Safety Enhancement in Maritime Transportation: SEAHORSE Project

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Human factors have been the main cause and a major contributing factor of numerous maritime accidents, such as the Exxon Valdez, Herald of Free Enterprise and the Costa Concordia. Despite the fact that safety standards and technological developments in maritime industry have been increased, accidents are still occurring since the limitations of the human being is underestimated. The aviation industry which is in many aspects similar to the maritime sector has been approaching the same problem systematically and developing advanced methodologies and techniques. The EU FP7 funded SEAHORSE (Safety Enhancements in transport by Achieving Human Orientated Resilient Shipping Environment) project aims to transfer the effective and successful safety concepts utilised in the aviation industry, adapting and tailoring them to the unique needs of maritime transport. The project has the potential to create a significant impact, at not only a European level but also an International one, in making the ship operation a safe, resilient, attractive and efficient environment. In this study, an overview of the SEAHORSE project is presented. Recent progress and future directions of the project is given in conclusion.

Key words: Resilience, maritime, aviation, safety, SEAHORSE project

1. Introduction

Human factors is a complex subject which effects many different aspects of all different transport modes and involves the study of all aspects of the way humans relate to the environment around them, with the aim of improving operational performance, safety, through life costs and resilience.

Currently within the maritime industry, the modern seafarer 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 seen as one of the reasons causing accidents. It is well reported in the studies of transport related accidents that 80% of shipping accidents are attributed to Human Error [1], [2], [3]. The statistical research of Rothblum [4], O'Neil [5], Darbra and Casal [6], and Toffoli et al. [7] has identified human error as the primary factor in the majority of maritime accidents [8]. Maritime accidents are the result of error chains rather than single events [9].

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. Prevention of accidents has only recently gained the deserved attention, as the 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 maritime 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 maritime industry while utilising the experience of air transport.

The SEAHORSE [10, 11] project proposes to address human factors and safety in maritime transport by transferring the well proven practices and methodologies from air transport to maritime transport in an effective, collaborative and innovative manner. This will be primarily achieved by introducing the principles of resilience engineering and smart shortcuts 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 SEAHORSE Project consortium is shown below:

- Unıversıty Of Strathclyde, United Kingdom
- Nederlandse Organisatie Voor Toegepast Natuurwetenschappelıjk Onderzoek – TNO Nederlandse Organısa Netherlands
- Deep Blue Srl, Italy
- Lloyd's Register EMEA, United Kingdom
- Sakatunta Maritime Faculty, Finland
- Calmac Ferries Ltd, United Kingdom
- Danaos Shıppıng Company, Cyprus
- Kahn Scheepvaart Bv Jumbo, Netherlands
- The Provost, Fellows, Foundation Scholars & The Other Members Of Board Of The College Of The Holy & Undivided Trinity Of Queen Elizabeth Near Dublin Tcd, Ireland
- Instituto De Investigacion En Seguridad Y Factores Humanos – Esm, Spain
- Ap&A Ltd, United Kingdom
- Kratis Training And Consulting Limited, Cyprus
- Istanbul Technical Unıversity Maritime Faculty, Turkey

The SEAHORSE project’s aim will be realised through the implementation of the following objectives:

I. Identification of the key human/organisational factors, which lead to operational successes and failures in maritime transport and air transport and perform gap analysis in marine practices in comparison to air industry
II. Investigation of 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 maritime to improve human/organisational errors and safety
III. Development of the Technology Transfer Framework from air to maritime for successful implementation
IV. Introducing a smart SHORTCUT methodology in marine operations to identify and assess non-standard procedures carried out on board ships to quantify the positive/negative effects in order to enhance overall resilience.
V. Development and validation a multi-level resilience model and virtual platform as well as guidelines for maritime transport which encompasses individual, team, multi-party and organisational resilience that linked and integrated. The SEAHORSE Platform addresses:

    - The crew needs and limitations that may affect their resilience with regards to navigation/operation of the ships
    - System design, equipment and procedures which promote/add/remove, by design or accident, resilient and/or shortcutting behaviour
    - Shared situational awareness, leadership, organisational drift, insufficient/non-existing safety culture, team work
    - Suitable training materials to implement the multilevel resilience

VI. Implementation and evaluation the benefits of the SEAHORSE multi-level resilience tools through the comparison with traditional maritime safety methods and operations in training, simulator and actual ship environment.
VII. Educating stakeholders within the maritime transport industry of the benefits of resilience engineering and the SEAHORSE concepts.

