Maritime Falls

Provisions, accident statistics, and fall protection systems: a review and a way forward.

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Executive summary

This study addresses the issue of 'maritime falls' accidents, which include falls from height to a lower level, falls overboard, and being washed away by green seas. For the purpose of this study, fall protection is broken down to three ingredient modes (securing, restraint and arresting) and the existing relevant international and EU provisions on fall protection systems are presented, which allow for a variety of protection systems to be used in the marine industry.

Subsequently, an insight in terms of an abstract analysis is carried out by engaging a retrospective approach based on the *Safety-I* logic. Data from relevant accidents, which have already been reported at European level in EMCIP[1], is used. Following this analysis, a different approach is adopted based on the *Safety-II* theory, by analyzing context and practices on board for the relevant tasks.

Based on the results obtained from these analyses, the specifications and characteristics of normal appliances used in daily operations for fall protection is compare and evaluated qualitatively against criteria that derive from the fall protection modes, and an extra criterion ('position shifting'), which has been identified as a risk factor in practice.

The study concludes by suggesting optimal solutions on fall protection systems, and which may be included in the respective safety provisions at European and International level.

[1] European Marine Casualty Information Platform. EMCIP is a database and a data distribution system operated by EMSA, the European Commission and the EU/EEA Member States. EMCIP aims to deliver a range of potential benefits at national and European relevance. EMCIP is also connected to the Global Integrated Shipping Information System (GISIS), managed by the International Maritime Organization, thus supporting the dissemination of investigation data reported by the EU/EEA MS at a global level without any duplication of effort.

Abbreviations' table

The following list is an explanation of abbreviation which may be encountered in this document.

AIB: Accident Investigation Body

DMAIB: Danish Maritime Accident Investigation Board

EEA: European Economic Area

EMCIP: European Marine Casualty Information Platform

EMSA: European Maritime Safety Agency

EN: 'European Norm' – technical standards drafted and maintained by CEN (European Committee for Standardization), CENELEC (European Committee for Electrotechnical Standardization) and ETSI (European Telecommunications Standards Institute)

EU: European Union

FPS: Fall Protection System

GISIS Global Integrated Shipping Information System

HBMCI: Hellenic Bureau for Marine Casualty Investigations

Kg: Kilograms

ILO: International Labor Organization

IMO: International Maritime Organization

ISM: International Ship Management

m: meters (metric)

MS: Member State

MSC: Maritime Safety Committee of the IMO

MSIU: Malta Marine Safety Investigation Unit

No.: number

OSHA: Occupational Safety and Health Administration (United States of America)

PCF: Permanent Cooperation Framework (established by EU Regulation 651/2011)

PPE: Personal Protection Equipment

SMM: Safety Management System Manual

SRL: Self-Retracting Lifeline

1. Theories of safety investigation

Working on board sea-going vessels is a challenging occupation which, among others, is also attributed to the risks that the nature of tasks carried out on board come with. Safety accident investigation, as conducted in terms of the IMO[2]and EU[3] provisions, is looking to uncover the main causes behind marine accidents on one hand and, on the other, to contribute towards a safer, on board environment so that similar accidents will not happen in the future.

This notion comes in parallel with the modern aspect of safety analysis, as described by the theories on Safety-I and Safety-II[4]. A brief reference to the difference, which each approach comprises, defines in a simplistic manner that Safety-I is retrospective, meaning that it follows an occurrence in which things went wrong and by looking back at its history, one tries to uncover the contributing factors, which led to it. Under the Safety-I approach, the (linear) interactions and interfaces of human to human and / or human to technology sub-systems may fail and cause an accident. The retrospective accident investigation looks for the breakdown of single factors (root causes), such as human errors, technical malfunctions, or behavioral aspects, such as non-compliance and violations. The fundamental idea that underpins a Safety I investigation is that ship operations are inherently safe and reliable until something malfunctions, or a human intervenes and makes a mistake.

Safety-II focuses and analyzes daily operations, routines, habits and practices from a holistic perspective. 'Departures' from established procedures are no longer viewed as violations but necessary and indispensable because of the complexity, which seafarers have to negotiate and mitigate, in the form of conflicting goals. Safety-II considers performance variability as a characteristic of complex systems and a daily, normal matter for seafarers. It sees mishaps, rather than performance variability as the scarce event. This is a fundamental principle that underpins a Safety-II investigation. Accidents happen while seafarers try to adapt to these challenging circumstances. Therefore, given that these are daily events, understanding accidents necessitates mapping the normal workday and daily challenges, which compel seafarers to adapt.

