Quantification and analysis of risk exposure in the maritime industry: Averted incident costs due to inspections and the effect of SARS-CoV-2 (Covid19)

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Abstract

Shipping facilitates global trade and provides essential services even during global pandemics such as SARS-CoV-2 (Covid19). An improved understanding of the magnitude and change of risk exposure has become more important for all maritime stake holders. The present approach quantifies global and regional risk exposure at ship level expressed as the *monetary value at risk (MVR)* and measures the amount of *averted or mitigated incident costs due to inspections* which can maritime stakeholders better understand risk exposure and develop strategies and policies to mitigate risk with improved risk control options such as improved risk profiling. The analysis is based on the global fleet using many data sources including ship particulars, inspections, incidents, cargo values, secondhand prices of vessels, special drawing right limits, arrival data and traffic movement data of 133,799 unique IMO. Estimation scenarios are run for the years 2017 to 2020 resulting in millions of computations as risk components are estimated at the individual ship level. The analysis confirms the importance to estimate all components at ship level as safety qualities differ and each vessel benefits differently from an inspection. Estimates of MVR (TLVSS, total loss, very serious and serious incidents) are slightly higher than global insurance premiums and global MVR stands at 13.7 to 17.8 billion USD. Over half of risk exposure is due to other marine liabilities and hull and machinery with cruise vessels leading loss of life and injuries and oil tankers pollution. The top 25 flags account for 87.9% of MVR with open registries in the lead reflecting the structure of the world fleet. In terms of MVR per GRT value, traditional flags, Non-IACS flags and owners located in low to upper middle-income countries show the highest values. Total MVR decreased by 4.18% due to the effects of the pandemic but pollution risk exposure increased by 6% in 2020 compared to 2019. Averted yearly incident costs are estimated to be 25% to 40% of global MVR which highlights the importance of port state control inspection programs but as inspection coverage decreased, this translated into a reduction of 6 to 11% of averted incident costs due to inspections in 2020 due to the pandemic.

Keywords

Risk exposure, monetary value at risk, binary logistic regression, averted incident costs, inspection effect, port state control inspections

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1. Introduction

Shipping facilitates global trade even in times of economic downturns and the pandemic has shown the importance of maritime transport as an essential sector for the delivery of critical supplies and global trade in time of crisis (UNCTAD, 2020). According to UNCTAD, the crisis has also brough a variety of trends and shifts such as "*increased risk management and resilience building becoming the new policy and business mantras"*. Incident costs can be extremely high and substandard shipping can distort competition. It is important to understand the magnitude of risk exposure and how it can be mitigated. The present approach will demonstrate this using quantitative methods.

Shipping is characterized by a complex regulatory framework of over 50 conventions of the International Maritime Organization (IMO) and enforcement is the duty of sovereign flag states. Since the international legislative framework is not applied equally across all flag states and to combat substandard shipping which can have further adverse effects, a second line of defense exists which are port state control (PSC) and industry inspections. PSC is a right of a coastal state and not an obligation but forms an important risk mitigation option for coastal states along others (eg. Vessel Traffic Services, pilotages, under keel clearance, aids to navigation and navigational aids, emergency towing vessels and emergency pollution response equipment). There are currently ten port state control regimes or Memoranda of Understanding (MoU) covering almost all ports. For a detailed description of PSC, refer to Knapp (2006) who analysed and compared the effectiveness of port state control in detail.

Given the increased importance of risk mitigation and understanding of risk exposure, this report consists of three areas. First, it quantifies global risk exposure expressed as the monetary value at risk (MVR) and compares it with global insurance premiums building on research from Knapp and Heij (2017) but extending the legislative framework and applies it to a longer time period (2017 to 2020). Second, making comparisons between the times period 2017 to 2019 and 2020, the effect of the SARS-CoV-2 (Covid19) pandemic on risk exposure is quantified. Third, the effect of port state control inspections is measured (Knapp et al, 2011) and using MVR quantified which can be interpreted as the amount of *averted or mitigated incident costs due to inspections.* MVR is estimated at the global level but regional application is also demonstrated which allows application for coastal states. *Risk exposure* is quantified as the *monetary value at risk (MVR)* and can be interpreted as a proxy to incidents costs (Knapp and Heij, 2017). MVR is defined as the weighted average of potential damages where the following damage types are considered: cargo damages, damages to hull and machinery, loss of life and injuries, pollution (oil and HNS), total loss of vessel for wreck removals, other marine liabilities covered by the legislative framework

The analysis is based on comprehensive combination of data covering the global fleet (ship particulars, inspections, incidents, cargo values, secondhand prices of vessels, special drawing right limits from IMO conventions, arrival data, AIS data etc.) mainly from the time frame 2017 to 2020 resulting in 489,435 observations or 133,799 unique IMO. Estimation scenarios are run for the years 2017 to 2020 using relevant input data feeds from various sources resulting in millions of computations as risk components are estimated at the individual ship level at a specific time. A software program called SOMRS was created that can estimate probabilities and calculate MVR at ship level which form the basis of the analysis presented here.

2. Data used

Table 1 provides a list of data streams and data sources that was used. Two main data streams are distinguished with two difference purposes also indicated in Table 1. Type 1 data is used to estimate risk formulas and to estimate the effect of an inspection and type 2 data feeds which are needed by SOMRS. Type 3 data is used for comparisons, to make data checks or to provide high level overviews of relationships of interest. Ship types are grouped into major ship types as follows: general cargo, dry bulk, container, tanker (oil, chemical, product, other), passenger (cruise, other), tugs, fishing vessels, pleasure craft (with IMO which are large yachts) and all other ship types. All vessel related data is linked at ship level (using IMO) except for Secondhand Prices of Vessels and Cargo Values where average values by unit/ship type are used and are calculated at ship level. For regional application, data from two coastal states were received (arrival data and nautical miles travelled derived from AIS positions). Two different regional applications are tested to convert the global MVR value to the regional level.

Table 1: Combination of data used

Type of data	Purpose	Data sources	Time frames
World fleet data – ship particulars	Type 1&2	IHS Maritime	Jan 2011 to Dec 2020
Global PSC data (all MoU's)	Type 1&2	IHS Maritime	Jan 2011 to Dec 2020
Global Incident data	Type 1&2	IHS Maritime, LLIS, IMO, USCG	Jan 2011 to Dec 2020
Regional arrival data	Type 2	From 1 coastal state	Jan 2017 to Dec 2020
Nautical miles travelled and days at sea at IMO level in EEZ from AIS data	Type 2	From 1 coastal state	Jan 2017 to July 2020
Exchange rates	Type 2	IMF	2017 to2020
Secondhand Prices of Vessels	Type 2	Clarksons SIN	2017 to 2020
Cargo Values	Type 2	ABPmer, Vivid Economics	
Special Draw Rights limits	Type 2	IMO Conventions	
Insurance premiums	Type 3	IUMI, P&I Clubs	2017 to 2019

SIN = Clarkson's Ship Intelligence Network, IMF = International Monetary Fund, ARB = Australian Reserve Bank

Risk formulars using to estimate probabilities were estimated based on matrices from 2014 to 2019 (with lagged data to account for histories going back to 2011. The underlying data matrix for incident type models is 721,767 observations (27,809 incidents) and for conditional damage type probabilities, the subset of incidents (27,809 observations) is used. For the inspection effect models, 222k inspections are used.

Global incident information is combined from at least four different sources and duplicates are eliminated (IMO, USCG, LLIS, IHSM). The remaining incidents are reclassified according to IMO definitions for seriousness which are very serious (including total loss), serious and less serious (IMO 2000). First events or the chain of events is identified when possible to determine the dependent variable needed to estimate the models used for conditional damage type probabilities (eg. loss of life, hull related failures, cargo related failures etc.). Note that in estimating risk formulars, less serious incidents are not included as otherwise the data will be biased since there is a lot of underreporting with less serious incidents and near misses.

Appendix A provides a high-level overview of the global fleet from 2017 to 2020 with respective status codes based on data from IHSM that were available for the analysis. Note that data on pleasure crafts which are large yachts with IMO number were not available for the years 2017 and 2018 but are more complete for 2019 and 2020. Overall, the fleet increased modestly with a modest increase in laid up vessels as of December 2020 compared to the previous year. The various other data sources listed in Table 1 are linked to the global fleet using IMO.