The work packages to fulfil the *SEAHORSE* project's innovative concept is shown in figure 1.

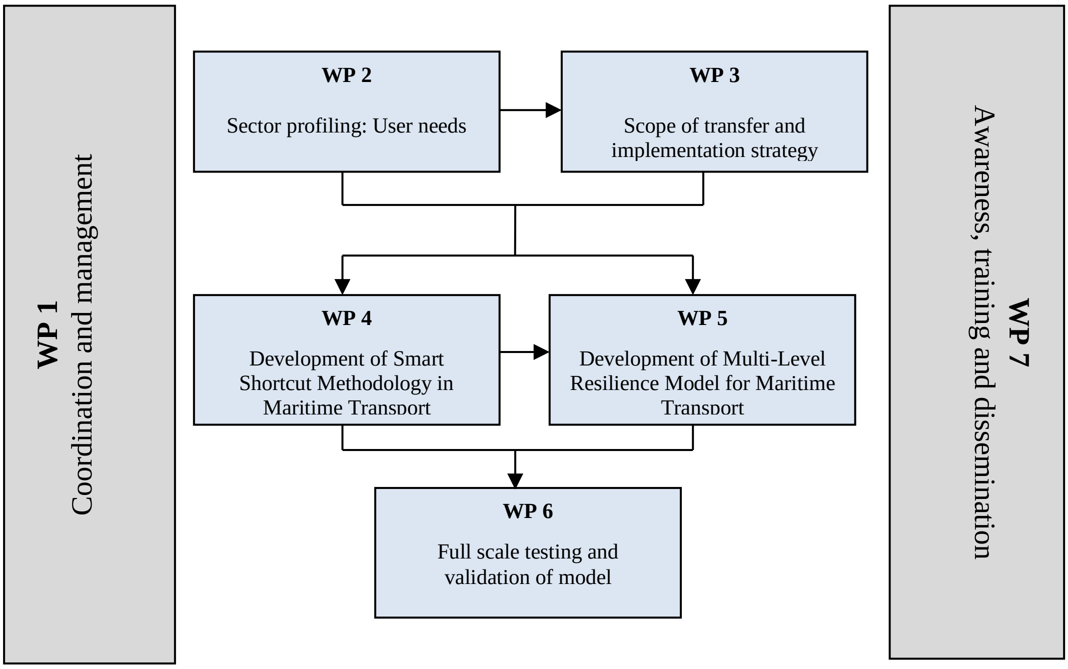

Figure 1. Work packages of SEAHORSE project

2. SEAHORSE Approach

The rapid development of new technology has changed the nature of work and has increased the complexity of systems within a variety of industries [12]. Aviation operations that require a tight coupling between both technical and human subsystems is one one of them [13]. Within the aeronautical industry having safe and reliable operations is critical in preventing accidents and mistakes that can potentially cause a huge loss of life and destruction. The influence of human factors on operational safety is one area were the aeronautical industry has led the way in terms of understanding and implementing tools, methodologies and systems to combat human error within a system.

One such principle which has been highlighted as being particularly successful is the integration and adoption of resilient engineering principles. As the number of accidents and incidents have been decreased through the utilisation of resilience engineering concepts, it seems that resilience engineering within the aeronautical industry has been very useful on board.

In addition, the psychological and social-economic elements, identified in the University of Strathclyde's survey of seafarers, relating to the societal status and perception of the crew and its effect on motivation and performance will also be addressed. Through utilising the air industry's approach of crew empowerment and promotion within society, this will be an important area of transfer between aeronautics and marine. This may also develop a pathway of the mitigation of low retention and employment rates within the maritime sector.

Within the SEAHORSE project the aim is to transfer the effective and successful safety concepts utilised in the aeronautical industry, adapting and tailoring them to the unique needs of maritime transport.