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2 Namely, the Casualty Investigation Code (Res.MSC.255(84)), as included in regulation XI/6 of the SOLAS Convention and all its relevant provisions.

3 Namely, the EU Dir. 2009/18/EC and all its relevant provisions.

4 There are various readings on Safety-I and Safety-II. A brief one would be: Hollnagel E. (2013). A tale of two safeties. *Nuclear Safety and Simulation, 4*(1), 1-9.

2. Risk of “maritime falls”

Following this brief theoretical introduction on safety analysis and investigation, the focus of this document turns to the risks associated with falls, while working on board commercial vessels. We will call them ‘maritime falls’.

Depending on the ship type and the operations carried out on board, various risks of falls may arise. The description of ‘maritime falls’ includes falls from height to a lower level, falls overboard, and even being washed away by green seas, which is a common risk associated with a variety of tasks on board seagoing vessels[5]. This document will focus on the sub-category of maritime falls, which have to do with falling while working or moving at height, regardless of whether the person fell on board (to a lower level) or overboard.

Such risks have well emerged and have already been identified, while specific measures against maritime falls have been put in place. These measures include relevant precautions and processes established to minimize dangers, as well as the use of the respective Personal Protection Equipment (PPE).

Safety belts, safety nets, safety harnesses, lanyards, lifelines are words often mentioned when protection from falls are discussed. However, it is first fundamental to explain the risks associated with falling, which go beyond the maritime sector and apply in all professional domains, at sea or ashore.

3. Fall protection definition

Protection against falls and reduction of the severity of their consequences includes what may be considered as three modes: position securing, fall restraint and fall arresting. A brief description of each mode may be given as follows:

1. **Position securing** ensures that the position held during working will remain statically intact (*e.g.*, during work on a specific height up a pole).

2. **Fall restraint** limits the movement of the person up to the limit where the possibility of falling will dramatically increase (*e.g.*, a person working on a platform can move up to the edge of the platform).

3. **Fall arresting** stops the unwanted consequences of a fall retrospectively *(e.g.*, preventing consequences of a free fall of a person after the fall has commenced, due to a misstep).

Not all three modes may be present simultaneously, depending on the task being carried out and the context in which the person carrying out the task must move and

[5] Slipping or stumbling and falling on the same level where the person was standing has not been considered as ‘maritime fall’.

act. The measures applied each time should, of course, address the relevant risks. For instance, in terms of PPE or safety appliances, for position securing, a safety belt or harness may be used; for fall restraint, a lanyard or lifeline may additionally be used; while for fall arresting, a combination may do the job. The specifications and the combination of such components or sub-systems will be further elaborated in the following sections.

4. Safety equipment and fall protection systems when working at height

Safety measures and precautions used in practice include, in most cases, the use of a safety belt or harness, which is attached to a fixed point by means of a lifeline or lanyard.

However, it should be noted that experience in the maritime accident investigation domain, has brought about the misconception to some seafarers that safety harnesses and belts are of similar use and therefore, both can be used interchangeably.

The International Labor Organization (ILO) has published "Accident prevention on board ships at sea and in port"[6]. In this publication, the use of safety harnesses is promoted against protection from falls, attached to a lifeline (sections 5.4.7 and 15.1.6). Safety belts are neither suggested nor mentioned as fall arresting arrangements.

At the same time, organizations and administrations, such as the Occupational Safety and Health Administration (OSHA) of the United States Department of Labor, has prohibited the use of safety belts for fall arrest since 1998, as *"they may cause damage to spine and internal organs, while their average tolerable suspension time is 90 seconds and the maximum arresting force is only 900 pounds (approx.4.03 kN); a force which may well be exceeded during a fall, in terms of impact load"*[7]. Safety belts are only allowed according to OSHA as safety positioning arrangements and not as fall arresting[8].

Thereafter, safety belts should not be considered as fall arresting appliances. Their use is mostly position securing, along with a connection, using a proper lanyard

[6] International Labor Organization. (1996). *Accident prevention on board ship at sea and in port*. Retrieved from https://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/normativeinstrument/wcms_107798.pdf.

