

RISK ASSESSMENT, AS AN INTERDISCIPLINARY SUBJECT

Dr., professor Vladimir Loginovskiy

Admiral Makarov State University of Maritime and Inland Shipping

198035, Dvinskaya ul., 5/7, Saint-Petersburg, Russian Federation

vl.loginovsky@rambler.ru, LoginovskijVA@gumrf.ru

Abstract

Accidents at sea have been continuously occurring despite the development in the performance of navigational equipment. One of the techniques to reduce their impact is risk assessment followed by risk management. Risk assessment, introduced by ISM Code, MLC 2006 and also by Manila amendments to STCW Convention and ISPS Code encouraged AMSU-MIS to develop the new interdisciplinary course for prospective deck officers under the title “Risk assessment in shipping industry”. Inclusion by IMO the risk topics into STCW 78 Convention and Code can be considered as a very wise step to raise the quality of Maritime Education and Training (MET) and to maintain the due level of safety, security and protection of environment.

Risk assessment, as preliminary procedure for decision making and as an interdisciplinary subject plays the great role not only for encouraging of more deep learning of all professional competencies, but also plays role of an efficient motivator for seafarer to be competent on board the ship, otherwise the non adequate and non professional assessment of risk in shipping operations followed by improper decision might produce the harm instead of benefit. In frames of this course students learn the fundamentals of risk assessment and management. Some items of the course devoted to a very important topic as “risk perception”. The paper shares some experience of teaching the subject ”Risk assessment in shipping industry” and describes some sensitive topics and difficulties faced while the delivering the subject. The paper also proposes to expand Risk Matrix into Human Element area by applying Heinrich’s Law approach.

Keywords: risk assessment, Heinrich’s Law, human element.

Introduction

Risk assessment as a basis for decision-making in shipping industry is regulated both the ISM Code and by other international instruments such as STCW 78 Convention, ISPS Code, Polar Code and the IGF Code, MLC 2006 and by number of other instruments.

There are many definitions of the term "risk" and also the variety of methods to assess it, but in shipping industry seafarers mainly use methods based on approaches of technical sciences, which are described in IMO documents (MSC-MEPC.2/Circ.12/Rev.1 2015, p.4).

If to say about "risk assessment" as an educational subject, it is quite obvious that it is interdisciplinary one. Moreover, by the opinion of the author, it can be considered as motivating subject for mastering the entire set of competences regulated by the STCW 78 Convention in order the prospective officer can be issued the first Certificate of Competency (CoC). It is impossible to make statements about safety, environmental protection or security at sea, not knowing how properly assess the risk in ship operations. It is also hardly possible to make effective decisions on this basis, without mastering the competencies to the full.

Risk assessment and STCW 78 competencies

Fig.1 presents the numbers of tables consisting the specifications of minimum standards of competences for officers under the STCW 78 Code, where the provisions for risk assessment as components of various competencies (white circles) are included.

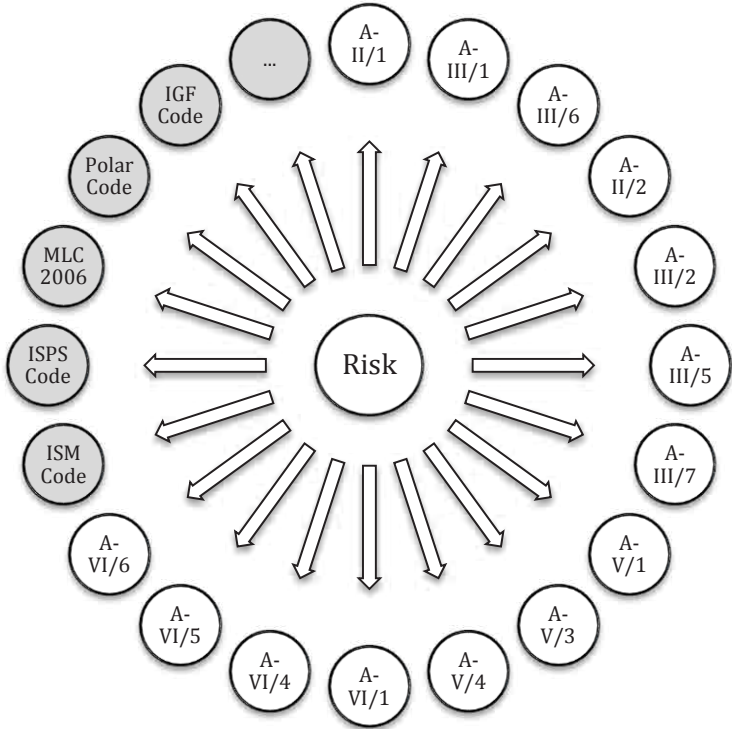


Figure 1. Some international standards regulating risk assessment in shipping industry
 Other instruments, regulating the risk assessment in shipping industry are also shown on the Fig.1.