3. Methodology to estimate monetary value at risk (MVR) and inspection effect

The methodology used for estimating MVR is based on Knapp and Heij (2017) but was extended to include all relevant IMO conventions and is based on more comprehensive and more refined data sources to estimate MVR using a longer period (2017 to 2020). The methodology for estimating and quantifying the effect of inspection is based on the methodology used by Knapp et al (2011). MVR and the inspection effect are calculated for different degrees of seriousness such as total loss, very serious and serious incidents (TLVSS) and all incidents irrespective of seriousness (ALL). The same underlying matrix to estimate the ship specific incident type and damage type probabilities is used for the inspection effect and is based on world fleet, incident data and inspection data for the years 2014 to 2019. The same covariates are used in all models. Note that estimates of TLVSS are more accurate compared to ALL since there is underreporting with less serious incidents. Three main components are needed to estimate MVR and to quantify the inspection effect:

- **Ship specific probabilities (TLVSS and ALL) and damage type probabilities:** This probability is a yearly probability and estimates the safety quality of a vessel. The conditional damage type probabilities (TLVSS and ALL) are estimated for the main damage types: pollution (oil and chemicals), loss of life and injuries, damages to hull and machinery, cargo related damages, wreck removal, property damages. Conditional probabilities estimate the degree of damage given an incident occurs. They provide the spread across damage types given an incident occurs.
- **The inspection effect to quantify averted incident costs (TLVSS and ALL):** The inspection effect is estimated using the same matrix as the ship specific probabilities, but the effect of interest is for the covariate that indicates whether a ship was inspected or not.
- **Total insurable values (TIV):** TIV values are based on various data sources and special drawing right (SDR) limits of international conventions. TIV values provide the maximum insurable limit that can be claimed in case of an incident and is calculated at ship level for the various damage types mentioned above.

Risk exposure expressed as MVR is defined as the weighted average of potential damages where the following damage types are considered: cargo damages, damages to hull and machinery, loss of life and injuries, pollution (oil and HNS), total loss of vessel for wreck removals, other marine liabilities covered by the legislative framework. The basis to determine damages is based on total insurable values (TIV values) such as cargo values, secondhand prices of vessels, special drawing rights of international conventions that determine the maximum of insurable values. The TIV values can be very high and since incidents normally have several consequences or damages for each individual incident, the split up the damages across all damages types is estimated by the conditional probability for each damage type which adjusts the individual TIV values (denoted $TIV_{adjusted}$).

Let the damage categories be denoted by j (j = 1, …, 7) and let V_j be the total insurable value for value type j. Then TIV is defined as the sum of individual V values for all damage type categories. Further let P_{inc} be the probability of an incident (TLVSS or ALL) during a period of one calendar year and let P_j be the conditional probability of damage category j (TLVSS or ALL) occurring given an incident, then the monetary value at risk (MVR) of a vessel is defined as

$$MVR = P_{inc} * \sum_{j=1}^{7} P_j * V_j \tag{1}$$

To estimate and quantify the effect of inspection Knapp et al (2011) use survival analysis to quantify the reduction in incident costs towards total loss (TL) by ship type. In the present approach, the methodology was adapted but instead of using the probability of survival (TL), the probability of incident (TLVSS and ALL) is modelled by means of the logit model. The estimated inspection effect as the reduction in the probability of incident IE_{prob} at ship level becomes $IE_{prob} = P_{notinspected} - P_{inspected}$ where $P_{notinspected}$ is the probability of incident (TLVSS, ALL) without the effect of inspections and $P_{inspected}$ is the probability of incident with inspection at ship level. The inspections are merged up a maximum of 360 days prior to the incident date representing at least 1 inspection within 365 days prior to the incident.

The effect is then translated into a monetary value which can be interpreted as *averted incident costs due to an inspection*. To quantify the inspection effect into dollar amounts, Knapp et al (2011) used two boundaries, the upper boundary is IE_{prob} multiplied by the TIV value and the lower boundary is IE_{prob} multiplied by the TIV value adjusted by the conditional damage type probabilities (denoted $TIV_{adjusted}$). The upper boundary assumes 100% damages for all damage types and is the maximum effect (more a hypothetical figure that gives an indication of the range) while the lower boundary is the one most relevant for this analysis as it corrects the TIV values with the conditional damage type probabilities and adjusts the damage types by their relevant spread. Incidents rarely have 100% loss or damage for an incident but are rather a combination of damage types with a spread across it (eg. 10% loss of life, 5% cargo, 40% hull and machinery etc.). $TIV_{adjusted}$ rather than MVR is used because MVR account for the inherent probability of incident which partly accounts for inspections effects and other risk control options since it is estimated based on observed incident data.

3.1. Ship specific incident and damage type probabilities

Two types of ship specific probabilities are used in this analysis and the underlying matrix to estimate the formulars to estimate probabilities is based on world fleet, incident data and inspection data for the years 2014 to 2019 (see Appendix B for model statistics). The formulars are then implemented in SOMRS which then estimates probabilities given input data feeds at a specific point for the years 2017 to 2020. First, the unconditional probability of incident (TLVSS or ALL) denoted P_{inc} and second, the conditional damage type probability given an incident (TLVSS or ALL) occurred denoted P_j. The selection of variables to estimate the formulars is based on Knapp (2006), Heij and Knapp (2012), Knapp and Heij (2020) and are as follows:

- *Basic ship particulars such as age, size of vessel, classification society*
- *Country of built grouped into four groups and interaction effects with three age groups*
- *The 'presence of maritime expertise' expressed as concentration of ownership companies, DoC companies, main engine builders, main engine designers in a particular country*
- *Years of existence of beneficial ownership and DoC company*
- *Main engine designer (individual company) and Main engine builder (individual country of location) if the model is large enough*
- *Lagged inspection and incident history of the ship within 30 to 360 days prior to the event*
- *Changes of ship particulars overtime such as flag changes, ownership changes, DoC company changes and class changes (within 3 years prior to the event date)*
- *Flag, Beneficial Owner and DoC company location depending on the model type (eg. when investigating corruption at the flag level, flag would not be included)*

The base model to model the probability of detention or incident is binary logistic regression. The base model used to estimate incident type and damage type models is binary logistic regression. In the models constructed here, the dependent variable (y) is binary, with two possible outcomes: 'incident (1)' or 'no incident (0) for type A model and 'damage type B (1)' or 'no damage type but an incident occurred '(0). Let x_i contain the explanatory factors such as e.g age, size, flag, classification society, and owner etc., then the logit model postulates that $P(y_i = 1|x_i) = F(x_i\beta)$, where the weights β consist of a vector of unknown parameters and F is a cumulative distribution function (CDF). A popular choice is the CDF of the logistic distribution, which gives the well-known logit model.

This model states that $P(y_i = 1|x_i) = \exp(x_i\beta)/(1+\exp(x_i\beta)$ where $x_i\beta$ is a weighted average of all explanatory factors and changes plus the intercept. The probabilities are estimated at the individual ship level (i) using Eviews. For further details on logit models, refer to Heij et al. (2004) or Verbeek (2008). To estimate the coefficients, quasi-maximum likelihood (QML) is used (Greene, 2000) as method of estimation in order to give some allowance for a possible misspecification of the assumed underlying distribution function. The following statistical models are used to compute the monetary value at risk (MRV) where type A is unconditional and quantifies the inherit risk profile of the vessel and type B are conditional damage type probabilities given an incident occurred (TLVSS and ALL).

- *Type A: Probability of very serious and serious incident (TLVSS and ALL)*
- *Type B: Conditional probability of hull and machinery damages (TLVSS and ALL)*
- *Type B: Conditional probability of cargo damages (TLVSS and ALL)*
- *Type B: Conditional probability of loss of life and injuries (TLVSS and ALL)*
- *Type B: Conditional probability of oil pollution (TLVSS and ALL)*
- *Type B: Conditional probability of chemical pollution (TLVSS and ALL) as proxy to HNS*

- *Type B: Conditional probability of total loss (TLVSS and ALL) used for wreck removals*
- *Type B: Conditional probability of other marine liabilities (TLVSS and ALL)*

Note that the models for HNS are based on small sample sizes and are to be interpreted with caution. Appendix B provides the model statistics (Appendix B1), boxplots of probabilities at ship level (Appendix B2) and average conditional damage type probabilities per ship type (Appendix B3). The boxplots clearly demonstrate the differences in the risk profiles at the individual ship level. While individual probabilities change over time, they do not change significantly across the time frame provided here.

3.2. Total insurable value (TIV)

The total insurable value (TIV) of a vessel is a combination of values provided in Table 2. It provides an estimate of the total insurable values of each of the damage types. The value of hull and machinery is based on average second-hand prices from the Shipping Intelligence Network (SIN) of Clarkson's. Cargo values are complex, and estimates are used based on a study by ABPmer and Vivid Economics (2019) for the UK government. Cargo values vary significantly across ship types. The unit values for cargo values were transferred into DWT unit prices and are calculated at ship level.

