Scientific Journals
of the Maritime University of Szczecin

Zeszyty Naukowe
Akademii Morskiej w Szczecinie

2018, 54 (126), 44–53
ISSN 1733-8670 (Printed)
ISSN 2392-0378 (Online)
DOI: 10.17402/284

Received: 24.10.2017
Accepted: 16.05.2018
Published: 15.06.2018

Safety trends in the oil tanker industry

Peter Vidmar, **Marko Perkovič**

University of Ljubljana, Faculty of Maritime Studies and Transport
Pot Pomorščakov 4, 6320 Portorož, Slovenia
e-mail: {Peter.vidmar; Marko.Perkovic}@fpp.uni-lj.si, @fpp.uni-lj.si
corresponding author

Key words: risk assessment, safety, oil tanker, maritime safety, risk criteria, oil pollution

Abstract

The paper presents the overall risk management state for the crude oil tanker fleet, evidenced by EMSA and other international marine organisations. Based on historical statistical data related to fleet size, accident reports, amount of oil spilled on the sea and the economic value of the crude oil transport business, the risk acceptance criteria are evaluated. The Formal Safety Assessment is further used for a systematic assessment of risk, where potential hazards are analysed with structured methods (HAZID) and represented in event trees. The paper studies three risks: PLL (potential loss of lives), PLC (potential loss of containment) and PLP (potential loss of property). A general approach is presented and discussed with a particular focus on the evolution of risk acceptance in recent decades and evaluations of risk F-N curves for different tanker sizes.

Introduction

Maritime safety is governed by maritime safety policy instruments, which aim to maintain the risk level within an acceptable range. For accidents mainly concerning persons, the criteria are related to potential loss of lives and represent individual and societal risk. Oil tanker transport directly impacts the safety of a crew that is limited, depending on ship size, to between 20 and 30 crew members. The European Maritime Safety Agency (EMSA) reports that the annual number of fatalities among crew on cargo ships varies from 30 to 50 (last five years). Oil tankers have the lowest frequency of fatalities compared to other ship types (Burgherr, 2007). The direct impact of tanker accidents on civilians is limited and analysed mainly for port areas close to cities and straits passing populated areas (Burgherr, 2007). This implies a specific risk assessment that usually considers local ship traffic statistics. Small ports or new terminals are not included here, because the representative data are not available, and so a qualitative approach (like that of the Ports and Waterways Safety Assessment, PAWSA) or a comparative method with data from a similar region or terminal is used. A comprehensive approach is proposed by the International Maritime Organisation (IMO) in the Formal Safety Assessment for Crude Oil Tankers (IMO, 2008) and further developed by Skjong et al. (Skjong, Vanem & Endresen, 2005) and Eliopoulou and Papanikolaou (Eliopoulou & Papanikolaou, 2007) in the SAFEDOR project (Design, Operation and Regulation for Safety) and related team publications.

Oil tanker transport risk is particularly sensitive from the environmental aspect, related to the loss of containment, particularly in coastal areas. The reason can be mainly explained from the economic view. First there is the cost of cleaning a polluted coastline; second, much more comprehensive, is the loss of revenue from other economic sectors (tourism, mariculture, quality of coastal living, value of land and property…) (Etkin, 2001; 2015; Montewka, 2013).

The third risk estimation regards the economy of the oil transport itself. This refers to the risk of the loss of property, including the value of the ship and cargo, but also the costs of penalties, compensation and other direct and indirect costs. Different insurances reduce the economic risk for the shipping company (like ship insurance, cargo insurance during carriage, insurance for war risks and risks of environmental damage, such as oil spills and pollution). For a single accidental event, the economic value could vary depending on the value of the ship and cargo or the location of the accident, though mainly on the magnitude of the accident. The Maritime Safety Committee (MSC) Formal Safety Assessment (IMO, 2000; 2008) assumes that, for severe collision damage, the ship damage cost is 5% of the ship's value. Information on damage costs is not in the public domain, which is why an average value was used.

All three risks are calculated from the same interrelation of data. The tanker world fleet review is obtained from the German ISL (Institute of Shipping Economics and Logistics) statistical publication (ISL, 2016) from 2007 to 2016. Fleet statistics and casualties up to 2007 are analysed in the MSC FSA report (2008) and used to extend the statistical period back to the year 1980 and evaluate a more representative result.

Focus on risk assessments

The Formal Safety Assessment (FSA) for crude oil tankers is a tool for risk evaluation developed by IMO, more precisely the SAFEDOR project consortium (Skjong, Vanem & Endresen, 2005), to enhance the safety of ships, crews, and the environment. The FSA uses five steps: hazard identification (HAZID), risk assessment, risk control options, cost benefit assessment and decision-making recommendations. Its goal is a systematic approach to safety in all aspects regarding particular vessels. This paper examines the FSA in relation to the latest tanker fleet and accident statistics, with a particular focus on risk acceptance criteria and events that have most influence on the level of risk. The use of statistics and expert opinion for hazard operability (HAZOP) is valuable information for the evaluation of probability, rather than the evaluation of consequences. The magnitude of these last is more a matter of physics and consequence analysis. The following chapters present the proposed methodology and results, which are validated and discussed with a view to wider application.

Risk evaluation criteria

Risk Acceptance has been included in the assessment of methods and tools, as it might be a decision criterion for organizations (e.g., in the financial and insurance sector, in critical infrastructure protection, the shipping sector). Again, one reason for explicitly mentioning Risk Acceptance is the need to draw management's attention to this issue. The risk criteria should reflect the organization's values, policies, and objectives, should be based on its external and internal context, should consider the views of stakeholders, and should derive from standards, laws, policies, and other requirements (Bottelberghs, 2000). Considering the IMO FSA guidelines for crude oil tankers regarding the principle of ALARP (As Low As Reasonably Practicable), one can understand the reasons for risk acceptance levels based on cost-benefit computations. However, depending on the country and company policy on risk acceptance level, risk treatment could and should be a continuous challenge, independently based on results of risk evaluation or cost-benefit equilibrium (Vidmar & Perkovič, 2015). For crude oil tankers, the risk criteria are based on three primary risks; potential loss of life (PLL), potential loss of containment (PLC) and potential loss of property (PLP). The responsibility to keep each of these primary risks at an acceptable level is shared between the shipping company, state legislation, maritime rule regulator and individual seafarer. The calculated tolerable risk is directly related to the product of accidental events and the economic value of the assessed business; that which delivers higher business values allows higher tolerable risks (Bichard, 1989).

