Optimizing the transportation of heavy parts inside the Engine Room in the context of Crew Centred Design

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Some design requirements in the maritime industry and in other industries exist to cover operational and maintenance aspects but somehow fail to be applied in a human centered approach. Such bad designs create environments where operation and maintenance is performed with a higher risk than necessary (e.g. crowded working environment, valves too close to each other to be operated easily, valve/control difficult to reach, etc.). The aim of this paper is to implement Crew Centered Design (CCD) principles and by taking into account existing design requirements with respect to anthropometrical limitations to optimize the transfer of heavy equipment in a vessel's Engine Room (ER) by reducing the possibility of the human injuries and errors. In this context, the elaborated analysis is focused on two logistical aspects of the engine department: (1) movement of equipment and personnel within the machinery space to/from specified nodal locations and (2) movement of equipment to/from the ship's main deck and the entrance(s) of the engine department. The optimal routes are illustrated in multiple drawings of different ERs based on the link analysis. Link analysis is a task description method that demonstrates a generalized summary of activities performed by crew members. This approach enables engine crew tasks located throughout a ships structure to be represented in General Arrangement (GA) drawings, revealing node connections, relationships and routes between key locations and functions within a physical space.

Keywords: Crew Centred Design, link analysis, transportation of heavy parts, Engine Room, optimization

1. Introduction First-level heading

In many industries it is now generally agreed (Markus, 2004) that Human Centred Design (HCD) can lead to decreased development costs, improved user productivity, reduced training costs, reduced customer service costs and Improved safety. A lot of human factors and ergonomics recommendations exist and ought to be applied in ship design process. However, there is often a distance between the designer, the regulator and the operator' perspectives. By introducing Human Factor (HF) at the ship design phase, the designer has the ability, across the whole design process, to identify mainly the needs of the crew members, to integrate their needs and to evaluate his work towards this objective. Figure 1 illustrates (Mery & McGregor, 2010) a suggestion for Human Centred Design method for ship designs from Bureau Veritas. It all starts with some data collection and user feedback investigation. Once this information is collected and analysed, it can feed a first reflection on the different sources of hazard on board ships, but also help analyse the human-machine interactions and define a first set of prescribed tasks. This first set of prescribed tasks and the analysis of the real activities on board will help reiterate on hazard identification and human machine interaction analysis. These two steps will influence the design and the arrangement of the machinery spaces. In return design modifications may interact back with other hazards identified or human-machine interactions or other prescribed task / real activities. In that case (if necessary) a control loop is to be planned and is represented with the dotted arrows. Ultimately, these iterations between design and human centred approach will feed typical ship design spiral and ultimately lead to more human centred ship designs.

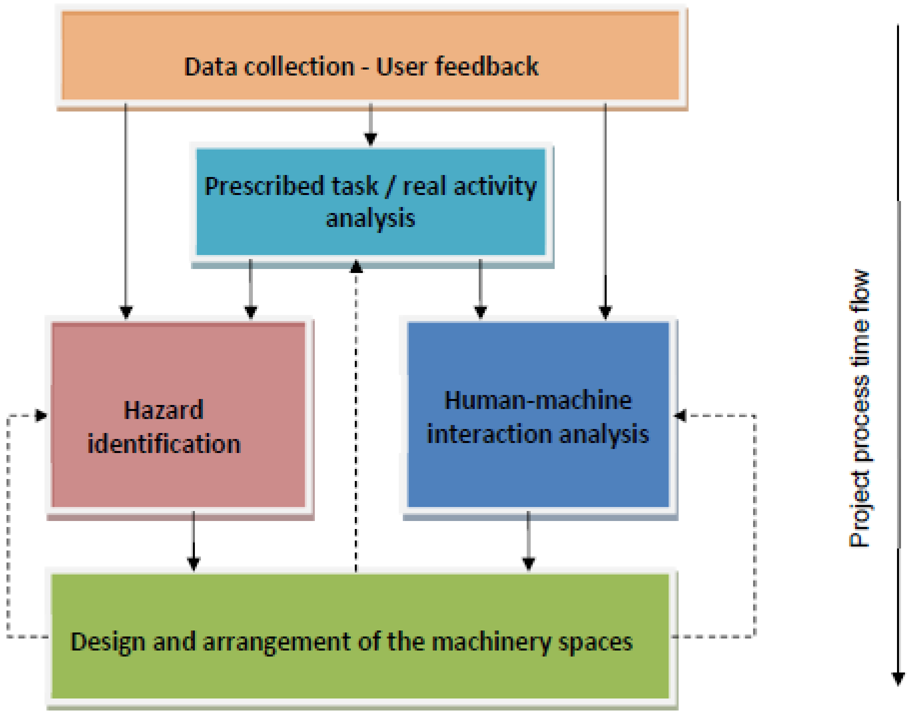

Figure 1. Suggested methodology for deriving standard design requirements based on human factors and ergonomics (possibly iterative: dotted lines).