Table 2: Overview of data sources used for TIV values

Damage category	Source/convention	Units
Hull and machinery	SIN, vessel value	Second-hand prices (DWT)
Cargo	ABPmer, Vivid Economics	Various units (mainly DWT)
Pollution (oil-cargo)	CLC/IOPC Convention	SDR/GRT
Pollution (bunker)	LLMC Convention	SDR/GRT
Pollution (HNS-cargo)	HNS Convention/Fund	SDR/GRT
Life and injuries	Athens Convention	SDR/passenger
	LLMC Convention	SDR/GRT
Property damages	LLMC Convention	SDR/GRT
Wreck removal	Nairobi Convention	SDR/GRT

The various TIV limits for pollution, property damages, wreck removal, loss of life and injuries are based on the Special drawing rights (SDR) and limits of IMO conventions or respective Protocols and depend mostly on size of the vessels such as GRT or number of passengers:

- *International Convention on Civil Liability for Oil Pollution Damage (CLC), 1969 and the 1992 Protocol to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (FUND 1992)*
- *Athens Convention relating to the Carriage of Passengers and their Luggage by Sea (PAL), 1974*
- *Convention on Limitation of Liability for Maritime Claims (LLMC), 1976*
- *International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea (HNS), 1996 (and its 2010 Protocol).*
- *International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001*
- *Nairobi International Convention on the Removal of Wrecks, 2007*

The HNS Convention is not yet in force but the limits are used to account for damages related to pollution of HNS. For this reason, only the pollution part is applied as once the HNS convention is in force, there will be some overlaps with other conventions.

TIV values are large and vary considerably by ship type and do not change considerably from year to year since the majority is based on the special drawing right limits of international conventions. For the years 2017 to 2020, the average yearly TIV value of the world fleet is estimated to be USD 20.71 trillion of which 56.82% is allocated to Pollution, 22.25% for loss of life and injuries, 7.16% for cargo damages and 3.32% for hull and machinery and 10.45% for other marine liabilities such as damages to property as by the LLMC convention. When adjusted by the conditional damage type probabilities for each damage type to account for the combination of damages that occur and given an incident occurs, $TIV_{adjusted}$ becomes USD 1.42 (ALL) to 1.12 (TLVSS) trillion.

Table 3 provides mean TIV values by major ship type and Appendix C1 boxplots of TIV values at ship level. The boxplots clearly demonstrate the variability at ship level for TIV values and adjusted TIV values which emphasizes that values need to be estimated and calculated at ship level. Not surprisingly, the highest values are found with passenger vessels for loss of life, oil tankers for pollution and container ships for cargo values. Highest variability is associated with cruise vessels due to some large vessels (6000+ passengers). This study does not further analyze the TIV values which are adjusted at ship level with the ship level conditional damage type probabilities.

Table 3: Mean TIV values by major ship type, USD (millions), 2017 to 2020

	Total TIV	Cargo	Hull & Machinery	Lives & Injuries	Pollution	Other Liabilities
container	455.3	194.5	14.8	64.0	117.9	64.0
dry bulk	243.5	7.2	11.3	58.6	107.9	58.5
fishing	8.2	0.0	0.1	4.3	2.2	1.7
general cargo	60.9	2.5	1.9	12.2	32.5	11.7
other	17.0	0.2	1.2	6.7	3.3	5.5
passenger-cruise	860.3	2.1	32.5	746.3	26.7	52.7
passenger-other	308.0	2.1	2.4	276.4	21.1	6.1
pleasure craft	10.0	0.0	0.6	4.5	2.2	2.7
tanker-chemical	444.2	13.7	27.1	23.2	357.0	23.1
tanker-gas	527.2	7.6	29.4	55.6	378.9	55.6
tanker-oil	1348.7	46.7	23.5	89.0	1100.6	88.8
tanker-other	17.6	1.1	1.4	6.7	3.4	5.0
tanker-product	366.2	4.2	12.5	11.8	326.4	11.2
tugboat	7.6	0.0	0.1	4.3	2.1	1.2

Notes: Pollution includes oil and HNS, other liabilities include wreck removal and other property damages covered by the LLMC

3.3. Estimating the effect of PSC inspections

Table 4 provides the results of the regressions to obtain the inspection effect as described earlier based on a matrix of 222,354 global inspections (2014 to 2019). For translating the inspection effect into averted incident costs due to inspections using MVR, the yearly effect is taken which is the effect up to a maximum of 365 days and this factor was implemented into SOMRS. It is interpreted as the effect of having at least one inspection prior to the incident where the probability of incident is a yearly probability. The effect is mostly negative meaning an increase in inspections reduces the probability of incident with earlier time frames either been positive or not significant for both (ALL and TLVSS).

Table 4: Inspection effect for various time frames

	ALL, total 1=18,421			TLVSS, total 1=6,158		
Inspections prior to incident	**McFadR2**	**ALL**		**McFadR2**	**TLVSS**	
ALL MOU up to 365 days	**0.113**	**-1.15449**	*****	**0.093**	**-0.79397**	*****
ALL MOU 31 to 60 days prior	0.108	0.03468	***	0.092	-0.00940	ns
ALL MOU 61 to 90 days prior	0.108	0.00692	ns	0.092	-0.07318	**
ALL MOU 91 to 180 days prior	0.108	-0.08731	*	0.092	-0.08009	*
ALL MOU 181 to 270 days prior	0.108	-0.22578	*	0.092	-0.18378	*
ALL MOU 271 to 365 days prior	0.108	-0.33428	*	0.092	-0.23430	*

ALL = all incident types, TLVSS = total loss, very serious and serious

*Note: * significant at 1% level, ** significant at 5% level, *** significant at 10% level,- ns = not significant*

In order to visualize the partial effect of the decrease of the probability of incident due to inspections, the effect is plotted for global inspections in Figure 1. The probabilities are calculated based on an average ship profile of a dry bulk carrier (e.g ship type, size, GRT, flag, class, owner, inspection, and incident history etc.) and assuming all other variables stay the same, the estimated probabilities are estimated given an incremental increase in the number of inspections from 0 to 5. The resulting probability is plotted on the vertical axis while the incremental change is shown on the horizontal part. One can easily observe from Table 5 that the effect can range from 0.07% (large yachts) to a maximum effect of 17% for some ship types (fishing vessels). For this reason, it is important to calculate this effect at ship level which has been accomplished in the present study.

Figure 1: Inspection effect for global inspections (up to 365 days prior to even of interest)

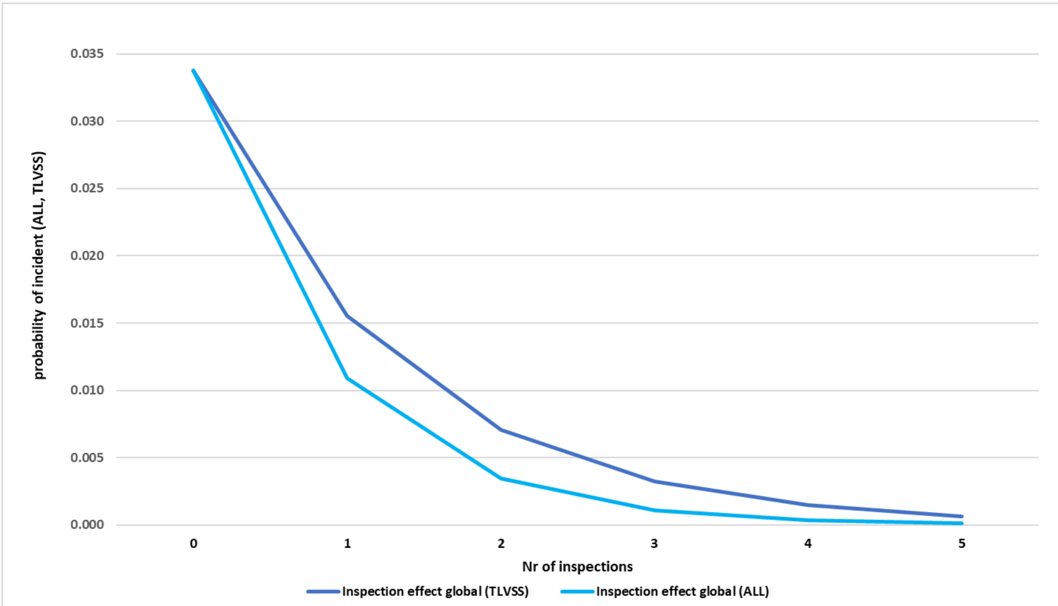


Table 5: Mean, median and maximum inspection effect by ship types (TLVSS)

	Mean	Median	Maximum
general cargo	0.50%	0.30%	12.20%
dry bulk	0.42%	0.33%	13.62%
container	0.49%	0.37%	7.36%
tanker-chemical	0.37%	0.21%	14.34%
tanker-gas	0.28%	0.21%	5.04%
tanker-oil	0.28%	0.23%	6.95%
tanker-other	0.13%	0.09%	0.68%
tanker-product	0.19%	0.12%	3.18%
passenger-cruise	1.02%	0.95%	6.69%
passenger-other	0.66%	0.38%	16.60%
other	0.19%	0.12%	6.16%
fishing	0.24%	0.13%	17.18%
tugboat	0.14%	0.09%	3.67%
pleasure craft	0.07%	0.05%	0.63%