The IMO defines risk as: The combination of the *frequency* (F) and the *severity* (S) of the consequence (MSC-MEPC.2/Circ.12/Rev.1 2015, p.4). Simple formula to assess risk is as follows:

$$R = FS \quad (1)$$

Where, F - *frequency* is defined as the number of occurrences per unit time (e.g. per year). In a lot of documents the terms *probability* and *likelihood* are used instead the term *frequency*. For practical tasks these terms are interchangeable; S is defined as the outcome of an accident or severity of consequences from accidents.

Initial ranking of accident scenarios

For the initial ranking of accident scenarios the risk elements F and S are presented in tables 1,2 and 3 below (MSC-MEPC.2/Circ.12/Rev.1 2015, p.40).The risk assessment matrix is based on the artificial indices RI , FI and SI replacing the real values of R , F and S , which allows to apply more simple approach for risk assessment procedures in practice by using integer positive numbers instead of using decimal fractions. For this, a logarithmic scale is used and formula (1) is transformed in the form (2), where A , B and C are positive integers, assuming that $A = B + C$:

$$\log(R) + A = \log(F) + B + \log(S) + C \quad (2)$$

The document introduces the following definitions:

$RI = \log(R) + A$ is the risk index, ($A = 9$); $FI = \log(F) + B$ is the frequency index, ($B = 6$);

$SI = \log(S) + C$ is the severity index of the consequences, ($C = 3$).

As a result, R is estimated through the corresponding indices as follows:

$$RI = FI + SI \quad (3)$$

Frequency index FI varies from 1 to 7, see Table 1.

Table 1. Frequency and Frequency index

Frequency index			
FI	FREQUENCY	DEFINITION	F (per ship year)
7	Frequent	Likely to occur once per month on one ship	10^1
5	Reasonably probable	Likely to occur once per year in a fleet of 10 ships, i.e. likely to occur a few times during the ship's life	10^{-1}
3	Remote	Likely to occur once per year in a fleet of 1,000 ships, i.e. likely to occur in the total life of several similar ships	10^{-3}
1	Extremely remote	Likely to occur once in the lifetime (20 years) of a world fleet of 5,000 ships.	10^{-5}

Severity index *SI* varies from 1 to 7, see Table 2.

Table 2. Severity and Severity index

Severity index				
<i>SI</i>	SEVERITY	EFFECTS ON HUMAN SAFETY	EFFECTS ON SHIP	<i>S</i> (Equivalent fatalities)
1	Minor	Single or minor injuries	Local equipment damage	10 ⁻²
2	Significant	Multiple or severe injuries	Non-severe ship damage	10 ⁻¹
3	Severe	Single fatality or multiple severe injuries	Severe damage	10 ⁰
4	Catastrophic	Multiple fatalities	Total loss	10 ¹

Risk index *RI* varies from 2 to 11, see Table 3.

Tables 1 and 2 form Risk matrix.

Table 3. Risk matrix

Risk Index (<i>RI</i>)						
Frequency of incidents (F) and Frequency Index (FI)			Severity (<i>S</i>) and Severity Index (<i>SI</i>) in equivalent of fatalities			
<i>FI</i>	<i>F</i> (per ship year)	<i>SI</i>	1	2	3	4
		<i>S</i>	10 ⁻² Minor	10 ⁻¹ Significant	10 ⁰ Severe	10 ¹ Catastrophic
7	10 (Frequent)		8	9	10	11
6	10 ⁰		7	8	9	10
5	10 ⁻¹ (Reasonably probable)		6	7	8	9
4	10 ⁻²		5	6	7	8
3	10 ⁻³ (Remote)		4	5	6	7
2	10 ⁻⁴		3	4	5	6
1	10 ⁻⁵ (Extremely remote)		2	3	4	5

The following criteria are broadly used in other industries and have been also published in the same circular: $RI=3$ or $R=10^{-6}$, it is negligible fatality risk to crew member per year; $RI=6$ or $R=10^{-3}$, it is maximum tolerable fatality risk to crew member per year; RI -from 4 to 6 is ALARP zone (As low as reasonably practicable).

A straightforward approach was introduced in circular, suggesting an equivalence ratio between fatalities, major injuries and minor injuries:

- one (1) fatality equals ten (10) severe injuries; and
- one (1) severe injury equals ten (10) minor injuries.

Risk assessment up to decimal order accuracy is fully justified for practical tasks by the presence of uncertainties in the estimation of its parameters F and S . The similar approach is used in most ship forms used for risk assessment.

The following comments are given in paper (IACS 2012, p.8): Risk is not a constant, measurable, concrete entity. Quantitative assessments of risk must be understood as estimates that are made at particular moments and are subject to considerable degrees of uncertainty. They are not precise measurements, and the rarer (and usually more catastrophic) the event, the less reliable the historical data and the estimates based on them will be.