The following procedure is emerged from the suggested methodology for deriving standard design requirements based on human factors and ergonomics (Figure 1). The initial step is the collection of statistical casualty data. Once this information is collected and analysed, it can shed light on the different sources of hazard on board ships and define a first set of prescribed tasks. This approach is applied to a vessel's Engine Room by analyzing the transportation of different heavy equipment. At first, the layout of a modern Engine Room is presented, with focus on the task of multiply equipment replacement procedure. By breaking down the objective, the identification of threats becomes easier. The next step is to assess the possibility of occurrence for each of the above threats, as well as its severity. The risk posed by each threat can be evaluated by comparison of possibility and severity. The final step is to identify ways to reduce those risks and prioritize the methods according to easiness of implementation. The purpose is to produce viable solutions that can be easily integrated during the design phase and ultimately to lead to more human centered ship designs.

2. Presentation of statistical data with respect to occupational safety onboard ships

The motivation for the identification of workplace and individual factors that combine to affect human performance (i.e. injury and error) during the performance of operational and maintenance tasks was based on collecting statistical casualty data in a database search, as well as performing a literature review. This section presents data from several sources regarding the accidents that are happening onboard. Figure 2 shows the number of different types of accidents per year, ranging from 1985 to 2008 (Mullai & Paulsson, 2011).

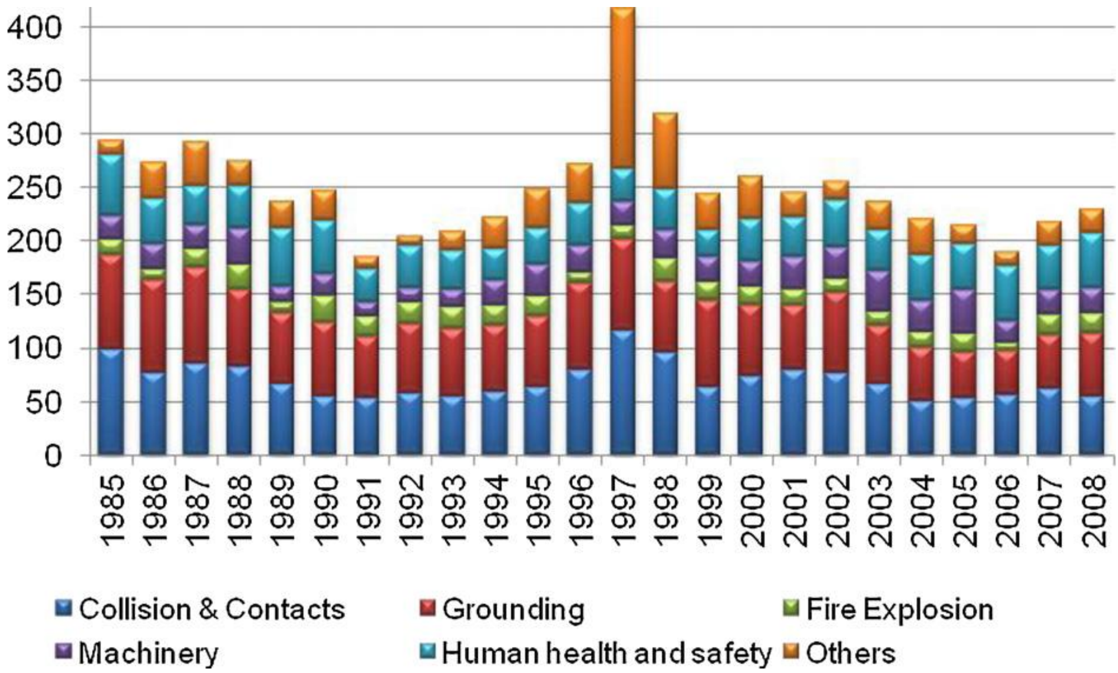

Figure 2. Different types of accidents per year.