Individual risk

Individual risk is the frequency of an individual fatality per year, the likelihood that the most exposed crew member will die as a result of an accident or event on board a ship. This report only considers events related to ship operation. Accidents due to intentional activities and occupational risks are not within our scope.

The authors Cornwell and Meyer (Cornwell & Meyer, 1997), Trbojevic (Trbojevic, 2005), Lohansen (Lohansen, 2009) and others have emphasized individual risk criteria based on existing national standards and guidelines. The harmonization of risk acceptance criteria for the transport of dangerous goods is proposed in the final report of the DG-MOVE (Director General for Mobility and Transportation) project (Spoure, 2014), finalized by DNV-GL for the European Union. The report indicates that a cost of £2M per fatality averted is often used to indicate where risk reduction measures were "reasonably practicable". Though there is logic to the amount and how it was arrived at, the idea is essentially misguided. The risk criteria should always be based on the economic value of the business. The value of 2 million per fatality is equivalent to the average earnings of a person in 40 years of work. In my opinion, the valuation of human life on this basis would not be socially accepted, because it is posting a price on people's lives. Basically, this could only be the measure of a lower acceptance criterion: the upper should always be based on the economic value of the business.

The potential loss of life is calculated as:

$$\mathrm{PLL}_A = r \cdot \mathrm{EV} \tag{1}$$

where r is the number of fatalities due to the activity divided by the financial contribution of the activity and EV is the economic value of the business; in this case, EV represents a reference vessel and is derived from the revenue of a ship per year. Based on this approach, both values change yearly (Crenes, 2017). The changes of main values in the last decade are presented in Figure 1.

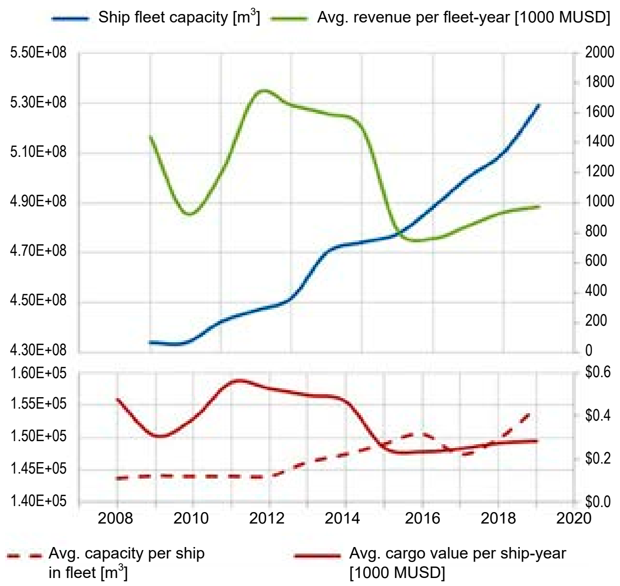

Figure 1. Global average oil tanker capacity and revenue

Considering the size of the oil tanker business and the number of crew members on a single ship (between 20 to 30), the calculated risk criterion for a crew member is very high compared to other transport processes. For the year 2016, r is calculated at 0.002623 fat/1000M\$. Converting this to risk-acceptable cost per fatality yields 381.2 1000M\$/fat. Compared to cruise shipping, the risk level acceptance criteria for passengers is about 1.5 fat/1000M\$ or 666 M\$/fat, for road transport 100M\$/fat and so on. Observing these values, risk criteria are posted very high, but they are not the only criteria dictating risk policy and risk control actions. The potential loss of life is calculated from Eq. (1) and gives 0.000617 fat/ship year for 2016.

Oil tanker shipping also has environmental risks due to pollution and economic risks due to potential loss of property in case of accidents.

Oil pollution risk

Assuming the same approach for calculating risk criteria as that for crew, the oil pollution criterion r is calculated as a fraction of total spill quantity and financial contribution of the activity in a single year. The spill quantity is obtained from ITOPF statistics (ITOPF, 2017) and varies from 2,000 to 15,000 tons per year. This gives a pollution criterion of 6.55 tons spilled/1000M\$ or 152.6 M\$/ton spilled. Further, the potential quantity spilled is a product of the pollution risk criteria and the economic value of the oil shipping business.

$$\mathrm{PLC}_A = r \cdot \mathrm{EV} \tag{2}$$

This gives a potential loss of containment that is 1543 ton/ship/year for 2016. This value is obviously a spill quantity for an average ship size in the fleet. The average ship size is calculated considering the number of ships in each category from Handysize to VLCC tankers. The average size is about 70,000 DWT (deadweight tonnage), almost Panamax size. Further, the frequency of accidents with a ton or more oil spilled is calculated and for the year 2016 it gives 1.3010^{-1} /year.

$$F_2 = \frac{\mathrm{PLC}_A}{\sum_{N=1}^{N_u} \frac{1}{N}} \tag{3}$$

where:

F_2 – is the frequency of accidents involving one or more ton spilled;

N_u – is the upper limit of spill quantity that may occur in one accident (total loss);

PLC_A – annual potential loss of containment.

The calculated value F_2 could be considered as the tolerable accident frequency for an oil spill. The boundary area around this value defines the ALARP region. This is defined by dividing F_2 by factor 0.1 for the upper border of ALARP and multiplying by 0.1 to bound the lower border.