[7] From simple physics calculations, if person with a body mass of 65 kg falls from a standing position, within 1 sec the person covers a vertical distance of almost 4.91 m and carries a weight load of 637.65 kp (corresponding to 638 kgs force).

[8] OSHA Shipyard Industry Standards 2268-11R 2015, §1915.159 – Personal fall arrest systems (PFAS).

secured to a fixed point. This is especially applicable for tasks, which are carried out in a static mode (*i.e.*, the worker does not move during the task).

There are various types of safety harnesses, depending on the number of securing points on the person (vest type, full body). In most cases, full body safety harnesses are used on board.

A lifeline may be a simple rope (or even wire), while a lanyard is usually either a rope or a belt-type strap, which includes a carabiner clip (D-clip) at both ends for connection, either with the safety harness and the lifeline or the fixed point.

In most cases, a shock absorber is included in this fall arresting system, which is used to minimize the consequences of high decelerations on the person's musculoskeletal tissue, resulting from an abrupt break of a fall. In some cases, a second (or dual) lanyard may be also used for securing the seafarer's position during vertical movement and which necessitates detaching the lanyard or lifeline from one fixed point to attach it to another further up or down.

Figure 1: A full body safety harness with a shock absorber and a double lanyard
(Photo credits: Indiamart https://www.indiamart.com)

In terms of fall restraint protection, when working includes a risk of a fall when moving in horizontal or vertical direction, a more ergonomic arrangement would include the use of a fixed length lanyard with a rope grab (movable device which is fixed on the lifeline). However, this may allow limited movement to the person and prevent movement outside the lanyard's length, thus reducing the chances of unintended falls, say, over the edge of a platform.

Figure 2: Safety harness with a shock absorber and a lanyard connected to the lifeline and a movable rope grab device

(Photo credits: lift safety group of companies, https://liftsafegroupofcompanies.wordpress.com)

For greater flexibility in movement, a fixing mechanism for the safety harness, with automatic self-retraction or slack arrester (auto-belay), instead of a common rope or wire lanyard, may be used. These mechanisms, such as the Self-Retracting Lifelines (SRL) would, on one hand, prevent the rope or wire from becoming slack for a specified margin of length (up to a maximum length specified by the manufacturer of the SRL[9]), while on the other hand, prevent the fall of a person. Thus, in case of unintentional misstep, the SRL works like the conventional seat belt of a car, breaking the free fall of the person and limiting the height of the fall to a safe drop, in accordance with the manufacturer's specifications for the SRL. Consequently, the person will remain safely suspended by the safety harness. Such mechanisms are widely used in the construction industry and climbing.

Figure 3: Safety harness connected to a self-retracting lifeline (SRL) with shock absorber

(Photo credits: ABCS safety training, https://www.youtube.com/watch?v=XBVQongE3V0)

9 Typical maximum lengths range from 2 m to 10 m or 15 m according to the nature of tasks used for.

A safety net may be also deployed as a complementary post-fall arresting appliance, but this is considered a passive safety measure, which can be used in combination with the active safety measures and systems referred to above.

Figure 4: Typical safety net
(Photo credits: Manfred Huck GmbH, https://www.huck.net)

Having had a first idea of the solutions on fall protection systems, it would be now feasible to construct a risk assessment – risk elimination index to be able to evaluate the levels of safety offered against fall protection parameters as set out in section 3 of this study, as covered by each solution or system.

5. EU standards and requirements for fall protection

The respective EU legislative provisions comprise Regulation (EU) 2016/425 of the European Parliament and of the Council of 9 March 2016: "on personal protective equipment and repealing Council Directive 89/686/EEC"**.** In terms of general provisions, the aforementioned EU Regulation states in Annex II:

> *[…]3.1.2.2. Prevention of falls from a height*
>
> *PPE intended to prevent falls from a height or their effects must incorporate a body harness and a connection system which can be connected to a reliable external anchorage point. It must be designed and manufactured so that, under the foreseeable conditions of use, the vertical drop of the user is minimized to prevent collision with obstacles while the braking force does not attain the threshold value at which physical injury or the opening or breakage of any PPE component which might cause the user to fall can be expected to occur. Such PPE must also ensure that, after braking, the user is maintained in a correct position in which he may await help if necessary.*
>
> *The manufacturer's instructions must specify, in particular, all relevant information relating to:*
>
> *(a) the characteristics required for the reliable external anchorage point and the necessary minimum clearance below the user*; and