Figure 3 depicts the number of injuries and deaths from 1998 to 2011 (MAIB, 2011). By the use of linear regression, the plot clearly indicates a declining tendency. Injuries tend to decline over the years –but with greater fluctuations- whereas death toll remains close to constant. Furthermore the percentage of accidents that lead to loss of life is much smaller than the one leading to injury (98.4% versus 1.6%). Figure 4 illustrates the categorization of the accidents per ship location for the time period 2013-2014 based on (HBMCI, 2013-2014). It is obvious that the space where there is significant risk of an accident is the engine room. The probability of an accident in the engine room is 24% along with category "other space", which are the biggest percentages of accident among the spaces of the ship. The category "other space" is referred to all the other accidents that cannot be sorted into a certain category. For that reason "other space" contains such a large percentage of accidents. Due to that fact, the engine room is one of the most hazardous spaces of the ship to work in.

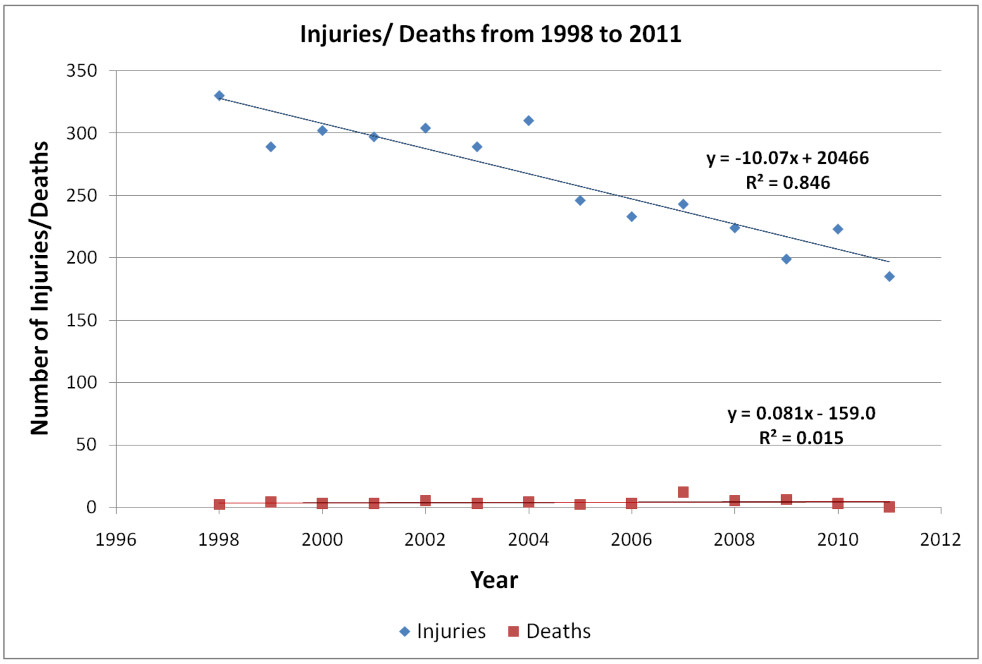

Figure 3. The number of injuries and deaths from 1998 to 2011.