Loss of property risk

The risk of losing part or all of the cargo and costs of ship damage or total loss is an economic risk that primarily influences the company policy. The world fleet statistics show that the number of accidents is increasing in recent years, along with the number of ships. On the other hand, the consequences of accidents are less severe, thanks to the continuous maritime standards improvements in ship construction, electronic navigation control, shore vessel traffic services and other factors.

The risk of property loss is here calculated with the same approach as PLL and PLC. The calculation for PLP is now:

$$\mathrm{PLP}_A = r_p \cdot \mathrm{EV} \quad (4)$$

where EV is an average ship revenue per year and r_p is an average loss of property per average revenue per ship.

$$r_p = \left(\mathrm{NA} \cdot \mathrm{SV}_{\mathrm{av}} \cdot f_{dmg}\right) + \frac{Q_{\mathrm{spill}} \cdot P_{\mathrm{av}_y}}{rev_{a\_s}} \quad (5)$$

where:

NA – is the number of accidents for oil tankers with 60,000 DWT and more in the analysed year;

$\mathrm{SV}_{\mathrm{av}}$ – an average new ship value (when analysing sizes from Handysize to VLCC, the average value is about 50 M$);

f_{dmg} – is an average factor of damage cost. According to the Marine Environment Protection Council, MEPC 58/INF.2, this is about 5% of the new ship value for severe collisions, 10% for severe fire and explosion accidents. Non-severe accidents have a damage factor of about 2%. For the purpose of this study f_{dmg} is assumed to be 4%;

Q_{spill} – is the quantity of oil spilled in the analysed year according to ITOPF (International Tanker Owners Pollution Federation);

$P_{\mathrm{av}y}$ – is the average oil price in the analysed year;

rev_{a_s} – is the average revenue per ship in the fleet during the analysed year.

The unit for PLP_A is the ratio of property loss in M$/ship year to M$ business economic value. Further, the frequency of property loss is calculated with Eq. (6), where N_u is the cost of a total loss, depending on ship type. An average value of $\sum_{N=1}^{N_u} \frac{1}{N}$ for Panamax size is 4.5.

$$F_3 = \frac{\mathrm{PLP}_A}{\sum_{N=1}^{N_u} \frac{1}{N}} \quad (6)$$

For the year 2016, the tolerable damage cost F_3 is 2.96E-2 property lost/M$/ship year. The acceptable area around this value is defined by a factor of 0.1.

Societal risk

In most countries, the risk assessment is performed on the basis of potential fatalities to the exposed population. Different countries use slightly different criteria for risk acceptability. In the UK, the Health and Safety Executive (HSE) guidelines are available for use for individual risk as the principal measure, but also for use as the societal risk criteria for land-use planning. Facilities are permitted only when these published criteria are met. In the Netherlands, however, both the individual risk criteria and the societal risk criteria must be met when considering those events whose hazardous effects extend to such distances at which the conditional probability for lethality is higher than 1%.

F-N curves are, however, a common way of presenting societal risk and are considered by some parties the best way of illustrating this data. The method of deriving societal risk evaluation criteria in this report is based on IMO (IMO, 2008) decision parameters, including risk acceptance criteria and updated by the EU Eco-Management and Audit Scheme (EMAS) report on risk level acceptance criteria (Spoure, 2014). The risk level is plotted as a cumulative function of consequence and frequency on a log-log graph.

$$F_1 = \frac{r \cdot \mathrm{EV}}{\sum_{N=1}^{N_u} \frac{1}{N}} \quad (7)$$

where:

F_1 – is the frequency of accidents involving one or more fatalities;

N_u – is the upper limit of the number of fatalities that may occur in one accident;

r – the number of fatalities due to transportation divided by contribution to GNP by transportation. It can be calculated as r = fatalities/$ GNP and

EV – is the economic value of the industry. In this case EV represents a reference vessel and is derived from the revenue of a ship per year.

The value of tolerable risk is calculated for the year 2016 and is 1.6E-4 fat/year. The upper tolerable limit has been obtained by multiplying the calculated tolerable risk by a factor of 10, obtaining F_{upper} = 1.6E-3, and the lower limit by dividing the calculated risk by factor 10, obtaining F_{lower} = 1.6E-5. The same approach is applied by IMO (IMO, 2008). The boundary limits are, therefore, computed; however, computed limits, as discussed in the introduction, could only be used as the lower boundary limit of the upper risk criteria limit. Additional reduction of the upper risk criteria limit could be based on company policy.

Based on equation (1) and the yearly statistics, the upper limit of the ALARP region changes its value. Taking into account only the period between 2010 and 2016, which is best documented, we can see the variation of the frequency of accidents involving one or more fatalities, spills and property loss depending on accident type. A simple trend prognosis is also applied for data up to 2019 to see the evolution of risk acceptability. The prognosis of risk is based on the short-term prognosis of ship fleet growth (ship orders, ships in construction) and the prognosis of world oil production. Figure 2 shows the calculated tolerable frequency of fatalities per year (F_1). Similarly, the tolerable spill frequency (F_2) and tolerable property loss (F_3) are presented. First of all, the magnitude of each is distinguished. The higher acceptability likelihood is for spill events that occur continuously. The continuous large number of these events influences their higher acceptability. The loss

