have a reputation for pursuing safety objectives in a sustained and rigorous way. This is different to the way safety is managed in the maritime sector and the question as to whether it relates to the capability of the maritime sector to manage intractable safety issues or the maturity of the maritime system needs to be teased out. What remains, however, is that for aviation safety has a commercial value – passengers question the safety record of an airline before they book (thereby giving 'safer' airlines a competitive advantage), but the maritime sector (being predominantly a cargo transport sector) is different. Clearly as cruising grows – and with high profile maritime accidents occurring in recent times – attention will shift in maritime and safety will begin to have a commercial value.

4.3. Economic pressures

So while it is predicted that the maritime sector will move the way of the aviation sector in terms of how safety is viewed as a competitive advantage it would seem that aviation, motivated by economic pressures, is in some respects following the maritime sector's lead and not making positive progress. In some ways aviation is moving backwards with the operational 'innovations' being spearheaded by budget airlines. Nowadays pilots only get paid for the hours they fly (in the past the salary was fixed irrespective of hours flown). This creates pressure on pilots, who have had to pay for their initial training, to earn as much money as possible to pay off the debts they accumulated to finance their flight training. This has created a situation where pilots are operating on the upper limit of their flight time limits and is introducing risk into the system as pilots must not fly longer than stipulated by regulations and could, foreseeably, lead to emergency landings if a flight accrued a delay and pushed the pilot over his flight time limits. Situations like this have already happened due to budget airlines' fuel policies – limiting the amount of fuel reserves an aircraft holds due to costs which then precipitates an emergency landing when the flight accumulates a delay.

In Europe, aviation regulation requires that the airline companies are obliged to provide training of its crew. Such explicit regulatory statement is not found in the maritime industry. Only a few airlines, usually budget airlines as well as small aviation companies handling goods transport, require the pilots to pay for the initial training themselves. But this is changing and aviation has an emerging safety challenge which might have implications for regulation and operations.

5. Scope of transfer

Resilience solutions available in airlines are for the first time compiled into a database with an aim of transferring the solutions from air transport to maritime sector with the involvement of practising maritime experts as well as safety managers. The experts ranked the solutions based on the potential benefits that they can bring to maritime sector in the area of operational safety through human and organisational resilience. Maritime experts had a regular face to face meetings, discussions and workshops with safety managers, pilots and trainers from air transport industry while listening to other maritime experts coming from different branches of maritime sectors such as LNG, oil tanker and cruise ship operators. Such a large participation of industry experts from both domains provided a platform where practical elements of the resilience solutions were discussed and analysed thoroughly resulting in more realistic expectations and strategies for maritime domain.

The SEAHORSE methodology employed to shortlist and ranks the resilience resources is based on a subjective evaluation made by maritime professionals and experts. The evaluation criteria were defined in order to assess clearly the potential applicability of the proposed solutions to the maritime domain. Three criteria were defined as; **Availability:** presence of the solution or something similar in the domain, even if not properly working; **Applicability:** ease of applicability of the proposed solution to the maritime domain and; **Impact on Safety:** safety benefits resulting from the implementation of the proposed solution.

In addition to these parameters, the maritime experts were also asked to select the most promising solutions to be transferred to the maritime domain according to their own judgment, without referring to any specific criteria. This, together with the explanation of the rationale for their choice, allowed the final shortlisting and ranking. After carrying out workshops with maritime professionals, the final step of the evaluation process was to ask the maritime experts to rank the 10 most promising solutions that emerged from the workshops. The criteria of these ranking was the benefit that the solution would bring to the maritime domain according to their judgment. On the basis of the outcomes of the above process the solutions contained in the database were classified and divided into six categories, each one defined by specific criteria. Here the most relevant three are described as;

1. **Most promising solutions**: this category includes solutions not available (or not working) that are ranked as the most promising for transfer by at least 30% of experts, very much beneficial for maritime safety by at least 50% with a high impact on safety.
2. **Promising solutions**: this category includes solutions not widely available (or not working) that are ranked as the most promising for transfer by at least 20% of experts, very much beneficial for maritime safety by at least 50% with a moderate impact on safety.
3. **Promising solutions to be further investigated**: this category includes the solutions evaluated as promising in terms of safety impact but already existing in the maritime domain.

Table 2. Most promising solutions.