The tables 1,2,3 are not mandatory. The risk matrix may be expanded to include more rows and columns, depending on how finely the company wishes to distinguish the categories. The terms used for *likelihood* (frequency, probability) and *consequence* may be changed to assist understanding. For example, *likelihood* may be expressed in terms of “once per trip”, “once per ship year” or “once per fleet year”, and consequence may be made more specific by the use of “first aid injury”, “serious injury” or “death”, not forgetting the consequences for property and the environment (IACS 2012, p.5).

One of the cornerstones in the ideology of on-board Safety Management Systems (SMS), regulated by the ISM Code, is the fundamental principle of feedback, without which no control mechanism can be built. Within the frames of risk assessment field this mechanism works on the basis of Heinrich's law, and its application is regulated by the 9th section of ISM Code. In accordance with ISM Code paragraph 9.1 «The safety management system should include procedures ensuring that non-conformities, accidents and hazardous situations are reported to the Company, investigated and analyzed with the objective of improving safety and pollution prevention».

Human element, Heinrich's Law and risk assessment

Little is known on psychological outcomes for seafarers who experience near miss grounding or near miss collision or other near miss incident.

It is necessary to state the fact that one of the sensitive parameters in the risk assessment process is the human element (MSC-MEPC.7/Circ.7, p.1), which it is one of the main causes of accidents and incidents at sea. The level of mental state of the seafarers' work is an important component of the human element, and it is difficult to account for, but a probabilistic approach to its consideration is possible if the information basis is taken by statistics described by Heinrich's law, which reads: the number of accidents is inversely

proportional to the severity of those accidents. It leads to the conclusion that minimizing the number of minor incidents will lead to a decline in major accidents (Skybrary 2016).

Graphical interpretation of the Heinrich's law describes four levels of negative events and is shown below. These levels from I to IV in the interpretation of NYK company (Chepok 2009) as well as by document (MSC-MEPC.2/Circ.12/Rev.1 2015, p.39) are given with accuracy up to a decimal order:

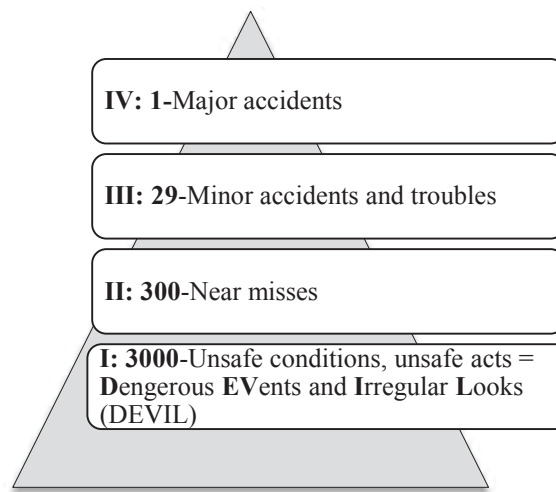


Figure 2. Heinrich's Law levels

Levels I and II do not lead directly to accidents and catastrophes, but they increase the likelihood (frequency) of their occurrence, which can lead to a mental strain of seafarers. If situations at levels I and II occur frequently, it is reasonable to assume that this can cause the increased mental tension and stress, which in turn can raise the level of risk in ship operations with an increase in the frequency F of such kind of events.

Using the approach to compiling the risk matrix described in (MSC-MEPC.2/Circ.12/Rev.1 2015, p.40) and combining it with Heinrich's Law levels I-IV, we can build an expanded risk matrix by linear extrapolation of the parameter S into the levels I and II. It is in principle consistent with the 9th section of the ISM code on near miss reporting procedures.

To do this it is necessary that the indicated constants A , B and C have the following values: $A = 11$, $B = 6$, $C = 5$.

As a result, the risk assessment matrix will look like this:

Table 4. Expanded Risk assessment matrix

Risk Index (<i>RI</i>)								
Frequency of incidents (<i>F</i>) and Frequency Index (<i>FI</i>)		Severity (<i>S</i>) and Severity Index (<i>SI</i>) in equivalent of fatalities						
<i>FI</i>	<i>F</i> (per ship year)	<i>SI</i>	1	2	3	4	5	6
		<i>S</i>	10 ⁻⁴ Mental tension	10 ⁻³ Mental stress	10 ⁻² Minor	10 ⁻¹ Significant	10 ⁰ Severe	10 ¹ Catastrophic
7	10 ¹ (Frequent)		8	9	10	11	12	13
6	10 ⁰		7	8	9	10	11	12
5	10 ⁻¹ (Reasonably probable)		6	7	8	9	10	11
4	10 ⁻²		5	6	7	8	9	10
3	10 ⁻³ (Remote)		4	5	6	7	8	9
2	10 ⁻⁴		3	4	5	6	7	8
1	10 ⁻⁵ (Extremely remote)		2	3	4	5	6	7
Heinrich's Law levels			I: Unsafe conditions, Unsafe acts = DEVIL	II: Near misses	III: Minor accidents or troubles	IV: Major accidents		

Where $RI=5$ or $R=10^{-6}$, it is negligible fatality risk to crew member per year; $RI=8$ or $R=10^{-3}$, it is maximum tolerable fatality risk to crew member per year; RI - from 6 to 8 is ALARP zone.