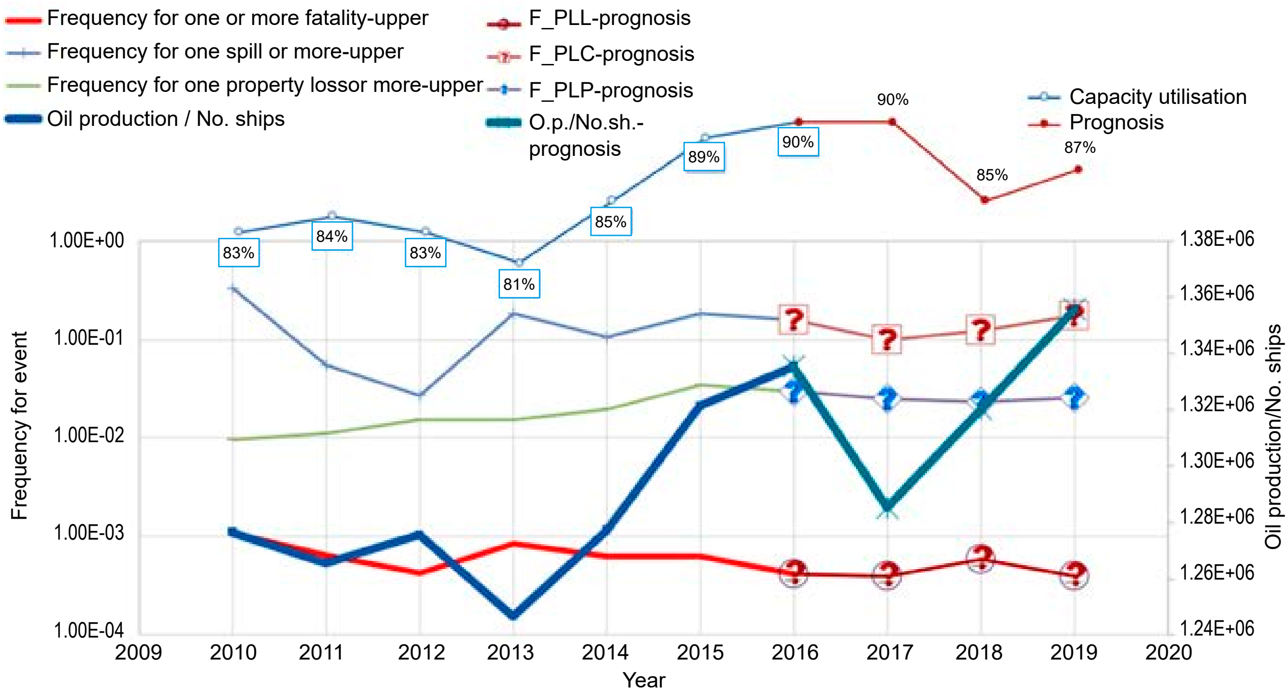

Figure 2. Calculated upper border of ALARP region per year

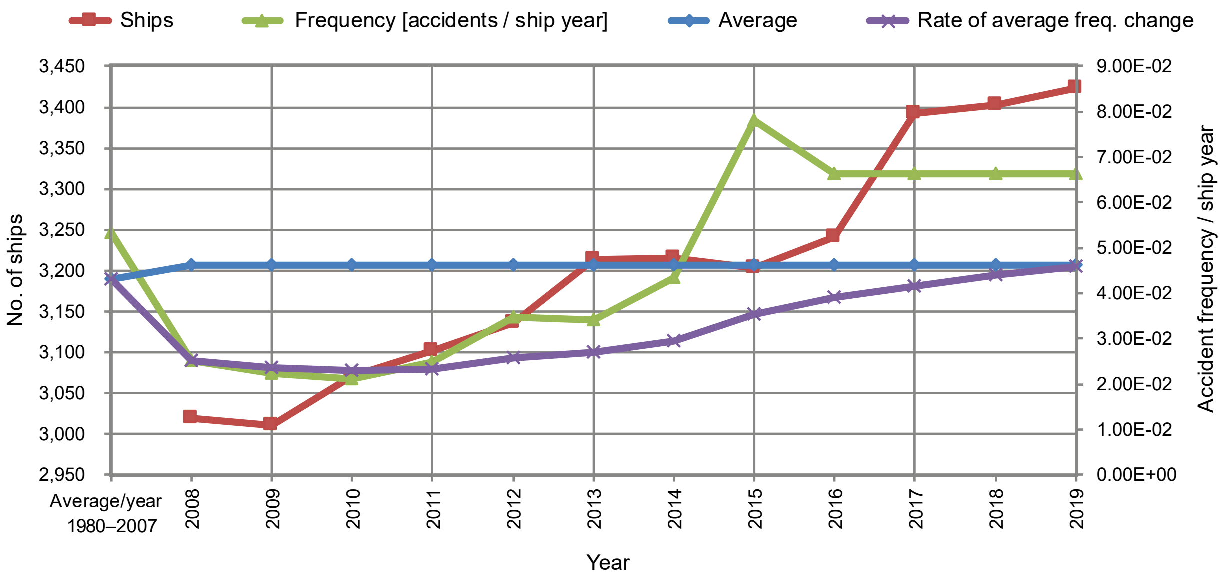

Figure 3. Accident frequency, year-by-year (per ship)

of containment itself gives just a first answer to oil spill acceptability; the second is the quantity of the spill directly related to the loss of property. The frequency of both loss of containment and loss of property have an increasing trend related to oil production and seaborne trade. Simply, more oil production and trade leads to higher acceptability of spill-related accidental events. Fortunately, the trend event frequency acceptability is much slower than the seaborne trade of oil (Tsaini, 2012; Whelan, 2016).

A review of the last three-and-a-half decades shows a dynamic accident trend, presented in Figure 3. The review takes into account high-risk accidents only; contact-collision, fire, grounding and sinking. From 2011 to 2015, 6,403 cargo ships were involved in 5,942 marine casualties and incidents, 670 of which were oil tankers (EMSA, 2016a; 2016b). Among the large number of reported accidents, about 15 are classified as high-risk. The graph shows an increase of the average accident frequency from 2008. Figure 3 shows the increase of accident frequency, which is related to the increase of ships in trade. The future is unknown, but the trend shows an increase of the tanker fleet in the coming years.

Accident frequency calculation

The exposure during the 1980–2016 period has been 71,422 ship-years and this will be used for the accident frequency calculations. The frequency calculations can be summarized as the ratio of accidents for each accident type to the total number of accidents. However, the number of accidents with fatalities is too few to represent any significant accident trend. As already mentioned, the frequency of accidents is increasing: the average frequency value from 1980 to 2008 was 4.3E-2 per year, but has increased to 4.6E-2 per year over the last decade. That is a relatively small change but still confirms the statistical relation between seaborne trade growth and the occurrence of accidents (OGP, 2010; Goerlandt, 2015).