Most promising solutions		
Name	**Topic**	**Short description**
HF Training – Maintenance	Training	Maintenance operators training on HF issues in everyday tasks.
Mandatory Safety Reports	Data	Structured EU reporting system for all aircraft accidents and serious incidents.
MEDA	Regulations & Procedures	Structured investigation process for maintenance technicians and inspectors error causes.
TCAS	Automation	Traffic alert and collision avoidance system implemented on aircraft, final barrier to avoid mid-air collisions.
Human Factors analysis and classification system	Incident investigation	Support tool for HF investigation process and consequent operators HF training.
SAGAT	Human Factors	Technique for the objective measure of operators Situation Awareness.
Just culture	Human Factors	Organisational approach on the management of blame and punishment of not-deliberated actions and errors.
Flight time limitation scheme	Human Factors	Specification of flight and duty time limitations.
Safety culture	Human Factors	Organisational commitment to safety, at all levels in the organisation.
Promising solutions		
Name	**Topic**	**Short description**
Integrated Safety Trend Analysis and Reporting System	Data	Web-based combination of safety-related datasets for an effective and integrated safety analysis.
Safety bulletins	Data	Periodical bulletins to inform operators on the status of the industry, on most frequent safety occurrences and corrective actions.
Accidents/Incidents investigation	Regulations & Procedures	Structured approach for accident or incident data collection and investigation.
Being a safe crew	Training	Organisational processes to ensure that every operator shares the same approach to safety.
Fatigue risk management	Human Factors	Data-driven means of continuously monitoring and maintaining fatigue related safety risks.
Design for maintainability	Design	Implementation of HF principles during the aircraft design phase, to reduce the possibility of human error in maintenance tasks.

Out of 166 solutions included in the database 73 were classified in the first four categories while the others were excluded. Within the first 4 categories, 9 solutions were classified as most promising, 6 as promising, 10 as promising to be further investigated and 48 as “nice to have”.

6. Workarounds

During on-board ship operations it is well accepted that crew members may deviate from the standard operating procedures due to practical and other reasons. This is called a ‘workaround’ and is directly related to individual resilience which potentially affects the overall reliability of ship operations. The main aim is to create a bespoke “SEAHORSE Smart procedure Methodology” for capturing and assessing the practice of performing workarounds as well as the potential positive and negative outcomes of the workarounds and finally managing the workarounds to improve ship safety through a structured workaround management procedure.

In order to identify and capture the workarounds, the first task was initially to gather the standard procedures and perform a mapping study to assign the captured standard procedures to different job ranks. The subsequent task was to develop a structured questionnaire to capture the workarounds as well as the standard operating procedures. The questionnaire was distributed worldwide including shipping companies, seafarers associations, and crew agencies as well as through web based systems) to identify and capture the workarounds. This questionnaire is believed to be the first questionnaire related to capture the workarounds in Maritime.

The first section of the questionnaire aimed to collect demographic information about the participants while ensuring the anonymity of participants. The second section focused on capturing the attitudes of a seafarer where participants were asked to agree or disagree with the given statements by using a Likert Scale. (i.e never, rarely, some-times, often, always). In this section attitude statements were carefully selected and categorised in following sections; *procedure design, training and competence, safety culture, employee – employer trust, matching procedures to operational reality*. In total this section has 48 questions. The third section asked, in an open-ended format, questions related to workarounds as follows; description of workaround, related standard operating procedure (SOP), frequency, type of operation, underlying reason for the workaround.

