On improper implementation of Formal Safety Assessment in practice

Piotr Kopacz
Gdynia Maritime University,
Gdynia, Poland

Abstract

The International Maritime Organization prepared documents and recommendations for use of the Formal Safety Assessment on board the ships to improve the level of safety in everyday practice. Based on "the Guidelines for Formal Safety Assessment (FSA) for use in the IMO Rule – Making Process, MSC/ Circ. 1023, MEPC/ Circ. 392" the new companies' Risk Assessments forms have been added to the ships' files. However it is often observed that improper understanding of the use of FSA caused generating the official documents containing the serious mistakes. That caused lowered the level of safety instead of improving standards on board the ships in aspects of e.g. passage planning or deck duties. The main reason for mistakes made concerns the problem of adopting the theoretical formulas and recommendations of the IMO guidelines into the ship companies' forms to be used in practice. The examples of problems taken directly from real life, analysis of solutions have been presented in the paper.

Keywords: *FSA, risk matrix, passage planning. decision making.*

1 Introduction

The problem of safety is the most important aspect analyzed by the international maritime bodies. How to improve it in the general scale? One of the latest steps was the Formal Safety Assessment to be in use on board the ships as a new common practice. Starting from the theoretical tools and models based on probability and statistics, guidelines have been created to implement this topic in a practical way. The shipping companies were obliged to adapt the rules to take into consideration the specific kinds of maritime sector. Thus the new safety assessments forms had to be created which should have been compatible with their featured works. The point was how to transform the advanced models and recommendations into the simple form which should not be complicated to use for the seafarer in charge. Based on two variables (frequency and the severity of consequence), the risk matrix can be evaluated.

Then the use of simple numeric parameters is followed by the assessment of risk before commencing the relative process. The designated persons were to create the special sheets to make the master's or chief officer's duties onboard easier. The serious problem occurred when the guidelines for the Formal Safety Assessment for use in the IMO rule–making process were not properly followed by the shipping companies. Thus the misunderstanding of the risk matrix can often be observed in the published forms or even recommended literature [5, 6]. Examples of these occurring problems are included in this paper. The consequence of such improper attitude produces a lower level of safety. The limits between minor or catastrophic risks are shifted. Moreover, it is shifted in a dangerous direction. This means the probable area of risky acting is considerably decreased according to wrong calculations. Though the range of the matrix values influences the symmetric distribution as the basic one, the additional data can modify the final boundaries between the different types of risk (safety).

Attention ought to be paid by the persons in charge when transforming the general guidelines into their specific company ISM forms concerning FSA. This was one of the reasons to focus on the presented problem here which has been coming directly from practice since 2006.

2 IMO recommendations concerning FSA

The Maritime Safety Committee and the Marine Environment Protection Committee approved Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule–making process. FSA is a rational and systematic process for assessing the risks relating to maritime safety and the protection of the marine environment and for evaluating the costs and benefits of IMO's options for reducing these risks. The use of FSA is consistent with and should provide support to the IMO decision making process. It provides a basis for making decisions in accordance with resolutions A.500 (XII) "Objectives of the Organization in the 1980's", A.777(18) "Work Methods and Organization of Work in Committees and their Bodies" and A.900(21) "Objectives of the Organization in the 2000s".

The application of the FSA may be particularly relevant for the proposals for the regulatory measures which have far reaching implications in terms of costs to the maritime industry, or the administrative or legislative burdens which may result. This is achieved by providing a clear justification for proposed regulatory measures and allowing comparison if different options of such measures are made. This is in line with the basic philosophy of FSA in that it can be used as a tool to facilitate a transparent decision–making process. It also provides a means of being proactive, enabling potential hazards to be considered before a serious accident occurs [1].