Note: based on all vessels in the world fleet and for the years 2017 to 2020, 489k vessels

3.4. Adjusting MVR and inspection effect to the regional level

Since MVR is a yearly estimate trading globally, it needs to be adjusted by a factor that accounts for the portion of its exposure in the Exclusive Economic Zone (EEZ) if applied at the regional level. Two metrics were tested based on data from two different coastal states – one based on nautical miles travelled in the EEZ derived from AIS data and a second one based on times spent in the EEZ derived from arrival data with merged LRIT position data. Nautical miles travelled are more accurate to measure EEZ exposure and time spent in the EEZ. For the metric derived from arrival data, an indication of the time spent in ports could be obtained. Based on average speed data by ship types, an estimate was made to reach 200 nautical miles and an estimate was made at ship level and added to the base time spent derived by the arrival/LRIT dataset

The EEZ adjustment factor calculates the adjustment based on the relationship of total nautical miles travelled or time spent in the EEZ divided by global averages by ship type as by Vander Hoorn and Knapp (2015, 2019). An example calculation would be a container ship with an observed distance travelled within the EEZ of a coastal state of 10,000 nautical miles while containership at the global level travel on average 60,000 nautical miles. The resulting calibration factors becomes 10,000/60,000 or 0.1667. For the metric using time, 365 days were used and for domestic vessels, an adjustment of 0.85 was made as vessels are not in operation all year round. Global traffic metrics are derived from the Fourth IMO GHG report (IMO, 2020). Appendix D provides boxplots of both metrics.

4. Risk exposure and inspection effect results

Based on the respective input data feeds for the years 2017 to 2020, monetary value at risk (MVR) is estimated for each year. The average global insurance premiums for the years 2017 to 2019 is at USD 29.84 billion and USD 12.62 billion without the cargo portion. For the comparison with global insurance premiums, the category cargo cannot be compared since insurance premiums for cargo include the whole logistics while the estimate here is based on the ship part only. Furthermore, IUMI premiums need to be combined with premiums from the International Group of P&I Clubs that cover about 90% of the world fleet by gross tonnage. The P&I Club figures cover all third-party liability (general average, pollution, personnel, third party property damages) but exclude claims of cargo interest. Furthermore, the premiums do not include the deductible which would be the ship owner's portion of the claim and that can vary from USD 5,000 to 100,000 based on industry sources. MVR (TLVSS) estimated by the routine is USD 14.13 billion, hence slightly higher than the global one with a ratio of 1.12.

Table 6 provides an overview of MVR for the years 2017 to 2020 and the percentage of regional MVR for the two coastal states to global MVR up to the year 2019. MVR stands at 17,832 (ALL) to 13,735 (TLVSS) million USD based on the yearly average for 2017 to 2020. The regional figure is obtained by applying the EEZ factors described earlier. MVR of coastal state 1 was derived by using *nautical miles travelled* as EEZ factor while MVR of coastal state 2 was derived by using *time spent* as EEZ factor. The EEZ of coastal state 1 is about 70% of coastal state 2 and both are above 8 million square kilometers.

Table 6: MVR at global and regional level (MVR in million USD)

MVR at global level	2017	2018	2019	2017-19	2020	2017-20
Nr of Unique IMO in routine	115,719	119,221	125,495	120,145	129,000	122,359
MVR (ALL) global	18,795	18,679	17,288	18,254	16,565	17,832
MVR (TLVSS) global	15,763	14,976	12,350	14,363	11,851	13,735
Nr of Unique IMO in routine – coastal state 1	6,546	6,795	6,978	6,773		
% to global (ALL)	2.37%	1.97%	1.81%	2.05%		
% to global (TLVSS)	1.82%	1.91%	1.72%	1.82%		
Nr of Unique IMO in routine – coastal state 2	16,325	16,347	16,155	16,276		
% to global (ALL)	12.08%	12.08%	13.11%	12.42%		
% to global (TLVSS)	5.51%	5.76%	5.67%	5.65%		

The regional level will not be explored further here but regional comparisons could be made using this methodology. Appendix E1 provides boxplots of MVR (ALL and TLVSS) at the ship level and demonstrates variability across ship types. Based on the 2017 to 2019 mean, global MVR stands at 14.3 to 18.2 billion USD with the coastal states exposure to be 1.8 to 2.1% for coastal state and 5.6 to 12.4% for coastal state 2. The higher difference for coastal state with respect to MVR (ALL) is related to the larger portion of domestic vessels trading in the EEZ of coastal state 2 while coastal state's domestic vessels are not accounted for in the calculation since they mostly do not have IMO numbers. The routine could be adapted to include vessels without IMO number but would require further development of risk models based on risk factors most relevant for smaller, domestic vessels.

Based on combined incident data from the various sources used in this study, overall, the empirical incident rates for TLVSS decreased since 2011 and in 2020 it stands at 1.29% (1.68% in 2019). Due to the economic situation in 2020, substandard and smaller companies and their vessels are are forced out of the market and there is an adjustment of tonnage and risk exposure. Table 7 provides the quantification of the effect of the pandemic by comparison previous years with 2020. Note that foreign exchange rates also have an effect albeit the average yearly exchange rates did not change that much for the time periods on hand with the exception for 2017. For this reason, the 2017 to 2019 yearly average is also considered besides changes from 2020 to 2019.

Table 7: Difference in MVR due to pandemic, million USD

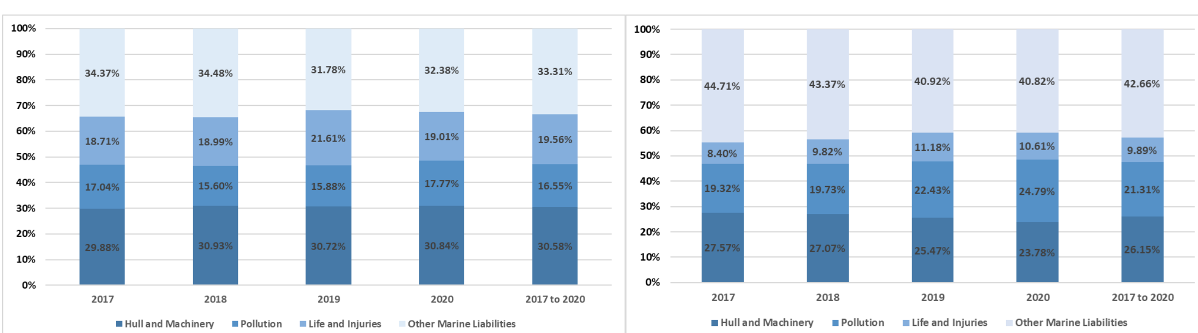
				Diff 2017-2019 to 2020		Diff 2019 to 2020	
	2017-19	**2019**	**2020**	**$**	**%**	**$**	**%**
MVR total (ALL)	18,253.8	17,287.6	16,565.1	-1,688.7	-9.25%	-722.5	-4.18%
MVR total (TLVSS)	14,363.0	12,349.7	11,851.3	-2,511.7	-17.49%	-498.4	-4.04%
Hull and Machinery	3,848.7	3,145.2	2,818.6	-1,030.1	-26.76%	-326.6	-10.38%
Pollution	2,923.6	2,770.0	2,937.5	13.9	0.48%	167.5	6.05%
Loss of Lives and Injuries	1,391.6	1,380.6	1,257.4	-134.2	-9.64%	-123.2	-8.92%
Other Marine Liabilities	6,199.1	5,053.8	4,837.8	-1,361.4	-21.96%	-216.0	-4.27%

Other marine liabilities = damage to property, cargo, wreck removal as by the LLMC

In 2020, MVR (TLVSS) decreased by 4.18% compared to 2019 and by 9.25% compared to the 2017 to 2019 average. Pollution exposure (TLVSS) increased by 6% in 2020 compared to 2019 but only slightly compared to the 2017 to 2019 average (0.48%). Hull and Machinery shows the highest decrease with minus 10.38% compared to 2019 followed by loss of lives and injuries (-8.92%) and other marine liabilities (-4.27%). The decrease in loss of life is associated with the reduction of active cruise vessels. Cruise ships in particular have been affected by the pandemic. From Appendix A1, one can see that the fleet continued to grow for 2020 with a slight decrease of vessels under service as of December 2020 (-0.14%) and a higher percentage of vessels been laid up (+0.25%) compared to the 2017 to 2019 average.