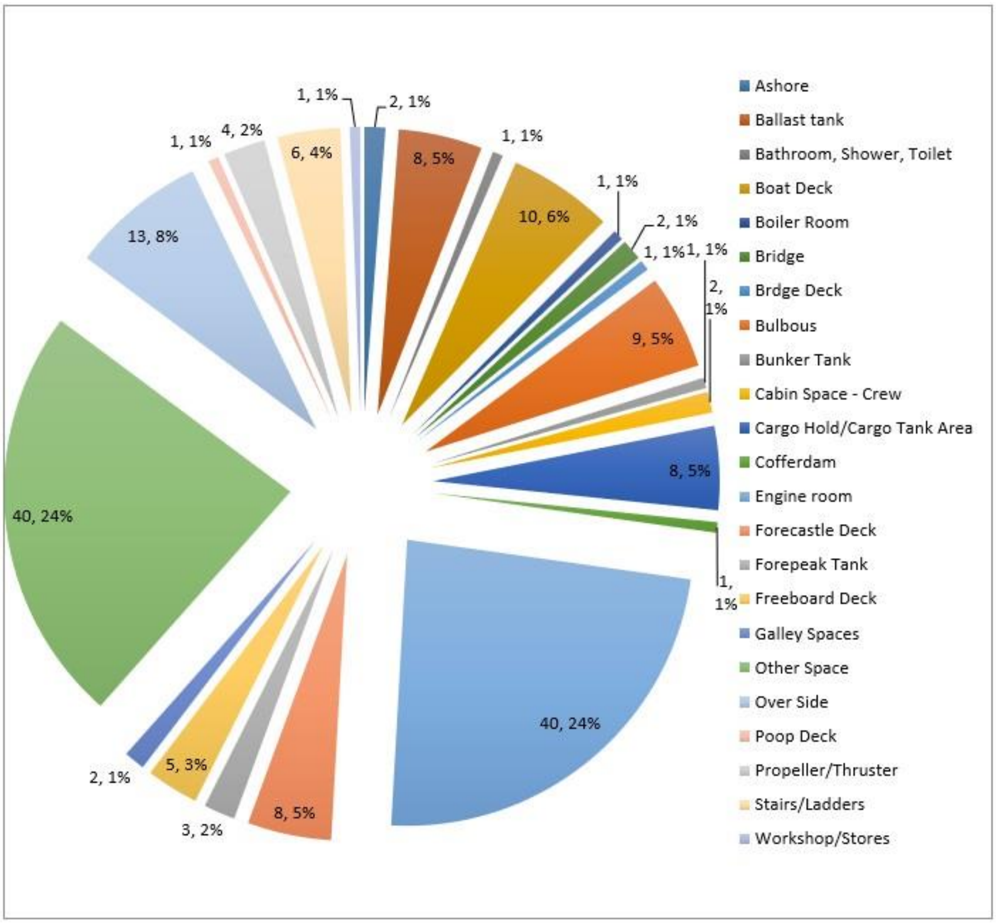

Figure 4. Percentage of accidents per ship location for the period 2013-2014.

3. Transportation of heavy equipment: Procedure Analysis

According to the Planned Maintenance System (PMS) for machinery spaces, a number of necessary activities should be carried out periodically to ensure proper function of the main engine and auxiliary systems. Since repairs are implemented in the workshop and new replacement parts should be transferred from outside, lifting equipment is necessary. Cranes should be able to carry the equipment to various places inside the engine room, as well as to the upper deck.

This investigation focused on two logistical aspects of the engine department: (1) movement of equipment and personnel within the machinery space to/from specified nodal locations and (2) movement of equipment to/from the ship's main deck and the entrance(s) of the engine department. The illustration of these routes in multiple drawings of different ERs based on the link analysis. Link analysis is a task description method that produces a more generalized summary of activities performed by end-users, focusing on operator actions rather than work-defined tasks (Getka, 2011) and (Mallam, 2014). Link analysis allows engine crew tasks located throughout a ships structure to be represented in GA drawings, revealing node connections, relationships and routes between key locations and functions within a physical space (Mallam & Lundh, 2014). . Full sets of two dimensional GA drawings of the entire structure, including top and cross-sectional perspectives of each deck level were used in the analysis. To illustrate the GA link analysis assessment method, the following engineering equipments were chosen to explore in detail:

- The piston of the Main Engine (ME);

- A flange to the service jacket pump;
- The oily water separator;
- The motor of the air compressor;
- The evaporator;

Most of the selected equipments correspond to actual occupational incidents and accidents.

3.1 Piston Replacement

Two distinct procedures involving a piston are selected as a case study.

- Piston repair: The piston has to be transferred into the workshop, where maintenance work can be properly conducted. After completion, the part returns to its original position, being placed back at the cylinder.
- Piston replacement: The process requires the piston to be removed and be transferred out of the ship. According to the General Arrangement, a hatch opening inside the workshop leading to the upper deck can be used for this purpose.

In this case, a 34,000 DWT handymax Bulk Carrier - General Arrangement plans provide basic crane path information. According to the plans, an overhead crane is placed close to 2nd deck ceiling, right above the main engine area. Since there are openings through 2nd and 3rd deck, the crane can lower to reach even the lowest place onboard, the 4th deck. Its lifting capacity can range from 0.5 tons to 15 tons. Below follows the link analysis of the two aforementioned maintenance working schemes (Figures 5 and 6).