In order to achieve the successful transfer and adaptation of the techniques and tools being utilised in the aeronautical industry, the SEAHORSE project will adopt the following approach;

- Analyse and study the effect of different business environments between aeronautics and maritime sector including the way that psychosocial and social-economic issues of crew are addressed. Determine the effects of contracts, pay levels, working and living conditions as well as the image of the seafarers/aircrew in the eyes of society, on the performance and motivation of seafarers and aircrew.
- Identify the best practices in aeronautical industry for managing errors and non-standard practices
- Assess the regulatory framework in air transport and carry out gap analysis in maritime transport to identify any potential gaps that may be affecting the successful implementation of safety management
- Evaluate implementation of resilience engineering principles within the aeronautical industry for different levels in terms of
    - Experience gained
    - Identifying the successful outcomes of resilience and the reasons of the success
    - Identifying the areas where resilience principles did not provide any measurable benefits and the possible reasons
    - Identifying the possible implementation gaps in multilevel resilience principles in air transport
- Adapt the identified resilience engineering principles of the aeronautical industry to the unique needs of maritime transport
- Develop a ‘Multi-level Resilient Maritime transport Framework’ to facilitate the integration and management of resilient human and organisational factors along with the required implementation steps and training needs.

3. Innovative multi Level Resilience System Developed for Marine Operations

An innovative topic integrated in to the objectives of the SEAHORSE project is the relatively new research field of resilience engineering. 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 (or in the presence of continuous stress).

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. Therefore the SEAHORSE project’s approach will be to implement resilience engineering principles in an integrated and innovative manner, taking into account the knowledge generated and experience gained by the aeronautical industry. By utilizing the SEAHORSE project's innovative approach, the user will be provided with new resilience resources to prevent a decrease in system performance, allowing the system to return to baseline performance much more quickly and display greater resilient behavior.

Resilience is subdivided into four *abilities* which are considered as the functional cornerstones.

- *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

The SEAHORSE project will introduce and develop a multi-level interlinked resilience structure, representative of the functions and systems onboard the ship, which will provide detailed relationships and interactions of the following 4 resilience levels:

1. Individual resilience (e.g., resources for the ability to react, such as shortcutting; and the use of pictograms instead of written procedures, particularly for crews that face reading challenges)
2. Team resilience (e.g. resources for the ability to anticipate such as safety buddies; or the ability to learn, such as debriefing. This seems promising, since that can be done at a point in time without time pressure.
3. Multi-party resilience (e.g., resources that describe how to work with subcontractors, stevedores, guests; Briefing before an operation can be regarded as an example ability to monitor. However, briefing is always conflicting with available time, which is an issue at the organisational level). Also resources that improve the gap between the ship and the shore organization; currently, an often heard saying is "what happens on board stays on board". Resources as trust etc., might be important here)
4. Organisational resilience (e.g., resources as an ability to anticipate, such as safety culture, a management that provides budget for safety campaigns etc.)

To deal successfully with operational demands (e.g., changes, disturbances, stressful situations), the project will develop new or improve existing resilience resources that can be optimally applied to one or more abilities at one or more resilience levels.

Resilience concept of the project and Multi Level Resilience matrix are demonstrated in Figure 2 and Figure 3, respectively.

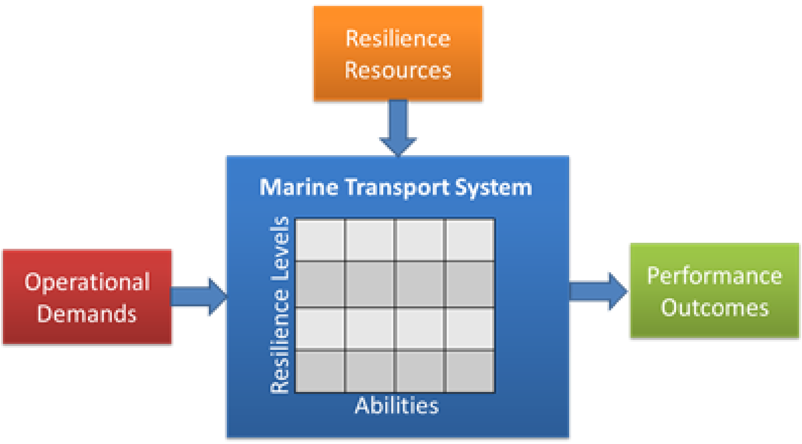

Figure 2. Resilience concept of SEAHORSE project

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

Figure 1. SEAHORSE Multi Level Resilience Matrix.