Figure 2 provides the percentage split up of MVR by main damage category as % of the total for each category. There is not much change in the split up across the years 2107 to 2020 but 2020 does show some changes compared to the other years. For MVR (TLVSS) for the year 2017 to 2020, the largest portion of risk exposure is associated with other marine liabilities (42.66%) followed by hull and machinery (26.158%), pollution (21.31%) and loss of life and injuries (9.89%). For MVR (ALL), loss of life and injuries are higher due to the inclusion of occupation incidents which are mainly of less serious nature and not included in TLVSS.

Figure 2: MVR-ALL (left) and MVR-TLVSS (right) as by main damage type category



Notes: Pollution includes oil and HNS, other liabilities include wreck removal, cargo damages and other property damages covered by the LLMC

One can see the increase in contribution of pollution compared to the previous years for 2020. For MVR (TLVSS) for the year 2020, the largest portion of risk exposure is associated with other marine liabilities (40.82%) followed by pollution (24.79%), hull and machinery (23.78%) and loss of life and injuries (10.61%). Note that for MVR (ALL), there is a greater degree of uncertainty due to the underreporting of incidents. Most relevant for interpretation is MVR (TLVSS) and more emphasis is placed on the results associated with MVR (TLVSS) going forward.

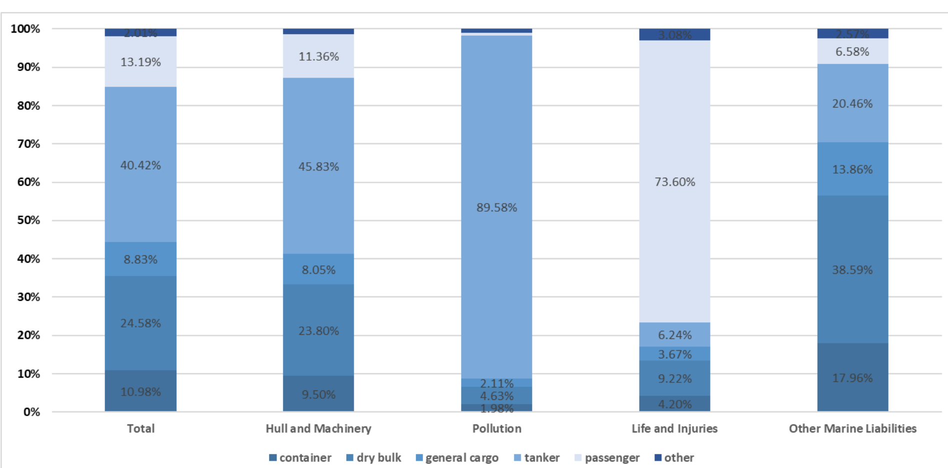
Table 8 provides the split up by ship type and damage type for MVR (TLVSS) while Figure 3 visualizes the percentage split up by major ship types. Not surprisingly, tankers are dominating pollution (89.6%) and are also leading within the category of Hull and machinery (45.8%) which is dominated by chemical tankers (23.3%). Passenger vessels are dominating loss of lives and injuries (73.6%) – in particular, cruise vessels (42.9%) due to the large risk exposure related to passengers with some vessels having a capacity over 6000 passengers. For other marine liabilities, dry bulk leads with 38.6% followed by tankers (20.5%) and container vessels (17.9%). Tanker and dry bulk carriers can carry large quantities of cargo while containers vessels can carry high value cargo with some vessels over 23k TEU carrying capacity.

Table 8: MVR (TLVSS) by ship type and damage type category (2017-2020 yearly mean), million USD

Ship Type	Total	% to total	HM Total	% to total	POLL Total	% to total	LIVE Total	% to total	OTHER Total	% to total
container	1,508.7	10.98	341.3	9.50	58.0	1.98	57.1	4.20	1,052.3	17.96
dry bulk	3,376.3	24.58	854.5	23.80	135.5	4.63	125.2	9.22	2,261.1	38.59
fishing	89.4	0.65	7.7	0.22	12.9	0.44	25.0	1.84	43.8	0.75
general cargo	1,212.6	8.83	289.1	8.05	61.7	2.11	49.9	3.67	812.0	13.86
other	150.4	1.10	43.2	1.20	13.7	0.47	10.6	0.78	82.9	1.41
passenger-cruise	1,026.2	7.47	230.2	6.41	8.4	0.29	582.9	42.92	204.7	3.49
passenger-other	783.3	5.70	177.0	4.93	10.4	0.35	416.4	30.6	179.5	3.06
pleasure craft	2.1	0.02	0.6	0.02	0.2	0.01	0.2	0.01	1.1	0.02
tanker-chemical	1,289.8	9.39	838.5	23.35	148.0	5.06	15.6	1.15	287.7	4.91
tanker-gas	523.0	3.81	233.2	6.49	60.5	2.07	17.3	1.27	212.1	3.62
tanker-oil	3,342.7	24.34	328.8	9.16	2,371.3	81.01	45.2	3.33	597.4	10.20
tanker-other	1.8	0.01	0.6	0.02	0.2	0.01	0.1	0.00	0.9	0.02
tanker-product	394.0	2.87	244.8	6.82	42.2	1.44	6.6	0.49	100.4	1.71
tugboat	34.6	0.25	1.6	0.04	4.1	0.14	6.1	0.45	22.9	0.39
Total	**13,735.1**		**3,591.1**		**2,927.1**		**1,358.1**		**5,858.8**	

HM = Hull and Machinery, POLL = oil and chemical pollution, LIVE = loss of life and injuries, OTHER = all other marine liabilities (eg. damage to property, cargo, wreck removal) as by the LLMC

Figure 3: MVR (TLVSS) by ship type and damage type category (2017 to 2020 mean)



Other marine liabilities = damage to property, cargo, wreck removal as by the LLMC

Appendix E2 provides the mean and median values of MVR (TLVSS) per ship type. Not surprisingly, the highest values for hull and machinery are associated with passenger vessels, chemical and gas tankers while loss of life is led by cruise vessels and pollution by oil tankers. Appendix E3 lists the top 25 flags and Appendix E4 the top 25 classification societies. The top 25 flags accounting for 87.9% of MVR (TLVSS) correspond to 58.5% of total Nr of vessels and 87.5% of global GRT. The top five flags are Panama (12.5%), the Marshall Islands (11.7%), Liberia (10.5%), Hong Kong (7.5%) and the Bahamas (7.3%) reflecting the high exposure related to cruise vessels and tankers. The top 25 classification societies accounting for 95.5% of MVR (TLVSS) correspond to 56.4% of total Nr of vessels and 96.4% of global GRT. The top five classification societies are DNV-GL (25.12%), Lloyd's Register (17.2%), ABS (13.6%), NKK (12.6%) and BV (9.34%).

Besides quantifying MVR (TLVSS) as total, another metric is calculated to make categories more comparable in terms of risk exposure which is MVR/GRT or per total passenger capacity for passenger vessels. First MVR per GRT or passenger capacity is calculated at ship level and the mean is then calculated for reach flag, class society and country of location of the beneficial owner. The results for the top 10 for each category are given in Appendix E5 and is based on a minimum of 100 vessel for the years 2017 to 2019. One can easily see that the total magnitude of exposure is not high with respect to the global exposure (below 5%) with the exception for passenger vessels where the top 10 account for 8 % of global MVR with Bahamas and Bermuda in the lead. Table 9 provides a summary of this type of analysis by main categories. Traditional flags show the highest MVR/GRT value with USD 13 followed by unknown or false flags with USD 11 and open registries with USD 9. For class societies, Non-IACS flags are in the lead with USD 16 and owners who are located in low or upper middle income country lead with USD 11/GRT.

Table 9: MVR (TLVSS) by flag, classification society and owner group (2017-2020 yearly mean)

		% to total fleet		MVR TLVSS			
Group	**Category**	**Nr**	**GRT**	**mill USD**	**% to total**	**mean**	**$ MVR/GRT**
Flag	Emerging Flags	32.77%	11.87%	1,341.1	9.76%	33,449	8.10
	Open Registries	29.88%	73.93%	9,799.1	71.34%	268,030	9.51
	Traditional Flags	27.14%	13.20%	2,441.5	17.78%	73,531	13.27
	Unknown Flags	10.22%	1.00%	153.3	1.12%	12,262	11.03
Class	IACS	47.56%	94.89%	12,760.0	92.90%	219,254	9.64
	Not IACS	11.86%	2.01%	451.6	3.29%	31,131	16.13
	Unknown Class	40.58%	3.10%	523.4	3.81%	10,541	12.11
Owner	high income	40.90%	72.42%	9,957.2	72.49%	198,984	9.86
	upper middle income	0.31%	0.08%	12.2	0.09%	120,713	11.16
	lower middle income	9.77%	3.38%	519.0	3.78%	43,426	11.03
	low income	34.18%	7.00%	1,052.9	7.67%	32,578	10.79
	unknown	14.85%	17.13%	2,193.7	15.97%	25,178	9.19

Notes: Ownership groups are based on the World Bank classification

The last part of this study will quantify the inspection effect as *averted incident costs due to inspections*. Using the methodology described under section 3, the inspection effect is translated into a monetary value using MVR and the lower boundary is calculated at ship level. Appendix F1 and F2 visualizes variability at ship level and across ship types for both – the inspection effect and averted incident costs as vessels have different safety qualities and benefit differently from inspections.