(b) the proper way of putting on the body harness and of attaching the connection system to the reliable external anchorage point. […]

The EU provisions on fall protection equipment and systems are supplemented by a series of relevant standards, in terms of manufacturing and testing characteristics and specifications per component, sub-system or system, such as:

- EN 355**:** on shock or energy absorbers;
- EN 353-1: on vertical fall arresters;
- EN 353-2: on guided type fall arresters;
- EN 360: on retractable fall arresters;
- EN 361: on full body safety harness; and
- EN 363: on fall arrester systems (combining sub-systems).

Further to the above, national provisions exist in each EU Member State which, of course, derive from the minimum requirements of the respective EU provisions albeit their extent may vary.

Thereafter, it is obvious that legislative provisions and standards on a variety of fall protection systems are available at international and EU levels, meaning that it has been well recognized that fall protection is a significant issue in occupational safety.

However, so far, there is neither a specific IMO regulation nor an EU legislation to define specifications on a complete fall protection system for use on board vessels and in that sense various combinations may be encountered in practice. Although quality standards exist on a component or sub-system level, even on full system level, there is no unique regulation or reference of a specific system type for use in the maritime industry.

Therefore, the notion is whether existing provisions and standards are adequate for the seafarers' working context, especially with respect to occupational safety. This will be examined in the following sections, by looking into maritime falls, using a type of abstract analysis as per Safety-I and Safety-II approaches.

6. The 'Safety-I approach'

6.1 Statistics of accidents related to 'maritime falls'

One of the most populated databases for marine accidents and incidents today is the European Marine Casualty Information Platform (EMCIP), which hosts over 30,000 occurrences. Statistics from EMCIP related to maritime falls and, specifically to fall protection systems and the respective PPE[10], for the time period from 2011 to 2020, has provided the following index:

Ship type	No. of accidents	Lives lost	Serious injuries[11]
Cargo ships-Solid cargo	23	7	22
Service ships	5	1	5
Cargo ships-Liquid cargo	2	1	2
Passenger ships	1	0	1
Recreational crafts	1	0	1
Total	32	9	31

Index 1: Accidents involving 'maritime falls' from 2011 to 2020

(Source: EMCIP)

Turning the focus on the ship type (cargo ship-solid cargo), on which accidents happen more frequently (72% of accidents, 78% of fatalities, 71% of serious injuries) and analyzing its sub-categories, the following index is obtained.

Solid cargo ships	No. of accidents	Lives lost	Serious injuries
Bulk Carrier	12	7	11
Container Ship	4	0	4
General Cargo	7	0	7
Total	23	7	22

Index 2: Accidents regarding 'maritime falls' from 2011 to 2020, for solid cargo ships

(Source: EMCIP)

[10] All occurrences which were related with falls and 'safety belt' or 'safety harness' references were made in their description were extracted from EMCIP. A total of 98 occurrences was produced and further analyzed according to their consequences on persons.

[11] Injuries which are sustained by a person, resulting in incapacitation where the person is unable to function normally for more than 72 hours, commencing within seven days from the date when the injury was suffered (Chapter.2.18 of the IMO Casualty Investigation Code – Resolution MSC.255(84)).

Breaking down the solid cargo ships' accidents, it becomes obvious that the majority of maritime falls with the heaviest toll in terms of human assets is on bulk carriers (52 % of accidents, 100 % of fatalities, 50 % of serious injuries). General cargo and container vessels share the rest of the 'maritime falls' accidents, which resulted in serious injuries.

6.2. The 'maritime falls' patterns

Seafarers will approach their tasks, acknowledging the potential risks related to their duties, but likewise, as professionals, they will most possibly try to synthesize and accommodate their occupational needs in the best way they can achieve. This is done by combining processes or procedures, experience, and practical workarounds. In the same recipe, ergonomics of any hardware used is also a main ingredient.