In the Guidelines for FSA by IMO, we can read that member governments and non-governmental organizations are invited to apply to FSA when it is deemed necessary, and to submit the results thereof to the organization in accordance with the standard format for reporting. The Guidelines for FSA includes the following items:

- Introduction (purpose of FSA, scope and application);
- Basic terminology;
- Methodology;
- Problem definition;
- Identification of hazards;
- Risk analysis;
- Risk control options;
- Cost benefit assessment;
- Recommendations for decision-making;
- Presentation of FSA results.

The details can be found in [1] and the references cited there.

Risk is defined as the combination of the frequency and the severity of the consequence. Consequence is understood as the outcome of an accident, and frequency as the number of occurrences per unit time. FSA should comprise the above mentioned steps from identification of hazards to recommendations for decision-making. Characterization of hazards and risks should be both qualitative and quantitative, and both descriptive and mathematical, consistent with the available data, and should be broad enough to include a comprehensive range of options to reduce risks. The availability of suitable data necessary for each step of the FSA process is important. When data are not available, the expert judgment, physical models, simulations and analytical models may be used to achieve valuable results. The human element can be incorporated by using human reliability analysis. The important item is the frequency and consequence categories used in the risk matrix have to be clearly defined. Then the combination of a frequency and a consequence category represents a risk level.

3 Improper use of FSA in practice

In the following paragraphs we try to show examples of improper implementation of the Formal Safety Assessment focusing on the risk matrices and relevant risk zones.

3.1. Directly from ships

Let us start with the example coming directly from the fleet of tankers in operation. The shipping company we'll name here simply "Company.". The persons in charge (managing director, ISM designated person) of adapting the new risk assessment forms prepared standing instructions followed by the concerned forms. On one of the pages of the new ISM Manual entitled *Company standing instructions applicable to all crews working on vessels owned, managed or chartered by the (...) Group* we can find *Risk Assessment Matrices - Guidance on Risk Assessment for use with form.* The risk assessment procedure basing on the proposed instructions and risk matrix are as follows:

Table 1. Severity levels in Company's form

SEVERITY		
1	Nil	Nil instances of medical aid / assistance, no or only very slight damage to vessel(s) or property and no oil spilt
2	Slight	Requires on site 'first-aid' only and is fit to return to work immediately. Slight damage to vessel(s)or property. No spill of oil.
3	Moderate	Requires on site 'first-aid' or a visit to hospital / doctor but fit to return to work in less than 3 days. Significant damage to vessel(s) or property, but still able to operate normally. Oil contained on vessel(s) or within shore facility.
4	High	Requires on site 'first-aid' and/or a visit to hospital / doctor, but unable to return to work in less than 3 days. Damage to vessel(s) substantial enough to take the vessel(s) out of service. Oil contaminates the marine environment but is contained within the immediate vicinity of the spill.
5	Very High	Fatal, Near Fatal Injury, Loss of Vessel(s) and/or a major uncontained oil spill.

Table 2. Likelihood levels distribution

LIKELIHOOD	
1	Unlikely
2	Likely
3	Quite Possible
4	Possible
5	Very Likely

Table 3. Risk zones with theoretic risk rating

RISK RATING No.					
Very Low Risk	01	02	03	04	05
Low Risk	06	07	08	09	10
Moderate Risk	11	12	13	14	15
High Risk	16	17	18	19	20
Very High Risk	21	22	23	24	25

Analyzing the above mentioned matrix we can easily find out that according to the company's recommended way of risk assessment it is not possible to obtain the following Risk Rating numbers: 7, 11, 13, 14, 17, 18, 19, 21, 22, 23, 24. These numbers cover 44% (!) of all matrix values (11 of 25). Taking into consideration only the numbers possible to obtain the proposed risk matrix looks as follows:

Table 4. Risk matrix composed of actual distribution of risk ratings

Risk level	Risk rating					Number of possibilities
Very low risk	1	2	3	4	5	10
Low risk	6	-	8	9	10	7
Moderate risk	-	12	-	-	15	4
High risk	16	-	-	-	20	3
Very high risk	-	-	-	-	25	1