On the other hand, the consequences of these accidents have been reduced. Table 2 indicates that the average oil-spill frequency has been reduced by a factor of 10 in the last decade, compared to the period between 1980 and 2007.

Consequences

The consequence of an accident is defined as the expected number of fatalities, if such an accident occurs. In order to perform consistent and comparable consequence assessments, fixed bands of expected numbers of fatalities are defined. As proposed by IMO (IMO, 2008), bands are defined to suit the reference vessel. In our case, tanker ships are ranged by their sizes from Handysize to VLCC. Each vessel band is further divided into 13 fatality bands, covering the full range of accident severities, from a minor scenario to a catastrophic accident resulting in a large number of fatalities. The same approach is applied for consequences of oil spills and for

Table 1. Accident frequency calculations for oil tankers between 1980–2016

Oil tanker	Collision/Contact	Sinking	Grounding	Fire/Exp.	Other	SUM
Ships > 20,000 GRT						
Accidents recorded 1980–2016	1222	6	599	435	678	2940
Ship years 1980–2016 [ship years]	66423.2	66423.2	66423.2	66423.2	66423.2	66423.2
Tanker accident frequency [per ship year]	**1.84E-02**	**9.03E-05**	**9.02E-03**	**6.55E-03**	**1.02E-02**	**4.43E-02**
Return period [No. of ship years per accident]	54	11071	111	153	98	23
Number of fatalities, 1980–2016	61	0	6	181	32	280

Table 2. Oil spill frequency calculations for oil tankers between 1980–2016

Oil tanker	Collision/Contact	Grounding	Fire/Exp.	Other	SUM
Ships > 20.000 GRT					
No. of spills 1980–2016	447	343	124	120	1034
Ship years 1980–2016 [ship years]	66423.2	66423.2	66423.2	66423.2	66423.2
Tanker spill frequency [spills per ship year] 1980–2007	**1.10E-02**	**8.43E-03**	**2.90E-03**	**2.80E-03**	**2.52E-02**
Tanker spill frequency [spills per ship year] 2008–2016	**9.57E-04**	**7.44E-04**	**4.61E-04**	**4.61E-04**	**2.62E-03**
Return period [no. of spills per ship years]	148.60	193.65	535.67	553.53	64.24
Oil spilled [tonnes] 1980–2016	229778	377282	844051	220991	1672102
Tanker spill frequency [tonnes per ship year]	3.46E+00	5.68E+00	1.27E+01	3.33E+00	2.52E+01

consequences of property loss. Bands of each consequence category are based on the average characteristics of the ship and are visible in Table 3, as the values for a specific band size. The second table presents category bands only for Panamax ship size, but any ship size in Table 3 has a similar band distribution, based on its cargo capacity, ship value and number of crew members. We can observe that the value of the ship in the two tables is different. The reason is that the second table includes the value of the transported cargo, calculated on its export price.

It is important to note that the identified fatality bands only apply to the referenced vessels defined for this study. Each final event is connected to an

Table 3. Ship size characteristics and consequence bands

	Capacity 100% [m^3]	Capacity 95% [m^3]	Ship value	Crew members
Other	4,200	4,116	10,000,000.00 €	
Handysize	30,000	29,400	25,000,000.00 €	20
Handymax	55,000	53,900	35,000,000.00 €	24
Panamax	79,000	77,420	50,000,000.00 €	26
Aframax	122,600	120,148	65,000,000.00 €	28
Suezmax	170,000	166,600	85,000,000.00 €	32
VLCC	340,000	333,200	130,000,000.00 €	32

Panamax	% of fatalities on board	Panamax	% of cargo spilled	Panamax	% Damage extent
CREW		Environment		Property	
0	0.00%	0	0.00%	– €	0.00%
1	4.00%	77	0.10%	**74,193.00 €**	0.10%
2	10.00%	193	0.25%	**185,484.00 €**	0.25%
3	15.00%	387	0.50%	**370,968.00 €**	0.50%
5	20.00%	774	1.00%	**741,937.00 €**	1.00%
6	25.00%	1,935	2.50%	**1,854,843.00 €**	2.50%
9	35.00%	3,871	5.00%	**3,709,687.00 €**	5.00%
13	50.00%	11,613	15.00%	**11,129,062.00 €**	15.00%
15	60.00%	19,355	25.00%	**18,548,437.00 €**	25.00%
18	70.00%	23,226	30.00%	**22,258,125.00 €**	30.00%
20	80.00%	38,710	50.00%	**37,096,875.00 €**	50.00%
23	90.00%	54,194	70.00%	**51,935,625.00 €**	70.00%
26	**100.00%**	**77,420**	**100.00%**	**74,193,750.00 €**	**100.00%**