In this way, the levels of Heinrich's law are harmonized with the IMO document MSC-MEPC.2/Circ.12/Rev.1. Two sets of events, described by the Heinrich law, are incorporated into the risk matrix, which makes possible to assess the risk, taking into account the occurrence of "near miss and DEVIL" situations, see Fig.2.

Difficulties in perception and understanding of risk by students

The main difficulties in understanding and perception of risk, as a certain value describing the level of safety of a particular ship operation, are associated with a lack of knowledge and experience to perform these ship operations, as well as with uncertainty of the information used to assess the risk. These uncertainties exist in the both risk components F and S due to the application of the probabilistic approach to assess them.

Uncertainty in risk assessment indicates that the event is not determined in advance, that is, it may occur, or it may not happen, but the uncertainty will reduce when our knowledge level

increases. Thus, the presence of uncertainties is an additional motivating factor for studying those areas (competences) in which risk is assessed.

The identification of hazards is the first and most important step since all that follows depends on it. It must be complete and accurate, and should be based, as far as possible, on observation of the activity. But hazard identification is not as easy as it may first appear. Completeness and accuracy can be achieved only if the process is systematic. Those charged with the task must have sufficient training and guidance to ensure that it is conducted in a thorough and consistent manner (IACS 2012, p.4).

The identification of hazards and scenarios for avoiding of their realizations is the main step in assessing and managing risk. It makes clear why risk assessment is an important interdisciplinary subject in all STCW 78 training programs for seafarers. The catch phrase "Safety first" is the universal slogan supporting the further need to study the process of risk assessment and conduct research in this area.

Conclusion

(1) Practically all the competences regulated by the STCW Code 78 include, to some extent, the skill of a prospective officer to assess and manage risk. Based on the experience of teaching the subject "Risk assessment in shipping industry" it becomes obvious that the subject has an interdisciplinary nature and is an important motivating factor for a deeper understanding and study of all the competencies required for issuing the first CoC under the STCW Convention 78. In turn, this also gives ground for enriching MET programs by including risk assessment and management into them.

(2) The paper proposes also to include levels from Heinrich's law into risk assessment matrix for expanding the risk matrix into the human element area, which is in principle consistent with the provisions of the 9th section of the ISM Code and can be a basis for risk assessment in view of hazardous situations and near miss incidents.

References

MSC-MEPC.2/Circ.12/Rev.1 Revised guidelines for FSA for use in the IMO rule-making process, 18 June 2015, 70 p., available from:

<https://www.google.ru/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjB9PyOvbbVAhUCJJoKHWuZAbEQFggmMAA&url=http%3A%2F%2Fwww.msa.lt%2FIt%2Fpapildomas-meniu%2Ftjo-dokumentai%2Fjuru-saugumo-komiteto-4151%2Fmsc.2-msc.3-msc.5-aplinkrasciai%2Fmsc-aplinkrasciai%2F2075%2Fdownload%2F5459.html&usg=AFQjCNE4dnEbH1Fe5XDSfMPJFoRBAOuEJQ>

IACS Recommendation No.127 “A Guide to Risk Assessment in Ship Operations”, June, 2012, 8p., available from:

https://www.google.ru/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKewjqieSLyLfVAhUDJFAKHRYVCp8QFggmMAA&url=http%3A%2F%2Fwww.iacs.org.uk%2Fmedia%2F2655%2Frec_127_pdf1842.pdf&usg=AFQjCNH7OsDwachH77AOI8bZOUhIjJsQLxQ

MSC-MEPC.7/Circ.7 Guidance for near-miss reporting, 10 October 2008, 6p., available from:

<https://www.google.ru/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwih5IeVybFVAhVPblAKHYbhCzYQFggMAE&url=https%3A%2F%2Fwww.register-iri.com%2Fforms%2Fupload%2FMSC-MEPC.7-Circ.7.pdf&usg=AFQjCNE9jv89EepzQRVVZbAPN39SFfDQTW>

SKYBRARY ,2016, *Heinrich Pyramid*

Available from: https://www.skybrary.aero/index.php/Heinrich_Pyramid

CHEPOK, A., 2009. *Heinrich Law to floor the DEVIL*, available from:

<http://alexeychepok.blogspot.ru/2009/12/heinrich-law-to-floor-devil.html>