Here are some corollaries:

a) The minimal rating RR_{min} = 1 and the maximal RR_{max} = 25 do not implicate existence of natural values RR Î [1; 25] Ç N, where RR stands for Risk Rating and N for a set of the natural numbers.
b) Very high risk level can be reached in one case only when both severity and likelihood ratings equal 5, i.e. $5 \times 5 = 25$. Not as stated (Table 3) in five cases when RRÎ {20, 21, 22, 23, 24, 25}. 25 pairs give us 14 different products.
c) Moderate and high risks can be obtained when Risk Rating equals 12 or 15 and 16 or 20, respectively. Not as far as stated in Tab. 3. Most of products cannot be achieved (3 of 5) for both risk levels. Risk Rating referring moderate risk can be obtained in 4 cases i.e. (3,4), (4,3), (3,5), (5,3) and the high risk in 3 cases i.e. (4,4), (4,5), (4,5) where the first number stands for severity and the second for likelihood.
d) According to the proposed scales for severity and likelihood ratings obtaining the risk levels looks as follows

- Very low risk: **40% (of all cases);**
- Low risk: **28%**;
- Moderate risk: **16%**;
- High risk: **12%**;
- Very high risk: **4%**.

what is presented graphically in the color coded Table 5

Table 5.Real risk zones of multiplicative risk ratings distribution

		Severity index				
		1	**2**	**3**	**4**	**5**
Likelihood index	**1**	**1**	**2**	**3**	**4**	**5**
	2	**2**	**4**	**6**	**8**	**10**
	3	**3**	**6**	**9**	**12**	**15**
	4	**4**	**8**	**12**	**16**	**20**
	5	**5**	**10**	**15**	**20**	**25**

where

- green color means very low risk;
- blue - low risk;
- yellow - moderate risk;
- orange - high risk;
- red - very high risk.

In the above mentioned case it is necessary to use a different formula for obtaining the Risk Ratings which are followed by the respective acting. One of proposed way of assessing the risk can look as follows.

The risk is obtained as stated in formula (1)

$$\underline{A} = \underline{B} * \underline{C}, \quad (1)$$

where $\underline{A}$ – risk, $\underline{B}$ – severity, $\underline{C}$ – frequency (probability) of considered situation.

To simplify the calculations we can use the logarithmic scale and define the relevant indexes: Risk Index (A), Severity Index (B) and Frequency Index (C).

Range of natural values for Severity and Frequency Index extends e.g. from 1 up to 5 only, as above suggested in Tables 1 and 2. Each value refers to a respective situation in both cases. Then the value of risk index is calculated as a sum of values of Frequency Index and Severity Index

$$log(\underline{A}) = log(\underline{B}) + log(\underline{C}), \quad (2)$$

what can be written in the shorter way

$$A = B + C \quad (3)$$

Thus the Risk Index (A) can be a natural number from 2 (the lowest risk) to 10 (the highest risk).

To use proposed method it is necessary to define the limits of the above mentioned indexes which implicate the respective actions. Then predefined criteria depend on the nature of the considered case.

The proposed risk matrix looks then as follows

Table 6. Risk matrix basing on addition of indexes

Risk Index *A*						
		Severity Index *B*				
		1	2	3	4	5
Frequency Index *C*		very slight	Slight	moderate	high	Very high
1	unlikely	**2**	**3**	**4**	**5**	**6**
2	likely	**3**	**4**	**5**	**6**	**7**
3	quite possible	**4**	**5**	**6**	**7**	**8**
4	possible	**5**	**6**	**7**	**8**	**9**
5	Very likely	**6**	**7**	**8**	**9**	**10**

It is important to see where the boundaries between the risk levels are situated. We can use above mentioned five levels of risk and then divide them accordingly:

- Very low risk (A = 2 or A = 3) – 3 cases,
- Low risk (A = 4 or A = 5) – 7 cases,
- Moderate risk (A = 6) – 5 cases,
- High risk (A = 7 or A= 8) – 7 cases,
- Very high risk (A = 9 or A = 10) – 3 cases.

what gives 25 cases, all possible to be obtained. Then the risk levels cover the matrix values symmetrically.