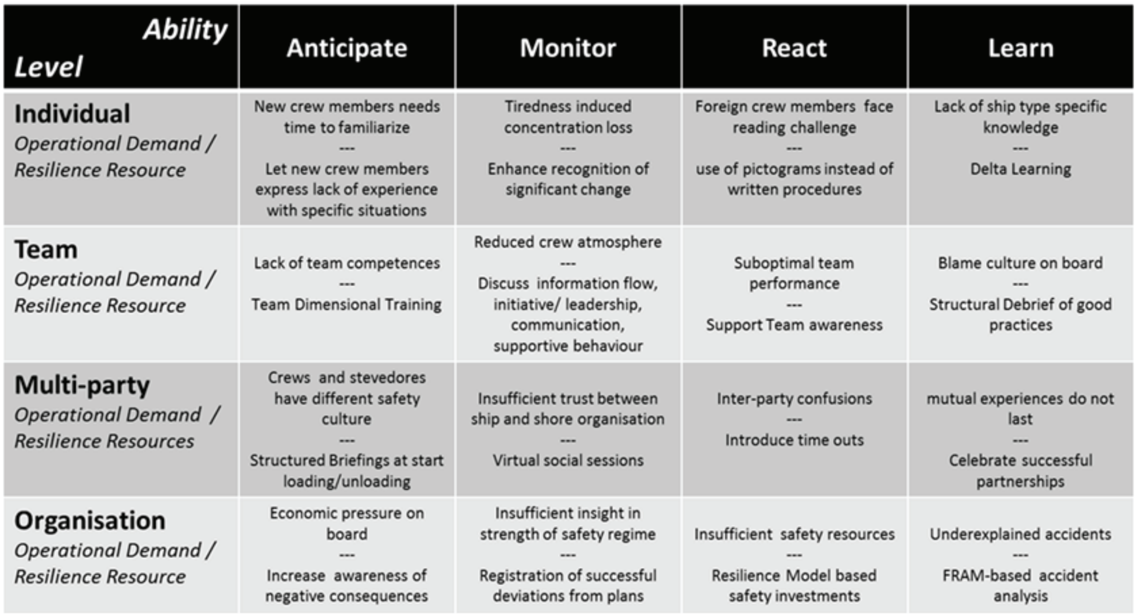
6.1. Initial results

The consortium managed to capture 451 questionnaires in a very sensitive and controversial area and 259 workarounds and all these data are captured in a database. More than 65% of participants who joined our survey reported workarounds and 65% of the workarounds reported stated that most or all crew members do the same workaround. More than 50% of workarounds were reported in deck operations while most workarounds reported are applicable to whole ship followed by Engine room and Navigation/communication control space workarounds. The workaround were categorized under 108 group of workaround. Initial scan of the survey indicated that the most common workarounds are located in the areas of *reporting paperwork, personal protective equipment, Work-Rest hours, navigational rules and standards, and Hot-Work and permit to work.*

7. Multilevel Resilience Framework

Resilience is the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations even after a major mishap. In Resilience Engineering, failures do not stand for a breakdown or malfunctioning of normal system functions, but rather represent the converse of the adaptations necessary to cope with the real world complexity. Individuals and organizations must always adjust their performance to the current conditions; and because resources and time are finite it is inevitable that such adjustments are approximate. Success has been ascribed to the ability of individuals, groups, and organizations to anticipate the changing shape of risk before damage occurs; failure is simply the temporary or permanent absence of that.

In order for the operational procedures on board to be able to deal successfully with safety critical operations and harsh environments; system resilience is required. Resilience is subdivided into four abilities which are considered as the functional cornerstones (Hollnagel, 2011). These are **Anticipate:** events beyond current operation, applying a broader perspective; **Monitor:** know what to focus on, be able to perceive significant change in performance and environment, using valid lead indicators; **React**: detect, recognize and assess events in time, know when and how to react, having resources available and ready; **Learn**: promote, facilitate and enhance learning from both good and bad experiences. Once the system is developed multi-level resilience principles will improve the safety in maritime domain through management of errors for any operational demands. This part of the work is still under development.



Ability *Level*	Anticipate	Monitor	React	Learn
Individual *Operational Demand / Resilience Resource*	New crew members needs time to familiarize --- Let new crew members express lack of experience with specific situations	Tiredness induced concentration loss --- Enhance recognition of significant change	Foreign crew members face reading challenge --- use of pictograms instead of written procedures	Lack of ship type specific knowledge --- Delta Learning
Team *Operational Demand / Resilience Resource*	Lack of team competences --- Team Dimensional Training	Reduced crew atmosphere --- Discuss information flow, initiative/ leadership, communication, supportive behaviour	Suboptimal team performance --- Support Team awareness	Blame culture on board --- Structural Debrief of good practices
Multi-party *Operational Demand / Resilience Resources*	Crews and stevedores have different safety culture --- Structured Briefings at start loading/unloading	Insufficient trust between ship and shore organisation --- Virtual social sessions	Inter-party confusions --- Introduce time outs	mutual experiences do not last --- Celebrate successful partnerships
Organisation *Operational Demand / Resilience Resource*	Economic pressure on board --- Increase awareness of negative consequences	Insufficient insight in strength of safety regime --- Registration of successful deviations from plans	Insufficient safety resources --- Resilience Model based safety investments	Underexplained accidents --- FRAM-based accident analysis

Fig. 1. SEAHORSE Multi Level Resilience Matrix.

8. Conclusions

Seahorse project addresses the safety in maritime sector by transferring the best practices in airline sector to maritime sector by using the multi-level resilience principles. This paper presents the initial results of Seahorse project and highlighted that there are gaps between both air and marine sector in around 44 areas. Furthermore, resilience solutions were generated in a database. First time, a workaround survey is performed and type of workarounds are captured in maritime were identified. Seahorse project demonstrates that best practices in one transport sector can be shared and adapted to different transport sectors to enhance the safety.

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