Unfortunately, the Paris MoU inspection data except detentions was not available for the years 2017 to 2020 in format that is useful for analysis, hence a separation across the various MoU's will is not made here but only the global total of the effect is calculated based on actual inspections performed during 2017 to 2020 and the results is presented in Table 10 in relation to total MVR. The average for the years 2017 to 2018 where all inspection data was available is compared with 2019 and 2020. The main change of interest is from 2019 to 2020 as for both years, the Paris MoU data was not available and the drop in inspections due to the pandemic can be seen from Table 10. Appendix F3 provides mean and median values by ship type. A similar patten is found as previously with the TIV values and MVR – that is cruise ships and oil tankers are benefiting most from an inspection due to the very high incident costs associated with these two ship types. This is followed by container vessels due to the higher cargo values carried by this ship type.

Table 10: Averted incident costs due to inspections (million USD)

in million for USD		2017	2018	Mean 2017-18	2019	2020	Diff 2019-20
Total inspections		85,356	86,051	80,229	69,280	47,718	-21,562
Unique IMO in routine	Nr	115,719	119,221	117,470	125,495	129,000	3,505
Unique IMO inspected	Nr	31,565	31,803	31,684	26,844	22,354	-4,490
% inspected	%	27.28%	26.68%	26.97%	21.39%	17.33%	-4.06%
MVR (ALL) total	USD	18,795.2	18,678.6	18,736.9	17,287.6	16,565.1	-722.5
Inspection effect (ALL)	USD	7,608.3	7,627.2	7,617.8	7,152.3	4,931.1	-2,221.2
% to total MVR ALL	%	40.48%	40.83%	40.66%	41.37%	29.77%	-11.6%
MVR (TLVSS) total	USD	15,763.1	14,976.2	15,369.6	12,349.7	11,851.3	-498.4
Inspection effect (TLVSS)	USD	3,885.0	3,961.2	3,923.1	3,716.1	2,807.8	-908.2
% to total MVR TLVSS	%	24.65%	26.45%	25.53%	30.09%	23.69%	-6.4%

Based on the average of 2017 to 2018, averted incident costs due to inspections are estimated to be USD 7,152 (ALL) to 3,923 (TLVSS) million USD per year and as percentage to total MVR, the effect is between 25% (TLVSS) to 40% (ALL) assuming that 80k inspections cover most of the global inspections performed. Comparing the year 2019 with 2020, once can see decrease of inspections due to the pandemic and inspection coverage by 4%. 21.3% of unique vessels were inspected in 2019 but only 17.3% were inspected in 2020 excluding the Paris MoU inspections. The reduction translates into a reduction of 11.6% (ALL) and 6% (TLVSS) of the inspection effect.

5. Conclusions and Recommendations

MVR is defined as the weighted average of potential damages where the following damage types are considered: cargo damages, damages to hull and machinery, loss of life and injuries, pollution (oil and HNS), total loss of vessel for wreck removals, other marine liabilities covered by the legislative framework. Although both degrees of seriousness were estimated, MVR (TLVSS) is more accurate as less serious incidents included in MVR (ALL) show a high degree of underreporting.

The average yearly TIV values (2017 to 2020) of the world fleet are estimated to be USD 20.71 trillion which demonstrate the importance of global trade and value of assets involved. Highest variability is associated with cruise vessels due to some large vessels (6000+ passengers). The yearly average for 2017 to 2019 of MVR (TLVSS) excluding cargo is estimated to be USD 14.13 billion, hence slightly higher by a ratio of 1.12 than the global insurance premiums of USD 12.62 excluding the cargo portion.

Based on the years 2017 to 2020, global MVR stands at 13,735 (ALL) to 13,735 (TLVSS) million USD and largest portion of risk exposure is associated with other marine liabilities (42.66%) followed by hull and machinery (26.158%), pollution (21.31%) and loss of life and injuries (9.89%). The percentage split ups do not change dramatically but one can see the increase in contribution of pollution for the year 2020 with a contribution of 24.79%. By ship types, tankers are dominating pollution risk exposure (TLVSS) with 89.6% of total pollution and are also leading within the category of Hull and machinery (TLVSS) with 45.8% of the total for this category which is primarily dominated by chemical tankers. Passenger vessels are dominating risk exposure (TLVSS) of loss of lives and injuries with 73.6% of the total risk exposure – in particular, cruise vessels contribute 42.9% of this category due to the large risk exposure related to passengers with some vessels having a capacity over 6000 passengers. The pattern is similar for MVR and the inspection effect which reflect the high costs associated with cruise vessels and oil tankers in terms of potential damages followed by chemical tankers and container vessels.

The top 25 flags accounting for 87.9% of MVR (TLVSS) correspond to 58.5% of total Nr of vessels and 87.5% of global GRT. The top five flags are Panama (12.5%), the Marshall Islands (11.7%), Liberia (10.5%), Hong Kong (7.5%) and the Bahamas (7.3%) reflecting the high exposure related to cruise vessels and tankers. The top 25 classification societies accounting for 95.5% of MVR (TLVSS) correspond to 56.4% of total Nr of vessels and 96.4% of global GRT. The top five classification societies are DNV-GL (25.12%), Lloyd's Register (17.2%), ABS (13.6%), NKK (12.6%) and BV (9.34%). In terms of MVR (TLVSS) per GRT value, traditional flags show the highest MVR/GRT value with USD 13 followed by unknown or false flags with USD 11 and open registries with USD 9. For class societies, Non-IACS flags are in the lead with USD 16 and owners who are located in low or upper middle income country lead with USD 11.

The world fleet continued to grow for 2020 with a slight decrease of vessels under service as of December 2020 (-0.14%) and a higher percentage of vessels been laid up (+0.25%) compared to the 2017 to 2019 average. The empirical incident rates for TLVSS decreased since 2011 and in 2020 it stands at 1.29% (1.68% in 2019). In 2020, MVR (TLVSS) decreased by 4.18% compared to 2019 and pollution risk exposure (TLVSS) increased by 6% in 2020 compared to 2019. Hull and Machinery shows the highest decrease with -10.38% compared to 2019 followed by loss of lives and injuries (-8.92%) and other marine liabilities (-4.27). The decrease in loss of life is associated with the reduction of active cruise vessels. The results demonstrate that substandard vessels are forced out of the market and there is an adjustment of tonnage. Cruise ships in particular have been affected by the pandemic.

The inspection effect can range from 0.07% (large yachts) to a maximum effect of 17% for some ship types (fishing vessels) as vessels have different safety qualities and each vessel benefits differently from an inspection. Based on the average of 2017 to 2018, averted incident costs due to inspections are estimated to be USD 7,152 (ALL) to 3,923 (TLVSS) million USD per year and as percentage to total MVR, the effect is between 25% (TLVSS) to 40% (ALL) assuming 80k inspections that cover most of the global inspections performed. Comparing the year 2019 with 2020, once can see decrease of inspections due to the pandemic and inspection coverage by 4%. 21.3% of unique vessels were inspected in 2019 but only 17.3% were inspected in 2020 excluding the Paris MoU inspections. The reduction translates into a reduction of 11.6% (ALL) and 6% (TLVSS) of the inspection effect which highlights the importance of port state control inspections as risk control options to mitigate risk exposure.

The analysis demonstrates the variation at ship level and across ship types for all components to estimate risk exposure. Global MVR can be adjusted to the regional level and it is recommended to use nautical miles travelled derived from AIS data rather that time spent in the EEZ to calculate the EEZ factor since it provides a more accurate proxy to estimate exposure of a vessel within an area and time zone. For one risk control option, port state control inspections, the total amount of *averted or mitigated incident costs due to inspections* was quantified and brought into relation to total risk exposure which helps maritime administrations to understand the value of their inspection programs and can also help improve risk profiling of vessels and companies. It highlights the contribution and importance of this risk control option in mitigating risk exposure especially in terms of economic hardship and the pandemic. The use of MVR can be extended to other stakeholders in the maritime industry such as insurance companies as MVR (TLVSS) estimated at ship level can be used as approximation for insurance premiums as demonstrated in this approach.