By analyzing the descriptions of the accidents referred to in Index 2, using the Safety-I logic and focusing on accidents which involve the use of fall protection systems and the respective PPE, a pattern seems to appear. All 22 accidents were related to working at height or near openings, which lead to a significant depth below them (*e.g.*, cargo hold hatches). In all cases, there were similarities in the events leading to the accident. The seafarers involved either chose not to use a safety harness, use it without a lifeline or lanyard, or initially used it but later during the task (especially when required to move vertically (*e.g.*, up or down a ladder), detached the harness from the lifeline or lanyard. In one of the occurrences, the seafarer, despite the provisions of the Safety Management System of the vessel, used a safety belt instead of a safety harness which, again, was detached from the lifeline to climb down a vertical ladder.

Figure 5: A safety belt with shock absorber and lanyard attached to a rope which is fixed on a hatch opening; the seafarer removed the safety belt to move down the fixed vertical ladder, before falling from a height of approximately 8 m to the cargo hold bottom and sustaining fatal injuries

(Photo credits : HBMCI, www.hbmci.gov.gr)

Based on this pattern, it may be concluded that the use of existing systems (whether referring to hardware such as PPE and their components, sub-systems and systems, or software such as the safety processes), failed to ensure that the seafarer could ergonomically[12] work, whilst wearing fall protection equipment, especially either when movement outside a specific range was required during the task, or the activity was carried out on board.

7. The 'Safety-II approach'

In the Safety-II approach, one would try to analyze the usual way seafarers act and the safety measures they use in tasks related to their daily business, where the risk of maritime fall may appear, especially when working at a height; *i.e.*, regardless of whether the seafarer is working in free mode, on a boatswain's chair, or on a scaffold.

7.1 The context of working where the risk of falling exists

Working in positions and areas where the risk of falling may appear, offers an uncommon and rather unfriendly environment for workers in general. First, humans feel more comfortable when working on plain and steady ground, so the elevation of the level on which a person stands (even without working) creates an uncommon condition. This condition, combined with the complexity of maintaining a safe position and having to move and change positions at horizontal or vertical level and work in parallel, engulfs several hazards and risks for personal safety. It goes without saying that the situation gets even more complex when the height factor is combined with work on a moving vessel; so even the reference point of a 'steady ground' is not applicable (as it does for example in the construction industry).

Critical conditions related to a risk of fall when working on a vessel at sea, may be classified in practical conditions (due to workplace specifications and conditions), environmental conditions (due to the natural characteristics of the workplace) and personal conditions (due to the person's physical or psychological traits). They may include:

- narrow surfaces to walk on (*e.g.*, steps of vertical ladders, cranes, masts);
- limitations in finding a reference point to fix safety equipment, especially when required to climb up to reach the working position or working area;
- environmental impact (*e.g.*, wind, wave impact on ship, extreme temperatures, light conditions);
- ventilation and respirational conditions (*e.g.*, when working at a height inside cargo holds and / or on tank tops near hatches);
- acrophobia; and

[12] Ergonomics includes safety, efficiency as well as comfort.

- body size and weight in relation to the task and workplace (*e.g.*, a person too short, too tall, too heavy, without flexibility).
- crew not receiving formal training in the use of the specific equipment used on board – including the pros and cons of using different types of equipment?

This list of conditions to be considered when working on a ship, may include specific characteristics and interfaces that are not common for all types of tasks. Therefore, working at a height usually comprises a specific process in safety management systems applied on board the respective vessels (which are subject to ISM) at sea. However, a Safety Management System Manual (SMM) typically only mentions a few tasks and principles, which are easy to describe and leaves more complex and difficult situations to be resolved by the crew by themselves, *e.g.*, how to access a cargo tank, when there is no anchor point by the hatch.

Work safety processes, especially for tasks which comprise moving or staying at a height, may include the issuance of a specific permit. In turn, this may be preceded by a toolbox or safety meeting, checking and ensuring the proper conditions (weather, temperature, ventilation, *etc.*) before commencing the works, distribution and use of specific protection equipment (PPE including fall protections systems), monitoring and supervision in order to offer assistance not necessarily to the work itself but to the safety of the person carrying out the work (*e.g.*, fixing a lifeline, ensuring that the person remains in good shape and safe condition during the task).

Even though such processes may be in place, it is without doubt that any issues related to the specific conditions and context on board, including also environmental conditions or situations emerging during the execution of tasks, cannot be tackled by process related provisions. The crew members themselves have to adapt their way of planning, deciding and acting to successfully cope with the complexities and complications they may encounter when working at areas and positions where the risk of falling exists.