By adopting this new and innovative SEAHORSE multi-level resilience model, it will be ensured that the transfer of the resilience engineering principles utilised in the aeronautical industry will be achieved successfully to the unique needs of maritime transport. Through utilising the aforementioned multi-level structure, it will ensure that an intervention to improve resilience at one level does not create a negative impact on another level(s).

The main SEAHORSE outputs will be in six different forms:

- Multi-Level resilience model and procedures for maritime sector
- Assessment tool (software) for shipping companies on the basis of multilevel resilience framework.
- Crew Quality Audit tool
- Multi-Level Resilience design tool (software):
- Training material to provide the training to crew and management
- Guidelines for whole shipping industry to address the human/organisational

4. Smart Shortcuts Concept

Accidents attributed to human error have been closely analysed by governmental organisations as well as many researchers [14,15,16,17,18,19,20]. Common well known human factor problems are well identified however the findings of the studies conducted by different researchers or studies based on different accident databases tend to contradict each other.

In current accident databases information is being recorded for what people deem to be the most obvious accident factors. However it can be argued that the underlying factors which are really causing the accident are being unintentionally ignored which can led to the confusing situation described above. A good example of this comes from research of the MAIB's accident database where in the last 19 years of information, noise is only mentioned as an accident factor only twice. Compare this to the latest research in the field of noise and the impacts it has on the human, the comparison between reality and the database is contradicting. Therefore the approach of the SEAHORSE project does not rely solely on the accident statistics and subsequently, in order to capture the real design mistakes and occurrences of human error, a unique and innovative human error and measurement methodology will be developed.

SEAHORSE project aims to investigate human performance problems and human error through innovative 'SHORTCUT' methodology as part of developing individual resilience with the multi-level resilience system that SEAHORSE is proposing.

The definition of the term "shortcut" can be found as "a more direct route or action than the prescribed procedure" as well as "a means of saving time or effort". Shortcuts in the context of SEAHORSE Project are "the deliberate changes that the crew have applied to standard procedures and to the equipment on ships, due to practical and other needs". Shortcuts are the direct indicator of design problems on ships and can be considered as a usability fix applied by the end user after design. SEAHORSE projects main aim is to take this valuable information into consideration during the design stage.

Figure 4 shows a methodology to identify and assess current shortcuts and proposes a methodology that influences the design of ships and operations accordingly.