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Appendix A1: Counts by ship type and vessel status as % to total fleet (2017 to 2019)

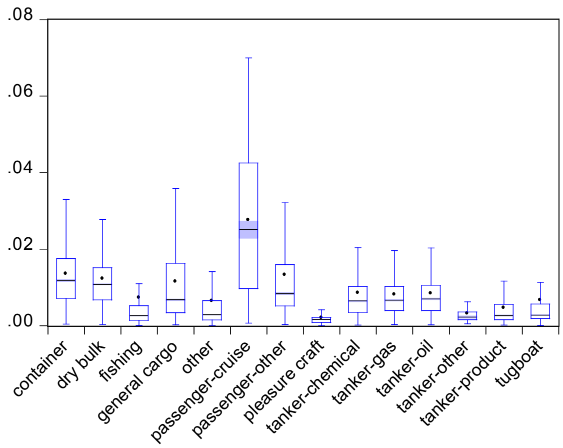
As at Dec of each year	2017	2018	2019	2020	2019-2020
Ship type	**Count**	**Count**	**Count**	**Count**	**Difference**
general cargo	17,842	17,991	18,151	18,182	31
dry bulk	11,695	11,906	12,331	12,629	298
container	5,168	5,289	5,334	5,387	53
tanker	16,339	16,996	17,640	18,182	542
passenger vessels	7,082	7,421	7,696	7,862	166
other ship types	17,270	17,722	18,853	20,699	1,846
fishing vessels	22,168	23,131	23,775	23,827	52
tugs	18,155	18,765	19,098	19,535	437
pleasure crafts	0	0	2,617	2,697	80
Total fleet	**115,719**	**119,221**	**125,495**	**129,000**	**3,505**
% in service	97.04%	97.19%	97.27%	97.03%	-0.238%
% laid up	1.14%	1.30%	1.39%	1.53%	0.144%
% in casualty/repair	0.56%	0.44%	0.35%	0.34%	-0.004%

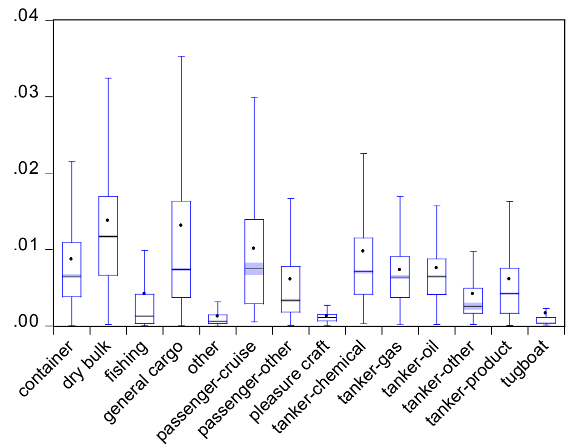
Appendix B1: Summary statistics of MVR probability models in SOMRS (2014 to 2019) sample data

2014 to 2019 sample data damage type models	Total	Incident	Rate	McFad R-sqrd	Schwarz criteria	HR% TPR	HR% overall	HL prob
Incidents (ALL)	721,767	27,809	0.03853	0.2248	0.2543	81.8	72.2	0.0000
TIV Hull & Mach (ALL)	27,809	11,700	0.42073	0.0424	1.3142	52.4	60.5	0.1359
TIV Cargo (ALL)	27,809	204	0.00734	0.0262	0.0878	57.8	60.3	0.9235
TIV TP (ALL)	27,809	8,723	0.31368	0.0478	1.2140	57.7	62.2	0.0000
TIV Life (ALL)	27,809	2,149	0.07728	0.1421	0.4881	69.0	68.0	0.0001
TIV total loss (ALL)	27,809	731	0.02629	0.3418	0.1877	86.7	81.5	0.0770
TIV Pollution oil (ALL)	27,809	2,032	0.07307	0.1468	0.4642	69.6	72.9	0.0135
TIV Pollution HNS (ALL)	33,588	42	0.00125	0.1803	0.0182	71.4	85.4	0.3249
Incidents (TLVSS)	721,767	10,443	0.01447	0.1555	0.1305	74.6	73.6	0.0000
TIV Hull &Mach (TLVSS)	27,809	5,118	0.18404	0.1397	0.8505	68.8	69.8	0.0000
TIV Cargo (TLVSS)	27,809	101	0.00363	0.0292	0.0496	75.3	43.5	0.9363
TIV TP (TLVSS)	27,810	4,368	0.15707	0.0870	0.8263	64.6	66.5	0.0000
TIV Life (TLVSS)	27,809	904	0.03251	0.0959	0.2772	65.5	68.6	0.0295
TIV total loss (TLVSS)	10,443	731	0.07000	0.2719	0.3809	81.9	76.1	0.0053
TIV Pollution (TLVSS)	27,809	572	0.02057	0.0491	0.1980	57.2	65.4	0.0217
TIV Pollution HNS (TLVSS)	33,588	18	0.00054	0.1881	0.0210	61.1	79.4	0.0784

Note: the HNS models are based on very small samples and are to be interpreted with caution.

Appendix B2: Incident probabilities at ship level



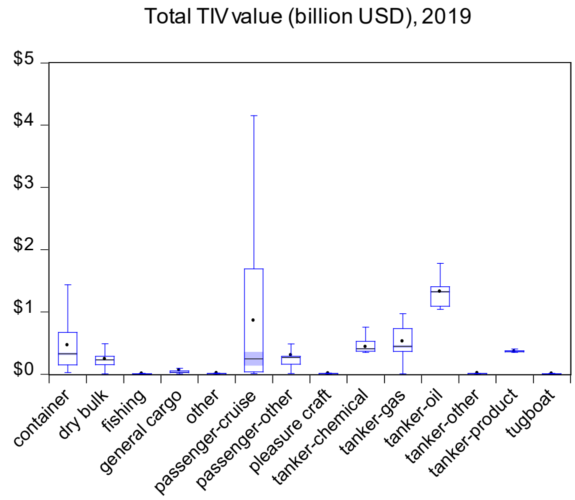


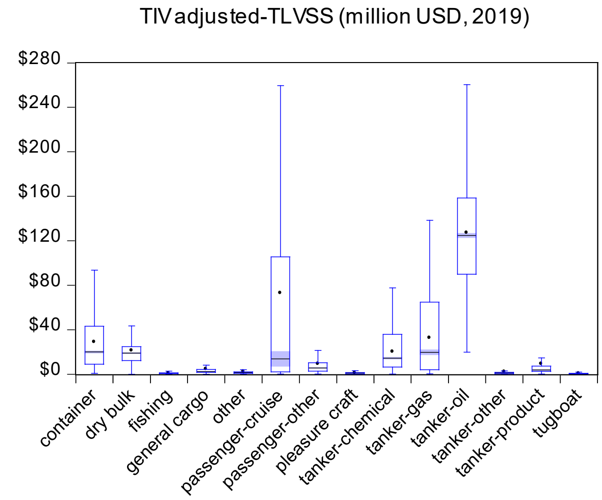
Appendix B3: Average conditional damage type probabilities (2017 to 2020)

Damage type probabilities	2017	2018	2019	2020
Hull and Machinery (ALL)	53.29%	53.17%	52.78%	52.55%
Loss of Life and Injuries (ALL)	2.31%	2.30%	2.19%	2.14%
Pollution - Oil and HNS (ALL)	6.97%	6.73%	6.96%	7.11%
Other Liabilities (ALL)	47.78%	47.92%	47.48%	47.55%
Hull and Machinery (TLVSS)	53.70%	53.73%	53.77%	53.64%
Loss of Life and Injuries (TLVSS)	3.92%	3.88%	3.74%	3.72%
Pollution - Oil and HNS (TLVSS)	6.05%	6.05%	6.18%	6.29%
Other Liabilities (TLVSS)	54.49%	54.45%	54.46%	54.69%

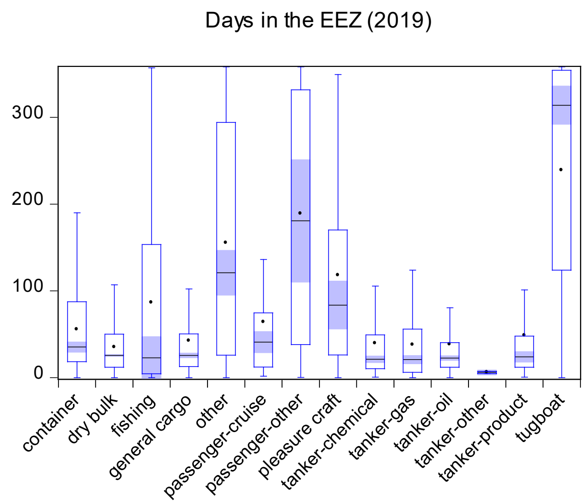
Note: other liabilities include wreck removal, cargo damages and other property damages covered by the LLMC