Using proposed scales for severity and likelihood indexes the risk levels look as follows:

- Very low risk: 12% (of all cases);
- Low risk: 28%;
- Moderate risk: 20%;
- High risk: 28%;
- Very high risk: 12%.

This is what is looks like presented graphically in color coded Table 7

Table 7. Real risk zones of additive risk ratings distribution

		Severity index				
		1	2	3	4	5
Likelihood index	1	2	3	4	5	6
	2	3	4	5	6	7
	3	4	5	6	7	8
	4	5	6	7	8	9
	5	6	7	8	9	10

whereas:

- green color - very low risk;
- blue - low risk;
- yellow - moderate risk;
- orange - high risk;
- red - very high risk.

In another solution the point is that the numbers are used without naming the risk levels. For instance the risk index equals 5 so it is higher than 4 in another case. However both are called the same name "low risk" here. In this way we can assess the risk more precisely avoiding further approximation. And that can be useful when referring the proper precautions to be taken in each case. It is necessary to guide the master (c/o, c/e) how to act when already assessed situation may occur and the risk index equals e.g. 9 of scale from 2 to 10. Thus the respective written forms ought to be adapted properly by the shipping companies.

General example. The job to be done onboard has been assessed in advance according to the new statements in the ISM Manual including FSA. The risk index equals 8 of above mentioned scale. The person in charge (master, c/o, c/e) should know if such a job is allowed to be done e.g. at anchor or alongside the berth only. Apart from the strict requirements and procedures there is a good seamanship, personal experience and common sense to be relied upon. However it differs depending on the person in charge, especially when an extraordinary situation happens -and this needs to be assessed as well. If the official manuals say that all actions of risk index equal or higher than 7 can be done only when alongside the quay with proper precautions taken then the decision (risk index 6 or 7) made onboard causes the serious consequences for the ship's operation. Another question occurring here is: if the risk index equals 9 or 10 (very high risk) so can a job (whatever it is) be done when at anchor or not?

We can see that there is a need for clearly defining the main actions to be taken following the risk index (especially at higher risk levels) in general by the company which can be used by the responsible person onboard. Otherwise, the risk assessment matrices as a guidance on risk assessment for use with respective form will not be pragmatic. To tell the truth it will not work at all and seem to be just the paper fulfillment of new IMO obligatory document. Let us think of not everyday situations when we are obliged to assess the risk indeed and make the decision onboard in not too long time period. We ought to know up to what risk level we are allowed to solve the problem.

It is impossible in practice to predict all situations onboard and have the manual ready in each imaginary but possible event. This article also shows how the new item works or can work, and how to optimize it following the IMO recommendations.

3.2 Literature

Formal Safety Assessment can also be used in the passage planning what is shown in Fig. 1 taken from the literature on practice and principles of passage planning [5, 6]. At the execution stage there are two important tasks to be considered:

- Risk assessment and management
- Bridge resource management

To assess the risk, five steps are used:

a) Identify the hazards;
b) Consider the potential harm;
c) Evaluate the risks. Establish if existing precautions are sufficient;
d) Record all findings and measures of control;
e) Review the assessment and if the risks are still not controlled, revise the plan until a satisfactory conclusion has been reached.