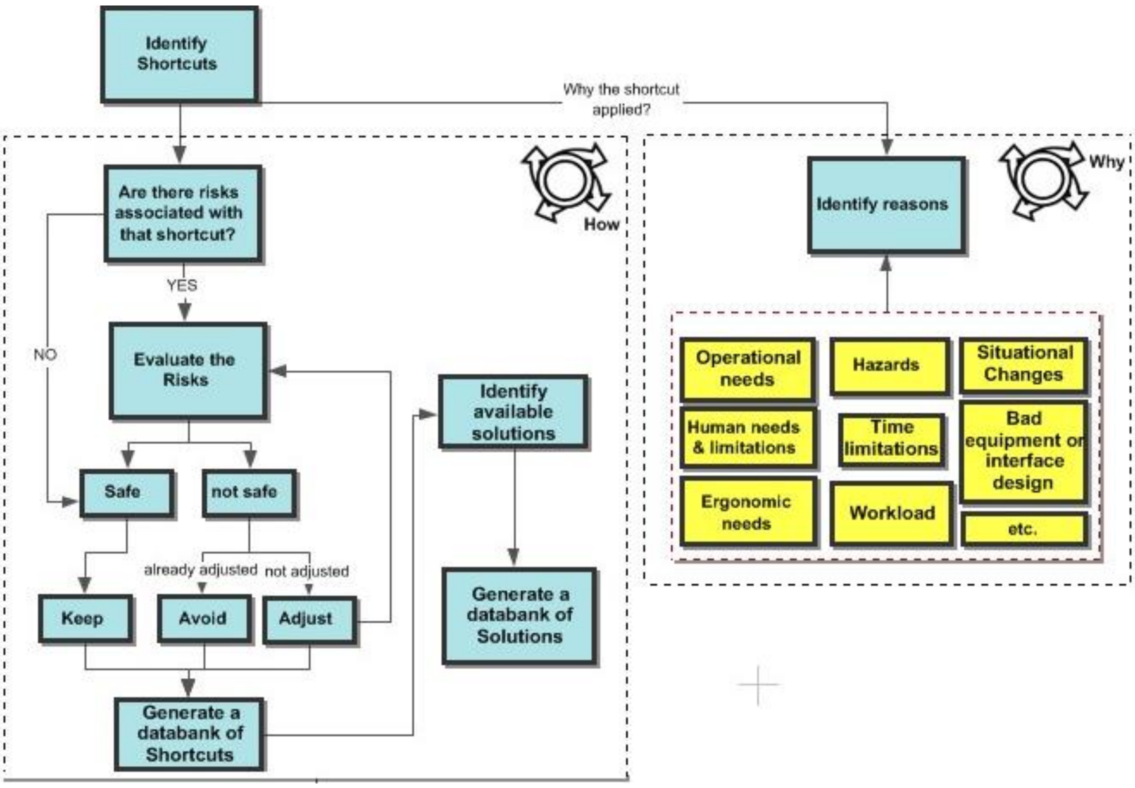

Figure 2. Methodology for identification and assessment of current shortcuts.

5. Development Innovative Resilience Tool

SEAHORSE, by taking into account the experience and successes achieved in air transport and utilising the multilevel resilience approach adapted and enhanced for Maritime transport, will be developing a Maritime Resilience Tool, which will provide the platform for companies to support them in their safe ship operation.

The SEAHORSE Virtual Platform will be the integration of all the created tools, databases and guidelines that will assist and support the end users in developing, assessing and maintaining a resilience structure that is tailored to their particular needs and operational requirements.

The SEAHORSE Virtual Platform is defined as:

1- Database Section: The database section will be designed to accommodate the following databases:
   - Crew database: It stores profiles of the individual crew including education skills, experience, certificates and involvement in accidents etc.
   - Ship Database: It provides the operational profiles of the vessels including technical details, routes, type of cargo they carry, number of crew they have in each department, onboard procedures, involvement of in any accident
   - Company Database: This will involve size of the company, ships that they operate, existing procedures,
   - Non-standard acts database: This database will be recording all the incidents, mishaps, non-standard actions including shortcuts
   - Rules and standards database:

2- Tools Sections: Tools will be developed to assist the company towards developing and maintaining the customised resilient structure for safe operation these tools are:

   - Individual and team Crew Quality Audit Tool (Software): The tool, by utilising the databases, audits the crew quality at individual as well as at team levels and identify the strengths and weaknesses of the crew and identify the training needs or suitability for type of ships for operation.
   - Shortcut assessment and smart short cut development tool (Software): This tool will utilise the shortcuts database and assess them according to the procedure described in Figure 4: The Smart shortcuts will be further assessed and developed and best practice procedure as part of multi-level resilience structure
   - Assessment tool (Software) of shipping companies on the basis of multiparty resilience framework: The tool will allow the safety managers to assess the company in terms of resilience compliance and identify the gaps/weaknesses/non-compliance that may lead to errors and accidents
   - Multi-level Resilience design tool (Software): This tool will assist the shipping companies to design/develop procedure to build the multiparty resilience structure, develop procedures to eliminate the gaps /weaknesses

3-Output Section: This part of the platform generates the customised reports using the results of each of the tools and there will be two types of outputs:

- Output reports for each assessment
- Customised multi-level resilience structure and relevant procedures for the specific company

Within the scope of the SEAHORSE project, the Virtual SEAHORSE platform will be initially developed in an offline personal computer based format. However after project completion, i.e. the platform has been successfully validated and tested, it is envisaged that a future research programme will be the transference of the Virtual SEAHORSE platform to a secure and interactive online format.

An outline of the Virtual SEAHORSE platform and the resilience tools can be seen in Figure 5.