Further description of the context and conditions of these tasks may assist in perceiving when and where such adaptations may happen.

7.2 Conditions related to fall protection systems and their use

Like most tasks on board, numerous specific conditions may exist during the process of preparation of working at a height, as well as during the execution of the works. The present document focuses on conditions which are related to fall protection systems, from a generic viewpoint and which includes most common tasks at height on board. Such tasks may comprise cleaning works on top of cargo holds, near hatch openings, on vertical ladders within cargo holds, climbing on cranes or booms, painting aloft or on ship side, entering ballast tanks from top, *etc.*

Significant details and conditions related to the choice and deployment of fall protection systems of working at height, may be grouped in the 'preparation' and 'execution' stages of a task, as follows:

1) *Preparation of tasks*:
   a) The safety / toolbox meeting is usually the first step in the preparation for work at a height. In optimal cases, all personnel involved is present. Thereafter, the risks identified and discussed during the toolbox meeting may be communicated to them. However, this is not always the case. Sometimes, only senior officers are present for this meeting and it is expected that any identified issues are communicated to the lower rank personnel through their hierarchy before the task commencement. Yet, this depends on a good communication structure and the relevant respect to hierarchy on board.

   b) In most cases, the risks identified and discussed during the safety / toolbox meeting include what is referenced within the SMM or on the work permit. However, focusing on the exact situation to be encountered during the specific task to follow, may at times offer a more realistic approach towards the conditions to be encountered; this may result in seafarers suggesting and deciding on the relevance and necessity of use for the PPE provided for a task, based on their own experience and mindset.

   c) The PPE required should be available on board and in good condition. This may be hindered when it is not the case, especially if stored in places which are not directly accessible to all crew members; time and nuisance to crew members responsible for accessing PPE should not hinder the 'motivation' of seafarers to seek or request for such PPE. Moreover, they should be properly maintained and checked for their condition prior to use and this item is also targeted by external inspections and controls.

   d) Crew members are often expected to be familiar with the correct use of all types of PPE and to get to know also the risks of deviating from proper usage. Various techniques are usually applied, including examples of marine casualties involving misuse of PPE. Still, as time is often a critical parameter on board due to tight schedules, crew availability and work / rest hours restraints, familiarization 'on the job', meaning that the use of the PPE is demonstrated just prior or during the actual use, may be commonly encountered in practice. As training and certification of seafarers has been upgraded in most cases during the last years, and crew selection is usually included in a company's priorities, seafarers come on board with a level of knowledge on PPE. Thus, in most cases, the use of PPE (even without the most efficient on board familiarization) may be conducted successfully. It should be noted that training and familiarization regarding the selection, deployment and use of fall protection systems are relatively simple and their application relies on factors such as the body structure, working environment and task to be carried out.

2) *Execution of tasks*:

a) In an optimal situation, the PPE required for the task are normally communicated and distributed to the involved personnel. However, a seafarer may opt against the use of PPE either for reasons of delays or comfort and flexibility during the task. Time delays have to do with the fact that in most cases, work at height is carried out during daytime and is related to the notion 'to get the job done at the soonest', especially if the schedule includes repetition (such as cargo holds' cleaning). For a seafarer, the completion of the tasks within (or even ahead) the allocated schedule is a measure of efficiency and success. Losing time to ensure safety standards (such as stopping the work in order to fix a lifeline to a new point so as to set a new range or radius of movement) may be seen as counterproductive. Comfort or flexibility have to do with the fact that PPE usually serve safety and not necessarily comfort. For example, wearing a helmet and a safety harness on a sunny day causes transpiration, while at the same time the seafarer may encounter difficulties to move freely during the task, as the harness is attached to a lanyard and a fixed point or a lifeline.

b) Although monitoring and supervising the tasks should be direct and are intended to complement a safer context during the works, (including the use of PPE at all times and in the proper way), this comes with certain limitations. For instance, when the task starts at top of a cargo hold, on a hatch cover, but the seafarer executing the task must climb down inside the cargo hold, the person acting as supervisor may neither follow nor be able to effectively monitor the seafarer's condition throughout the task. Thereafter, in case the seafarer opts, say, to detach from the lifeline, it may not be always observed by the supervisor. Moreover, daytime supervision may include multi-tasking; a bosun acting as a supervisor may be either attending more than one task, or carrying out a different task while supervising another. Finally, 'safety by example', meaning that the supervisor is the first who follows and demonstrates safe practices, is considered among the most effective ways of motivating the rest of the personnel to sustain a good level of safety throughout the conduction of work. Yet, it may be the case where an experienced seafarer has developed skills much more than an inexperienced officer who may act as supervisor. Hence, the experienced seafarer may be in a position to respond more efficiently to the emerging situations developing during a task, setting down good practices and reverting the direction of 'safety by example' in relation to hierarchy.