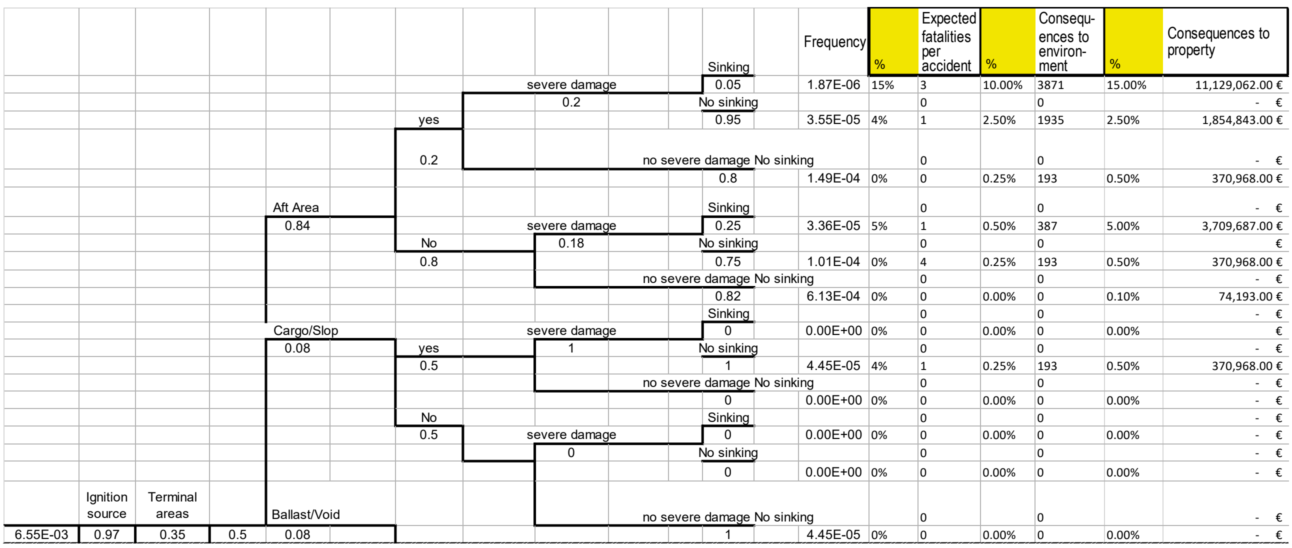

Figure 4. Tanker ship fire event tree (upper part)

estimated number of fatalities. The expected number of fatalities is selected from one of the thirteen possible bands, as defined before. The event tree and probabilities for each event have been carried out together with other participants involved in the Hazard Identification process. The basic structure of the event tree is based on the IMO (IMO, 2008). The same event tree and calculated frequencies for each branch are used for the calculation of PLL, PLC and PLP (Gucma, 2007). The assumption of fatalities, spill quantity and property loss is based on Table 3. The event tree for a fire event is presented in Figure 4.

The percentage value represents the share of the total number of crew on the analysed ship band. Similarly, the percentage of spill quantity is used in the second column and the percentage of cargo loss in the third column. The initial frequency of the accident event in Figure 4 for grounding is calculated using statistical data from 1980 to 2016 and is explained in Table 1. The intermediate probabilities of tree branches are used as in MEPC; however, further improvement of them is possible, applying wider HAZOP assessment. In the proposed event tree, the percentage of fatalities, oil spill quantity and property loss for each event is predicted on a qualitative basis, proposed by the HAZID group of experts; in our case the authors and port safety department. Those values could, therefore, be enhanced. Data is also partially based on a review of several oil tanker accident reports, available on EMSA and the ITOPF database.

Risk levels

Based on the calculated individual risk frequencies, the societal (collective) risk is computed. Integrating the probability of death for each event over the population specified N_u, represents the number of people killed by a given event. The presentation of results allows us now to observe F-N curves for each accidental event and each tanker size, considering three main risks: loss of life, loss of containment and loss of property. Only the F-N curves for a fire event are presented in the paper because of limited space. The F-N curve is a cumulative value of a frequency obtained from an event tree (Figure 5) for each consequence value in an event tree.