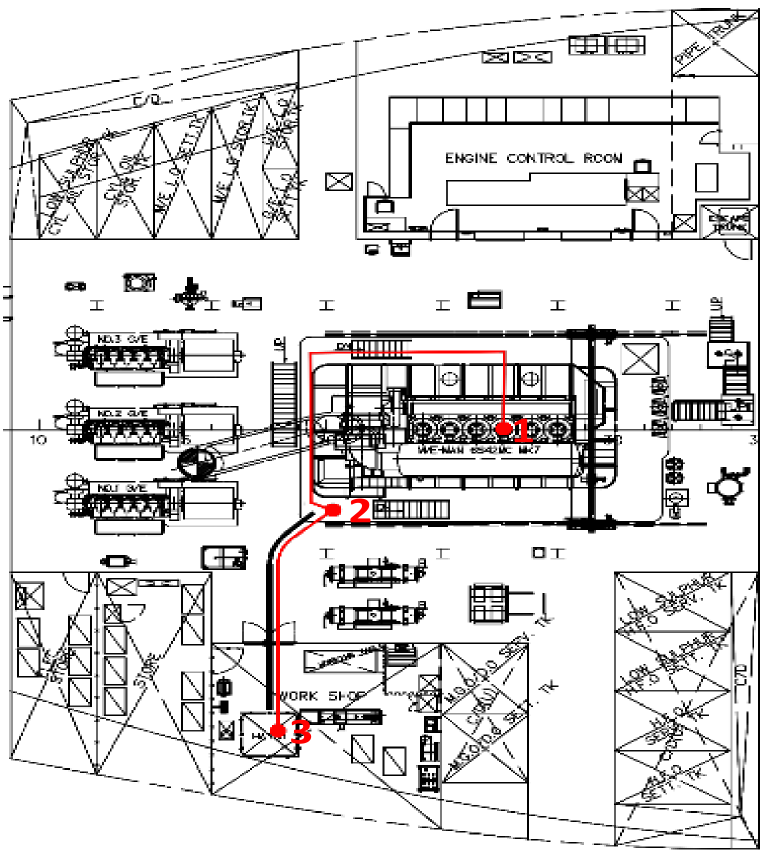

Figure 5. GA of the aft machinery space upper deck nodal linkages.

In order to transfer the piston (1) (weight: 930 kg, length: 2.855 m, diameter: 0.5 m) from the main engine (MAN B&W 6S50-C, type: low speed, power: 9,480 kW), the route passes via a hoist (2) inside the workshop (3). An onshore crane then lowers (4) inside the open hatch and lifts away the object (5). Either the onboard crane or an onshore installation can remove the part from the open hatch. During the process the piston must be carefully lifted in order to eliminate sway movements that can cause the item to collide with nearby objects (e.g. the hatch opening).

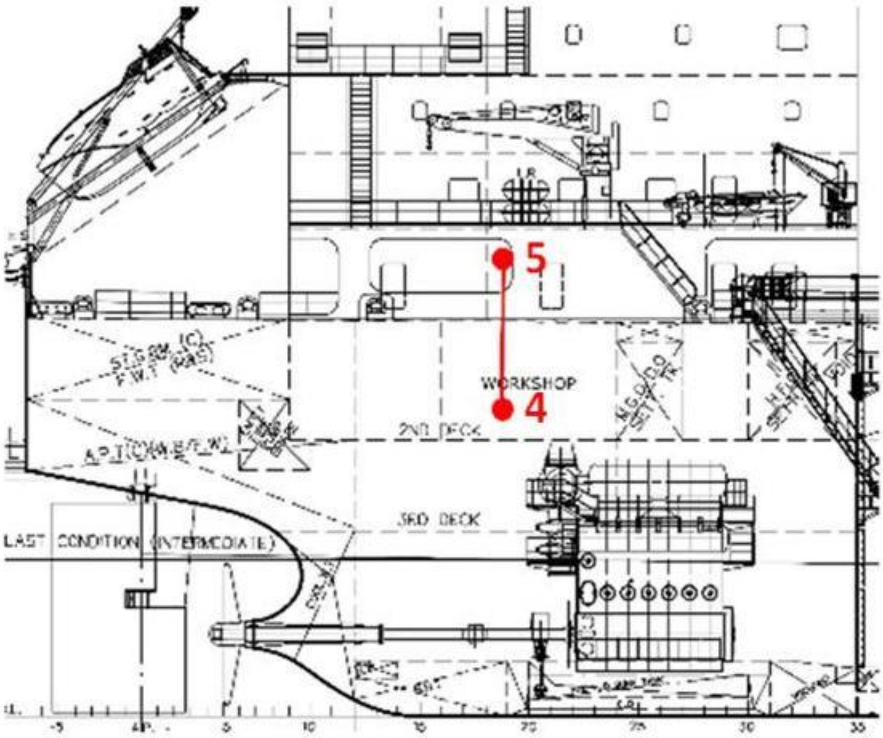

Figure 6. GA of the aft machinery space nodal linkages – Port elevation view.