c) Crew members normally carry out tasks with a safety conscience, influenced by their personal background and experience. There is either a choice or necessity to adjust to dynamic conditions, and act differently from what a process manual provides for either to save time or to feel more comfortable and flexible during the task. Typical examples are detaching the clip from the lifeline to climb either up or down a ladder, or to reach a point just outside the limits of the fall restraint system without having to reset the fixing point of the lifeline or the rope grab of a lanyard. In the majority of cases, this is a successful choice, which renders it as an effective practice. Such actions are even carried out under the supervision of senior crew members and based on previous successful completion may turn out to become normal practice on board.

d) Tasks may have emerging complexities and hence neither scheduled nor expected. During their execution, specific conditions may arise, causing the seafarer to take initiatives to cope with the situation. For example, a change in weather or in the movement of the vessel may encourage a seafarer to climb up or down a ladder to reach a safer level. Such an unexpected situation may not provide for enough time to move with comfort.

8. Fall protection systems: options and evaluation

The combination of the two safety approaches assisted in the identification of patterns and risks of accidents involving fall protection systems (Safety-I approach) and acquiring knowledge on the context of specific works on board, in relation to which, the risk of falling may appear, also mapping down certain relevant practical details (Safety-II approach). The next step is to examine the existing solutions of fall protection systems and try to evaluate them in a qualitative way, regarding criteria set in relation to the components of fall protection itself and the added value of the context knowledge gained.

8.1 Criteria for qualitative evaluation of Fall Protection Systems

The criteria chosen for a qualitative evaluation of the safety levels of the various available fall protection systems, may derive from the fall protection modes as introduced in section 3. Further to these modes (position securing, fall restraint, fall arresting), the ‘position shifting’ criterion has been adopted, to address the issue of having to change the fixing point of a lifeline, in case the seafarer has to move further than the initial position of range of positions, which is set by the length of the lifeline. This issue is of high ergonomic importance, as it has been identified by both safety approaches in the previous sections, since it may involve a time-period which the seafarer will have to spend to reach a new secure fixing point for the lifeline, but which may comprise an unsafe sub-period during which, the lifeline will not be fixed to any point. A combination in the sequence of actions carried out by the seafarer or by cooperation of the seafarer, who performs a task with another seafarer who is responsible for fixing the lifeline, may create risks for the safety of working at a height, which comprises the risk of a fall.

The values of qualitative ranking have been chosen to vary among three levels: low, medium and high in relation to the standards of safety they offer for each of the modes under the scope of the evaluation.

8.2 Options of Fall Protection Systems

Thereafter, upon the detailed description of the tasks, conditions and respective safety components or sub-systems in the previous sections, the following five combinations or Fall Protection Systems (FPS), which have been mostly encountered in practice on board vessels against protection from falls, may be singled out for further elaboration and qualitative evaluation, with respect to the criteria set above:

1. **FPS 1**: Safety belt attached to a lanyard via a shock absorber and thereafter either to a fixed point, or to a fixed length lifeline, which on the other end is attached on a fixed point.

2. **FPS 2**: Safety harness (full body), attached to a lanyard via a shock absorber and thereafter either to a fixed point, or through a fixed rope grab to a lifeline which on the other end is attached on a fixed point.

3. **FPS 3**: Safety harness (full body), attached to a lanyard via a shock absorber and thereafter either to a fixed point, or to a self-retracting lifeline (SRL) which on the other end is attached on a fixed point.

4. **FPS 4**: Safety harness (full body), attached to a lanyard via a shock absorber. The lanyard is attached either to a fixed point, or to a simple lifeline through a scrollable rope grab which locks its position on the lifeline, allowing the seafarer to unlock the grab move further on along the length of the lifeline and lock the grab to a new position.