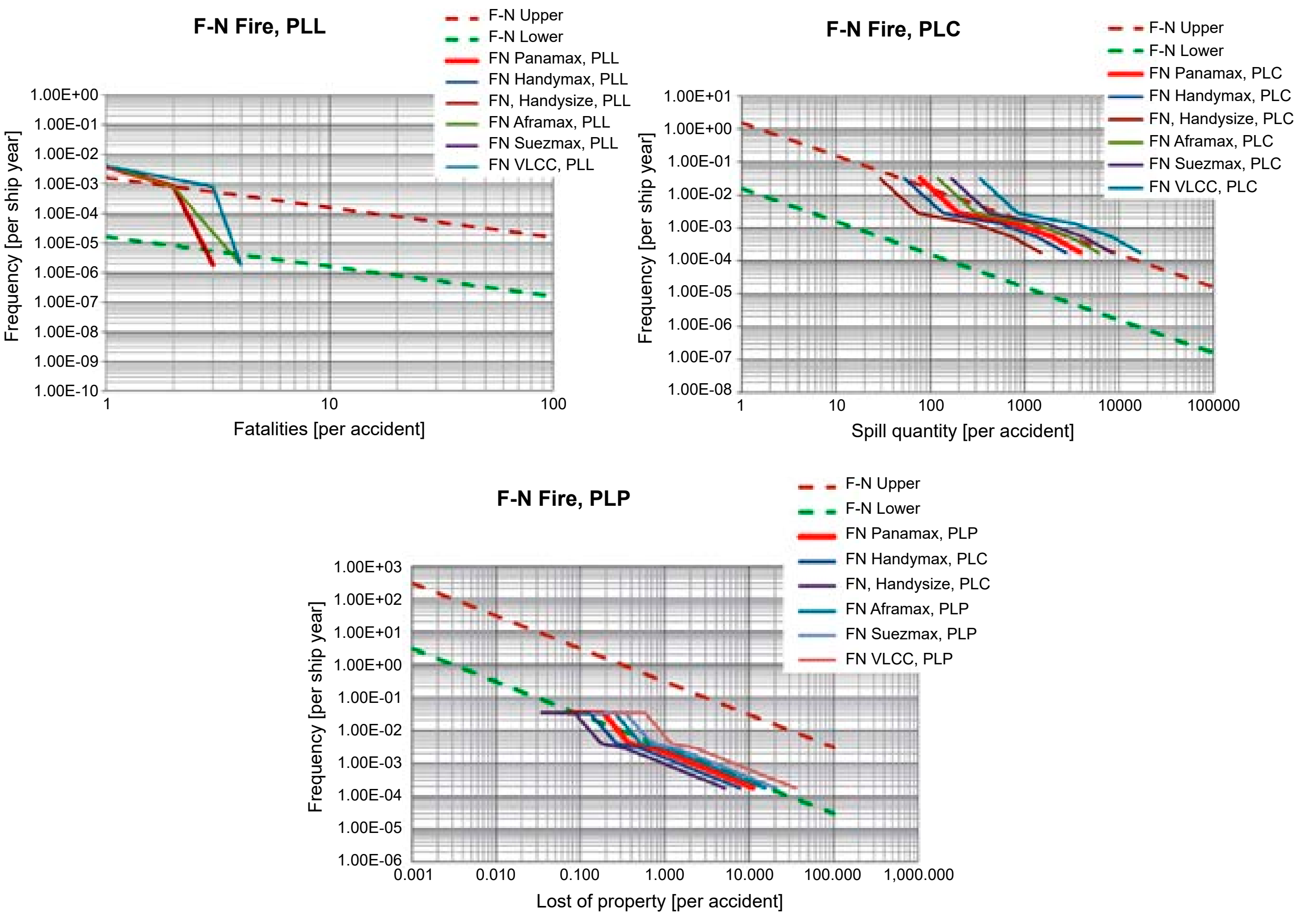

Figure 5. Collective risk level based on tanker category for fire event

The PLC risk for larger ships exceeds the tolerable risk, mainly because of the larger ship capacity. The actual investigation assumes the same percentage of oil spill for the same accident in the event tree, independently of the ship size. In a real seagoing situation, the probability of event evolution is different and also depends on ship size. The results of the assessment have produced risk curves for all the relevant accident types. Most relevant in terms of consequences are further collision, fire and explosion. Contact accident and NASF (Non-accidental structural failure) are presented only in the summary of results.

Overall risk for the oil tanker fleet

The overall risk is the sum of all individual risks of accidents. Risk curves in Figure 6 are considered for Panamax tanker size, because it's the average size in a fleet. The comparison of event risks yields the information that explosion accidents have an unacceptable risk potential for spills between 200 and 800 tons and grounding accidents have an unacceptable risk potential for spills between 4,000 and 20,000 tons. Other accidents are within the acceptable range. The sum of risk curves locates the overall F-N curve above the acceptable level. The conclusion regarding PLC risks is that risk-control activities should be implemented with a particular focus on explosion and grounding accidents. A deeper digging into particular accidents within the event tree model provides information regarding which accidents are critical. These are accidents in loaded or ballast condition that occur in cargo or slope areas (including the pump room and pipe lines), where severe damage occurs. Further investigation into the nature of such accidents and the reason for their occurrence could lead to control options. Further considerations could be that more concise and preventive maintenance is required for critical equipment and that the crew members in charge should focus on understanding risks that occur during the transfer procedure and focus more attention on these procedures.

Conclusions

Safety assessments are currently an integral part of any transport activity, mainly because of a need for transport reliability, which is strongly related to service revenue. The most significant finding is that containment risk exceeds acceptable levels and therefore requires control actions to reduce smaller and medium-size accidental and operational spills. The relation between risk evaluation for loss of containment and loss of property is relevant because the strong economic influence of the oil trade is