4. Risk assessment

The risk management is divided into two pillars. On the one hand there is the reactive approach where in this case when an accident occurs a root cause analysis is performed for the identification of the triggering factor and then different measures are applied in order to avoid in the future similar of identical types of accidents. On the other hand there is the proactive approach whereas measures are applied in advance focusing on the reduction of the accidents by simultaneously enhancing the safety and the productivity of the seafarers during operational and maintenance procedures. Analytically, the IMO (1998) has introduced a 7 × 4 risk matrix, reflecting the greater potential variation for frequencies than that for consequences. To facilitate the ranking and validation of ranking, consequence and frequency indices are defined on a logarithmic scale. The so-called “risk index” is established by adding the frequency and consequence indices. Based on this index risk matrixes regarding the transfer of heavy equipment inside the ER are developed. The whole process was supervised by three experts. The elaborated equipments are the following:

- A flange for the service jacket pump;
- The piston of the Main Engine (ME)
- The oily water separator;
- The motor of the air compressor.

The table 1 presents a segment of the final risk index matrix for the transportation of the piston of the ME from the ER to the deck.

Table 1. Risk index matrix for the transportation of the piston of the ME from the ER to the deck.

No	Tasks/Incidents	Existing control measures	Severity Index (SI)	Frequency Index(FI)	Risk Index (RI=SI+FI)	Risk control options	Severity Index (SI)	Frequency Index(FI)	Risk Index (RI=SI+FI)
1	Electric shock and serious injury due to incorrect maintenance of the jacket pump.	1) Personal protective equipment (PPE) as defined by the ISM code of the shipping company. 2) Maintenance work on electrical equipment is made only by the qualified personnel (e.g. electrician).	2	3	5	1)Placement of the switch machine to the OFF position from the local switchboard 2) Placement of special warning signs 'Man At Work- Do Not Start' not only at the local board but also at the board of the Engine Control Room. 3) Usage of dry fabric and avoidance of wet spots 4) Usage of shoes with rubber sole 5) Usage of insulated tools	1	1	2
2	Fall due to lack of maintenance of the ER spaces	1) Personal protective equipment (PPE) as defined by the ISM code of the shipping company.	2	3	5	1) Railings, safe passage corridors and attachment points should be distinguishably colored (e.g. yellow colour). 2) In the safe passage corridors and stairways, the paint should contain a sufficient amount of sand in order to improve the traction.	1	1	2
3	Fall due to lack of cleanliness	1) Personal protective equipment (PPE) as defined by the ISM code of the shipping company.	2	3	5	1) Workplaces and especially and stairwells should be clean from dirt and grease.	1	1	2
4	Transport of heavy equipment by mechanical means (falls and conflicts of heavy loads)	1) Personal protective equipment (PPE) as defined by the ISM code of the shipping company.	3	3	6	1) Use of lifting appliances which are marked in a stable manner with the values of the Safe Working Load (SWL). 2) Use of lifting gear with SWL more than the weight of the selected equipment to transfer. 3) Use of the fastening means with appropriate methods in each case. 4) Check the fastening means for visible signs of deterioration. 5) Use of lifting gear and fastening means which are approved and certified by the class and their certifications are still valid.	2	1	3

5. Conclusions

The constant effort of maritime organizations has led to a steady decrease in the number of accidents. Awareness and a strict regulatory system are the main forces behind maritime safety. However, the main cause of accidents is still the same: The day-to-day operations on board. These operations have been clearly recorded and carefully planned out by a series of regulations. Why then do these accidents occur over and over again? Not suitably qualified crew members, low maintenance, a rush in time are only some of the contributing factors that lead to injuries and casualties. This process aims at the reduction of the potential for human injury and error by applying CCD principles in the design phase, by taking into account existing design requirements – design boundaries / limits and by considering human anthropometrical, physiological and biomechanical limitations. The transportation of heavy equipment in the area of ER consists of only a small fraction with respect to the rest contributory factors. Nevertheless, the expected reduction of frequency of these incidents/accidents and the causes of the injuries completely justify the performed elaboration of the aforementioned task in the context of the HCD.

Acknowledgements

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