Risks have been divided into five zones, as what is presented in Table 8:

I. *Trivial Risks* – risks deemed unimportant. Action to reduce the risk is not normally required.

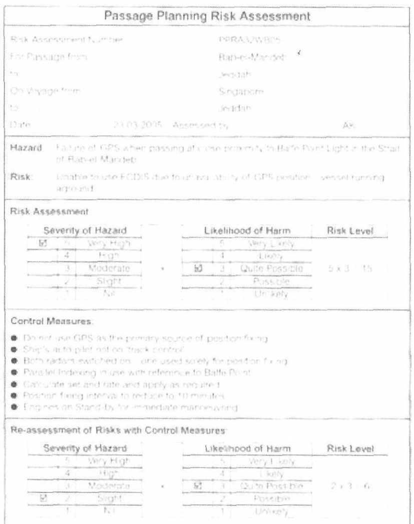
II. *Tolerable Risks* – risk that can be tolerated or accepted without any possible harm but that should be monitored to maintain control; e.g. transiting a narrow passage during the day as compared to a night transit in the same area.

III. *Moderate Risks* – additional resources are required to achieve substantial control of the potential risk, with a possibility of an increase in cost e.g. posting a helmsman.

IV. *Substantial Risks* – risks that are unacceptable and have to be reduced at any cost e.g. in restricted visibility, reduction of speed and doubling watch keepers on the bridge.

V. *Intolerable Risks* – risks that cannot be controlled or reduced due to the level of severity and the non-availability of resources. Under these conditions the passage cannot be continued e.g. when a ship meets very severe weather and has to seek shelter.

As an example, risk is given for a hazard *Failure of GPS when passing at close proximity to Balfe Point Light in the Strait of Bab-el-Mandab.* The risk has been identified as *Unable to use ECDIS due to the unavailability of GPS position, vessel running aground.* To pass through the area safely the vessel is using control measures to eliminate or reduce the risk.



Passage Planning Risk Assessment

Risk Assessment Number	PPRA32WB05
For Passage from	Bab-el-Mandeb
to	Jeddah
On Voyage from	Singapore
to	Jeddah
Date 23.03.2005 Assessed by	AK

Hazard Failure of GPS when passing at close proximity to Balfe Point Light in the Strait of Bab-el-Mandeb

Risk: Unable to use ECDIS due to unavailability of GPS position – vessel running aground

Risk Assessment

Severity of Hazard				Likelihood of Harm			Risk Level
☑	5	Very High			5	Very Likely	
	4	High			4	Likely	
	3	Moderate	×	☑	3	Quite Possible	5 x 3 = 15
	2	Slight			2	Possible	
	1	Nil			1	Unlikely	

Control Measures:

- Do not use GPS as the primary source of position fixing
- Ship's auto pilot not on 'track control'
- Both radars switched on – one used solely for position fixing
- Parallel Indexing in use with reference to Balfe Point
- Calculate set and rate and apply as required
- Position fixing interval to reduce to 10 minutes
- Engines on Stand-by for immediate manoeuvring

Re-assessment of Risks with Control Measures:

Severity of Hazard				Likelihood of Harm			Risk Level
	5	Very High			5	Very Likely	
	4	High			4	Likely	
	3	Moderate	×	☑	3	Quite Possible	2 x 3 = 6
☑	2	Slight			2	Possible	
	1	Nil			1	Unlikely	

Fig. 1 Example of the Formal Safety Assessment in passage planning [5, 6]

It is stated there that the risk level had been estimated with indicated control measures in place. If the control measures are not implemented, the risk assessment would not be valid and the risk level will increase. In reassessment of risk the likelihood of harm has been given a scale of 6 and it has been assumed that one radar is operational on parallel indexing throughout the passage.

It is suggested by the authors in [5,6] that a risk assessment be carried out and the resultant rating and action noted in the planning sheet and the assessment number entered in the passage plan check-list for the future references. It is also recommended to re-assess risks on a case-by-case basis and to ensure that control measures are in place.

Analyzing the risk matrix and applied algorithm we can find out that the analogous mistakes analogous as to presented in paragraph 3.1 have been made again. The essential point is that they caused very serious consequences in the context of proposed risk zones and followed actions to be taken.