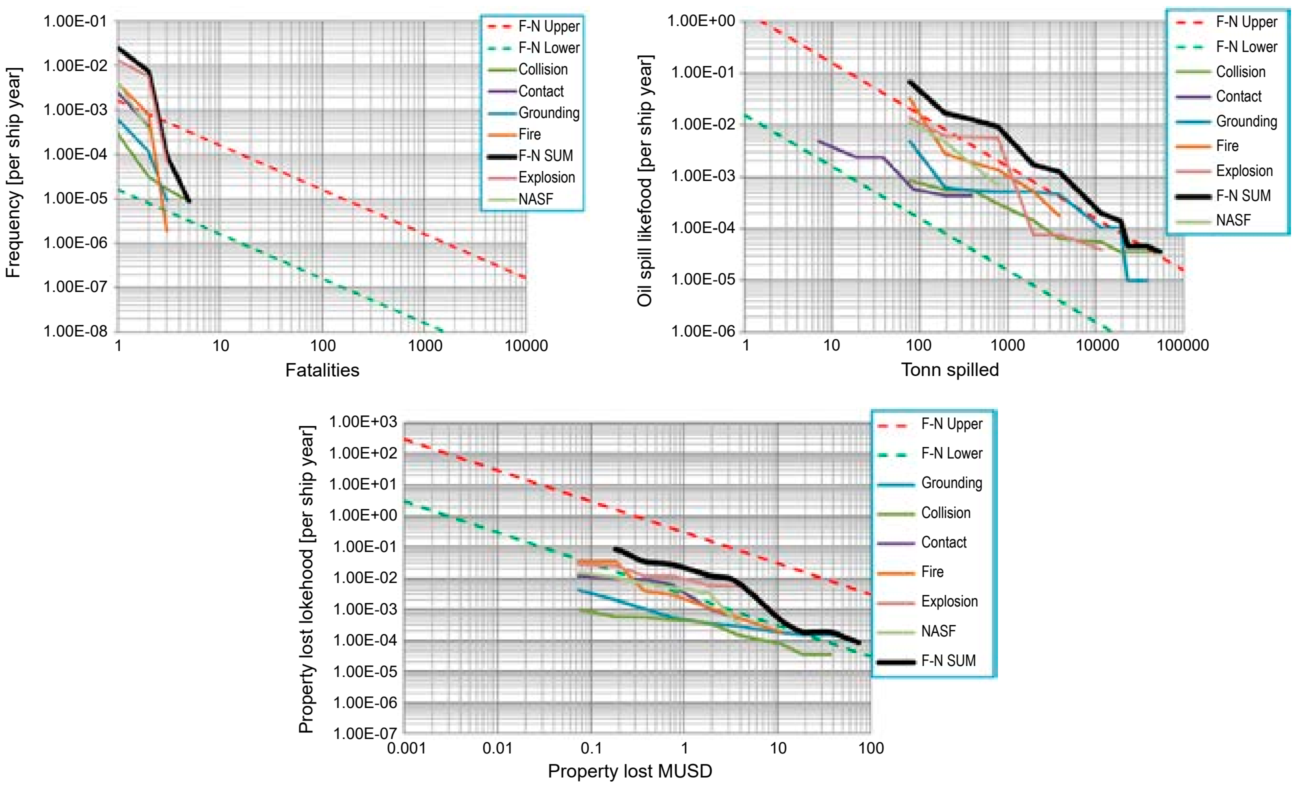

Figure 6. Overall collective risk level based on accident event

prevalent in the ecological realm. While the economic aspect is more related to oil trade companies, the ecological aspect is more related to regulatory parties, especially IMO. The findings of this paper could indicate that, concerning the revenue of the oil trade business, additional control actions should be taken by regulatory parties to reduce the global risk of the loss of containment from ships. The main findings have been stated above; however, on the system level, control actions imply mandatory marine traffic control through Vessel Traffic Services (VTS), the need for updated nautical charts, mandatory Electronic Chart Display and Information Systems (ECDIS), with updated on-line charts and trained, experienced officers in charge of navigation and engine watches.

References

1. Bichard, E.M. (1989) Health & Safety Executive, "Risk criteria for land-use planning in the vicinity of major industrial hazards" (Book Review) Town Planning Review 61(1), pp. 95. https://doi.org/10.3828/tpr.61.1.d2810470h5241061
2. Bottelberghs, P.H. (2000) Risk analysis and safety policy developments in the Netherlands. *Journal of Hazardous Materials* 71, 1–3, pp. 59–84.
3. Burgherr, P. (2007) In-depth analysis of accidental oil spills from tankers in the context of global spill trends from all sources. *Journal of Hazardous Materials* 140, pp. 245–256.
4. Cornwell, J.B. & Meyer, M.M. (1997) *Risk Acceptance Criteria or "How Safe in Safe Enough"*. Risk Control Seminar, Venezuela.
5. Crénès, M., Hafner, M. & Criqui, P. (2017) *Global Energy Scenarios to 2040, Understanding our Energy Future.* [Online] Available from: https://www.enerdata.net/publications/reports-presentations/world-energy-forecasting-scenarios-2017-edition.html [Accessed: May 15, 2018]
6. Eliopoulou, E. & Papanikolaou, A. (2007) Casualty analysis of large tankers. *Journal of Marine Science and Technology* 12, 4, pp. 240–250.
7. EMSA (2016a) *Annual Overview of Marine Casualities and Incidents*. European Maritime Safety Agency.
8. EMSA (2016b) *Maritime Accident Review (2007–2016)*. European Maritime Safety Agency.
9. Etkin, D. (2001) *Methodologies for Estimating Shoreline Cleanup Costs*. Proceedings of 24th Arctic and Marine Oil spill Program Technical Seminar, pp. 647–670.
10. Etkin, D. (2015) *Low probability high consequence events and risk of oil spills*. [Online] Available from: http://vancouver.ca/images/web/pipeline/David-Etkin-estimating-oil-spill-risk.pdf [Accessed: May 16, 2018]
11. Goerlandt, F. & Montewka, J. (2015) A framework for risk analysis of maritime transportation systems: A case study for oil spill from tankers in a ship–ship collision. *Safety Science* 76, pp. 42–66.
12. Gucma, L. (2007) *Evaluation of oil spills in the Baltic Sea by means of simulation model and statistical data*. International Maritime Association of Mediterranean, Balkema.
13. IMO (2000) *MSC 72/16, Formal Safety Assessment – Decision Parameters Including Risk Acceptance Criteria –Submitted by Norway*. International Maritime Organization.
14. IMO (2008) *MEPC 58/INF.2, Formal Safety Assessment – Crude Oil Tankers*. International Maritime Organization.
15. ISL (2016) Shipping Statistics and Market Review (SSMR) (2007–2016), World Tanker Market, Institute of Shipping Economics and Logistics.
16. ITOPF (2017) *Oil Tanker Spill Statistics 2016*. [Online] Available from: http://www.itopf.com/fileadmin/data/Photos/Publications/Oil_Spill_Stats_2016_low.pdf [Accessed: May 15, 2018]
17. Lohansen, I.L. (2009) *Foundations and Fallacies of Risk Acceptance Criteria, Norwegian University of Science and Technology (NTNU)*. Department of Production and Quality Engineering, Norway.
18. Montewka, J., Weckström, M. & Kujala, P. (2013) A probabilistic model estimating oil spill clean-up costs – A case study for the Gulf of Finland. *Marine Pollution Bulletin* 76, pp. 61–71.
19. OGP (2010) *Water transport accident statistics*. International Association of Oil & Gas Producers, Report No. 434-10, UK.
20. Skjong, R., Vanem, E. & Endresen, Ø. (2005) *SAFEDOR, Design, Operation and Regulation for Safety*. Integrated Project Report, DNV.
21. Spoure, J. (2014) *Harmonised Risk Acceptance Criteria for Transport of Dangerous Goods*. DNV-GL Project Report, UK.
22. Trbojevic, V.M. (2005) *Risk criteria in EU*. ESREL'05, Poland, pp. 27–30.
23. Tsaini, P. & Merikas, A. (2012) *International Shipping and World Trade*. University of Piraeus [Online] Available from: http://dione.lib.unipi.gr/xmlui/bitstream/handle/unipi/4680/Tsaini.pdf?sequence=2 [Accessed: May 15, 2018]
24. Vidmar, P. & Perkovič, M. (2015) Methodological approach for safety assessment of cruise ship in port. *Safety Science* 80, pp. 189–200.
25. Whelan, R. (2016) *Ship Owners Cut Oil Tanker Orders.* [Online] Available from: https://www.wsj.com/articles/shipowners-cut-oil-tanker-orders-1462815137 [Accessed: May 15, 2018]