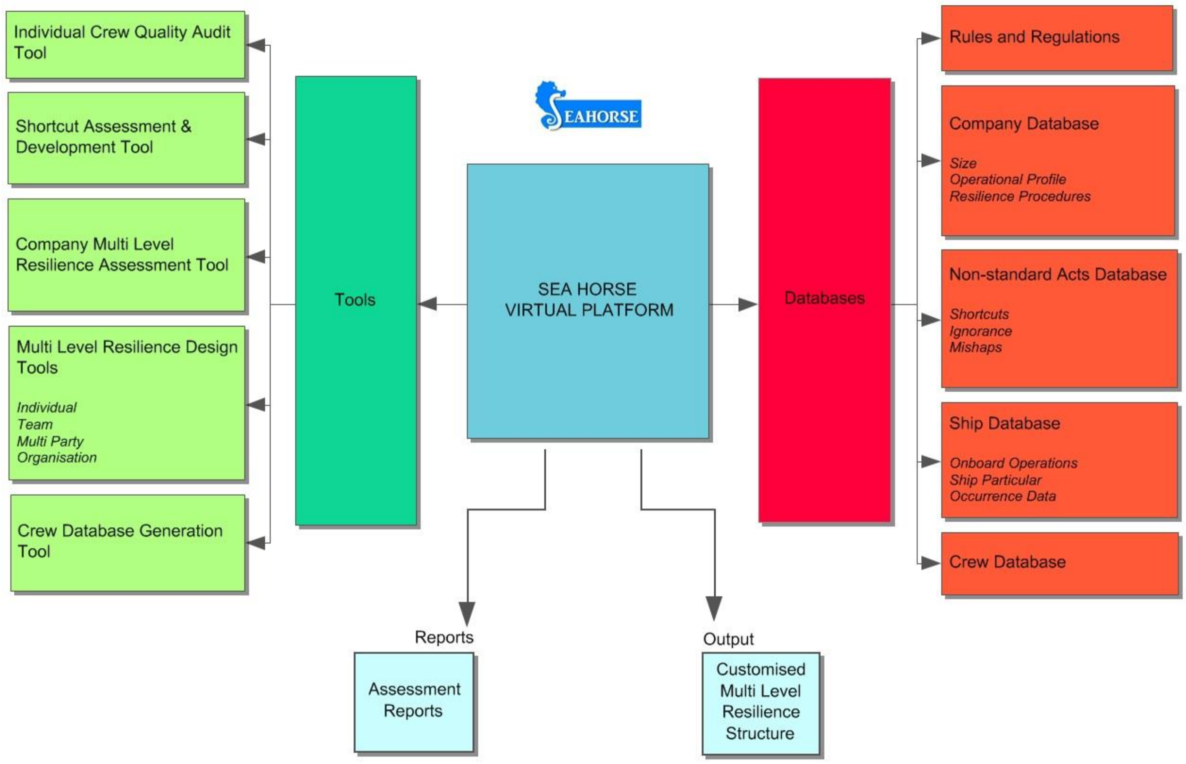

Figure 3. SEAHORSE Virtual Platform for Multi level Resilience in Maritime Industry

6. Innovative Data Collection, Observation and Validation Approach

In order to support the development, validation and refining of the multilevel resilience system for maritime transport, SEAHORSE will be utilising 8-12 ships of different type (tankers, bulk carriers, containerships and passenger vessels) and operational environments/routes to collect data from shortcuts and operational practices. The developed multi-level resilience system will be implemented and utilised on-board test ships in order to benchmark against ships not using the system and assess the envisaged benefits. This will be achieved by:

- Field observations and data collection on 8-12 ships to record good and bad practices in different operational conditions (normal and safety critical conditions).
- Implement 4 level resilient systems on ship operations: This will be done using the same ships that data is collected for and categorised into similar ship sizes, operational area and profile.
- One of the ships will be operated after implementation process of multi-level resilient system principles and compared with other vessels that will continue using the standard operational principles.

- Benefits of the resilient system will be evaluated and any potential adjustments to the proposed approach will be identified and implemented.
- Final results and findings will be disseminated to partners and industry.

7. Conclusion

Safety is still very crucial issue in maritime industry. Similar industries such as aviation industry are also safety sensitive industry.

SEAHORSE (Safety Enhancements in transport by Achieving Human Orientated Resilient Shipping Environment) project is a EU FP-7, Technology transfer in the area of Transport Project which is aiming a leap forward towards shipping safety achieved through technology transfer from air transport to maritime transport focusing on human factors problems in an innovative, integrated and multidisciplinary manner towards safer and more resilient shipping operations.

In this study, an overview of the SEAHORSE project and present safety gaps are discussed.

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