Table 8. Risk zones with symmetric risk ratings distribution [5, 6]

Level	Rating	Action
1–5	Trivial	No further action required
6–10	Tolerable	Monitoring required to ensure that the controls are maintained
11–15	Moderate	Efforts to reduce risks required with attention to allocation of resources and amount of time required for reducing risk.
16–20	Substantial	Ship cannot proceed on passage until risk is reduced. Allocation of resources and time can increase to very high amount but ship may proceed on voyage once risks have been reduced.
21–25	Intolerable	Passage cannot be continued even with unlimited resources.

As we read in foreword [6] *all Bridge Officers, experienced or otherwise* are to be encouraged *to consider their own passage planning standards against these two works* (i.e. [5, 6]), *particularly with reference to the highly important section on Risk Assessment*. That is the recommendation coming from Tanker Operators Safety Forum. So the idea is worth focusing on, however it is absolutely not allowed to base the FSA in passage planning including the same arithmetic misunderstanding as in above mentioned Company form in paragraph 3.1. The details are presented in Figure 1 and Table 8. The table, including the risk zones and respective range of values, seems to be divided equally in five zones. In fact the limits of safety are shifted considerably to what allows the dangerous situations to happen according to proposed partition instead of guiding the person in charge to avoid such a case. That is especially clear in substantial and intolerable zones. This proof is analogous as before for the Table

9 as well as Table 3. The example coming from the nautical literature says to pay attention again to the proper implementation of FSA in practice following the IMO recommendations.

4 Conclusion

The problem of the implementation of Formal Safety Assessment is present in various fields of maritime research and application. The motivation to focus on the problem has come directly from the real life. The improper use of recommended tools by IMO has the opposite effect to the assumed one. The level of safety is decreased indeed when basing on the arithmetic algorithm which is not properly used. In general it is difficult to expect from the seafarers in charge to be well educated in the methods of advanced statistics and probability and to use them in FSA onboard. That is why the mathematically complicated tools were to be made easier for general use. As a guidance, the risk matrix has been evaluated, including the natural numbers as a fundamental element of risk assessment. The new form affects various events of marine operations including passage planning, security and safety matters. Interested parties having carried out an FSA application should provide the most significant results in a clear and concise manner, which can also be understood by other parties not having the same experience in the application of risk assessment from the FSA study. The methods and techniques used to carry out the assessment should be described as recommendations for decision-makers. The importance of the proper implementation of risk matrices and the relevant techniques is shown in particular as the FSA is a rational and systematic process for assessing the risks relating to maritime safety and the protection of the marine environment. To facilitate the understanding and use of the results the respective forms and reports should be based on the mathematically correct assumptions and algorithms.

The examples of practical implementation of FSA including the improper use of recommended notions and methods have been presented in the article to make a better understanding of risk assessment tools well worth exploring.

Acknowledgements

This research is supported by the Foundations of Polish Science research grant 43./2007

References

[1] *Guidelines for Formal Safety Assessment (FSA) for use in the IMO Rule – Making Process*, MSC/ Circ. 1023, MEPC/ Circ. 392, London, 2002.

[2] Resolution IMO A. 500 (XII), *Objectives of the Organization in the 1980's.*

[3] Resolution IMO A. 777 (18), *Work Methods and Organization of Work in Committees and their Subsidiary Bodies.*

[4] Resolution IMO, A. 900 (21), *Objectives of the Organization in the 2000s.*

[5] Anwar N., Khalique A.(2006). *Passage Planning Practice.* Witherbys Publishing Ltd. & Seamanship International Ltd., London, Lanarkshire.

[6] Anwar N., Khalique A. (2006). *Passage Planning Principles.* Witherbys Publishing Ltd. & Seamanship International Ltd., London, Lanarkshire.

[7] Nincic D.J., Clark B. (2006). The utility of risk assessment tools in maritime security analysis. *Proceedings of Globalozation and MET, 7th Annual General Assembly and Conference. AGA – 7*, The International Association of Maritime Universities, Dalian, China.