5. **FPS 5**: Safety harness (full body), attached to a pair of lanyards via shock absorbers. One of the lanyards is attached either to a fixed point, to a self-retracting lifeline (SRL), or to a scrollable rope grab like in FPS 4, while the second lanyard is used for position securing (direct connection to a fixed point) during possible change of the fixing point of the SRL or the rope grab.

8.3 Evaluation of Fall Protection Systems

FPS 1 is optimal for position securing, especially if the safety belt is fixed directly to the working unit (*e.g.*, on a pole or mast). It also offers some protection in terms of fall restraint, as the fixed length of the lifeline may be adjusted according to the context of the workplace up to maximum safe length, although it may not be as practical and easy to measure and unravel such a length *ad hoc*. Fall arresting is, however, minimal in terms of safety, as the abrupt deceleration of the fall may cause shock injuries (see section 4). The position shifting safety is also low, since the fixed length of the lifeline necessitates that it must be removed and fixed to a new point, if the person wants to continue working outside the initially designated area (*e.g.*, climbing further up or down a ladder) and there is a danger of falling during this shifting. This may lead the seafarer risking detachment from the fall protection to continue working more without distractions.

FPS 2 offers safety for position securing and fall arresting through the full body safety harness and the shock absorber. However, the fixed length of the lifeline limits the fall restraint levels and renders the safe shifting of position to low.

FPS 3 has the similar characteristics of FPS 2, including enhanced fall restraint performance, as the self-retracting lifeline in use may offer effective safety in terms working within a radius equal to the maximum nominal length of the line. Nevertheless, position shifting is an issue, although flexibility exists here, as well as the predefined range of work (specifications of the SRL), thus the risk is present only when having to exceed the nominal length of the SRL.

FPS 4 uses the scrollable rope grab, which may be locked along the full length of the lifeline, thus allowing position shifting for the full length of the lifeline, without the need to detach the lifeline itself from its initial fixing position during shifting. Yet, the risk still exists during the time period when the grab is unlocked to change the position and locking it again on the lifeline, as the seafarer has no further fall arresting protection during this interval, irrespective of how short it may be.

FPS 5 has further upgraded safety standards in comparison with FPS 3 and FPS 4, by offering a control measure against position shifting in terms of the second lanyard, which addresses the risk of falling either during the change of the fixing point of the lifeline or the rope grab respectively. Either before the detachment of the lanyard from the SRL and its fixing point, or the unlocking of the rope grab's position, the seafarer will secure his/her position using the second lanyard and continue moving safely by securing each of the two lanyards respectively, until the SRL has been fixed again to a new point or the rope grab has been locked in a new position along the lifeline.

Taking into consideration the analysis above, the following matrix has been constructed:

Marine fall protection mode / Fall Protection Systems	Position securing	Fall restraint	Fall arresting	Position shifting
FPS 1	High	Medium	Low	Low
FPS 2	High	Medium	High	Low
FPS 3	High	High	High	Medium
FPS 4	High	High	High	Medium
FPS 5	High	High	High	High

Index 3: FPS qualitative evaluation in terms of safety ensured

9. Conclusion and the way forward

The brief analysis of maritime falls' accident statistics (Safety-I) revealed that the relevant accidents appear to follow similar risk patterns, especially related to the use of fall protection systems. The insight on normal operations and means of protection for working aloft (Safety-II) has shed more light on the nature of tasks and the relevance of the safety measures and systems, which are used in practice to ensure safety and successful execution, but also helps to identify some issues in between preparation and execution.

FPS 5, as presented in Index 3, seems to prevail in the evaluation of the systems examined, by addressing all four criteria set during the evaluation (position securing, fall restraint, fall arresting and position shifting). Yet, the existing legislative provisions allow for a variety of risk control options to be chosen and used on board, therefore accepting medium or low safety solutions.

A possible way forward is to regulate the standards of systems prescribed in the EU or IMO framework for fall protection in the maritime sector industry, in a way to offer the most optimal safety levels, based on seafarers' experiences, thus limiting the acceptable combinations of safety sub-systems and components used, to be in line with the FPS 5.

A cost-benefit analysis may be further elaborated in this direction, although not of vital priority, since the FPS compared are all existing solutions which are also encountered in the industry in general, including the maritime sector; they are of relatively similar cost and their mode of usage is relatively simple, in terms of familiarization with specifications, proper selection and use by seafarers.

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