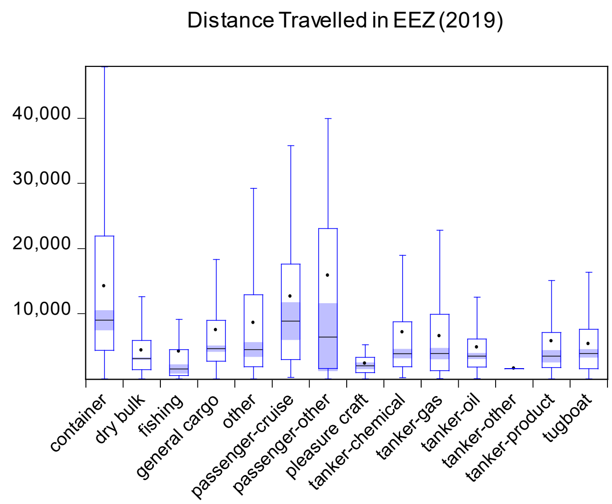
Appendix C1: TIV values at individual ship level (world fleet)



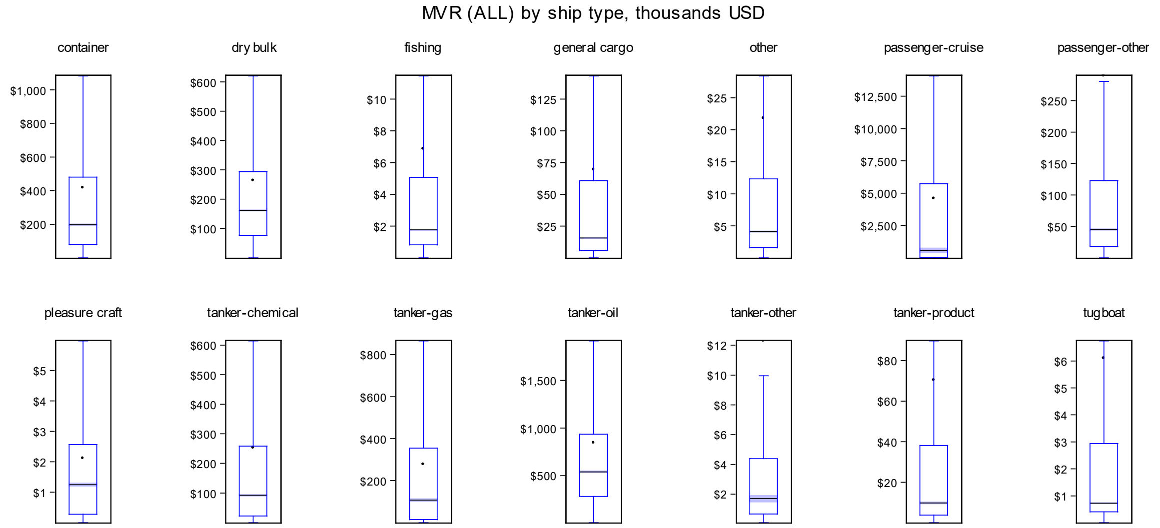


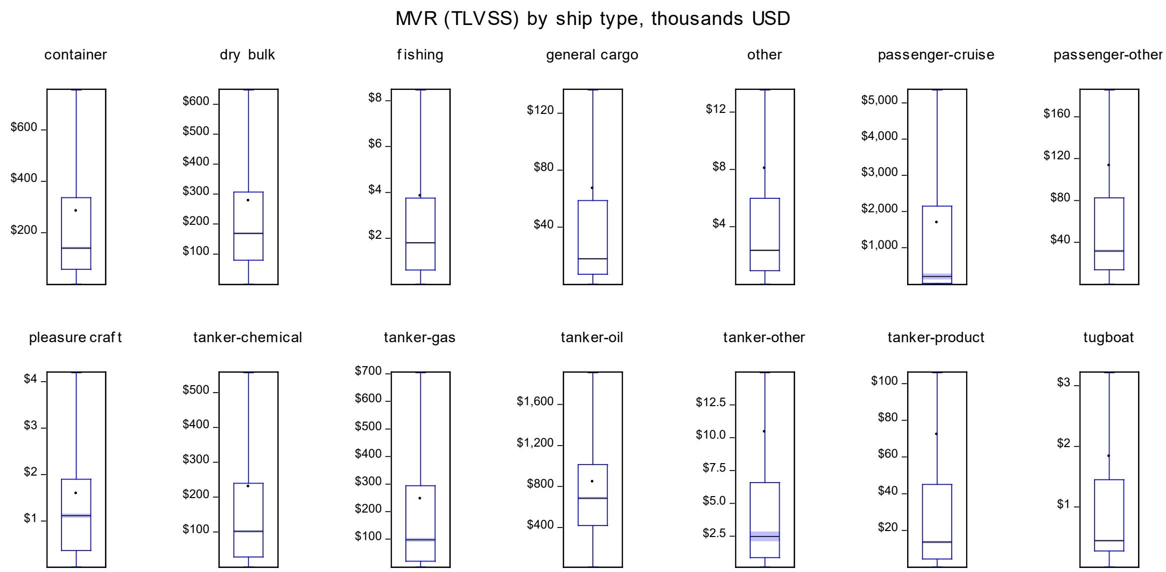
D1: EEZ adjustment factor by ship type





Appendix E1: MVR by ship type (2017 to 2020), thousands USD





Appendix E2: Mean and median MVR-TLVSS by ship type (2017 to 2020), thousands USD

	TLVSS		TLVSS mean			
	Mean	**Median**	**HM**	**LIFE**	**POL**	**Other**
container	284.96	140.79	64.47	10.78	10.96	198.75
dry bulk	278.11	169.08	70.39	10.31	11.16	186.25
fishing	3.85	1.81	0.33	1.08	0.55	1.89
general cargo	67.21	17.81	16.02	2.77	3.42	45.01
other	8.07	2.36	2.32	0.57	0.74	4.45
passenger-cruise	1,698.30	210.96	380.96	964.66	13.95	338.73
passenger-other	113.34	31.99	25.62	60.25	1.50	25.98
pleasure craft	1.59	1.12	0.46	0.15	0.16	0.82
tanker-chemical	230.56	102.06	149.88	2.79	26.46	51.43
tanker-gas	246.90	98.38	110.06	8.15	28.55	100.13
tanker-oil	846.48	687.46	83.27	11.45	600.47	151.29
tanker-other	10.45	2.50	3.53	0.36	1.33	5.23
tanker-product	72.28	13.63	44.91	1.21	7.74	18.42
tugboat	1.83	0.45	0.08	0.32	0.22	1.21

Appendix E3: MVR by flag (2017 to 2020), sorted by % MVR to total MVR (TLVSS)

		% to Total		MVR (TLVSS)			
Nr	**Flag**	**Nr**	**GRT**	**USD total (millions)**	**% to total MVR(TLVSS)**	**Mean (000's)**	**Median (000's)**
1	Panama	6.74%	16.08%	1,721.1	12.53%	208.6	87.9
2	Marshall Islands	3.08%	11.37%	1,606.6	11.70%	426.3	222.2
3	Liberia	3.02%	11.92%	1,437.0	10.46%	389.3	219.1
4	Hong Kong	2.16%	9.01%	1,024.0	7.46%	388.1	217.5
5	Bahamas	1.14%	4.47%	1,001.7	7.29%	719.8	232.9
6	Malta	1.93%	5.63%	871.1	6.34%	369.1	181.5
7	Singapore	2.79%	6.49%	640.2	4.66%	187.2	65.4
8	Greece	1.15%	2.89%	488.0	3.55%	345.4	94.6
9	Russia	3.22%	0.74%	307.1	2.24%	78.0	14.8
10	Cyprus	0.87%	1.66%	269.9	1.97%	254.9	114.5
11	Indonesia	7.58%	1.32%	261.2	1.90%	28.2	1.1
12	Bermuda	0.14%	0.78%	239.2	1.74%	1,447.2	560.3
13	Italy	1.24%	1.10%	225.3	1.64%	148.3	5.5
14	China	5.00%	4.00%	221.9	1.62%	36.3	4.2
15	Isle of Man	0.33%	1.14%	211.6	1.54%	522.6	207.6
16	Canada	0.83%	0.22%	198.5	1.44%	194.4	10.5
17	United Kingdom	1.29%	0.95%	195.8	1.43%	123.7	6.4
18	USA	5.10%	1.09%	193.5	1.41%	31.0	4.0
19	Norway (NIS)	0.53%	1.19%	188.0	1.37%	292.5	112.3
20	Denmark (DIS)	0.51%	1.44%	169.6	1.24%	270.0	109.8
21	Japan	4.39%	2.01%	140.8	1.03%	26.2	4.4
22	Netherlands	1.16%	0.51%	121.2	0.88%	85.2	23.5
23	Antigua & Barbuda	0.62%	0.41%	113.9	0.83%	150.6	78.6
24	Korea, South	2.48%	0.83%	113.0	0.82%	37.3	2.4
25	Norway	1.22%	0.21%	110.3	0.80%	73.7	17.4
	Other flags	41.48%	12.52%	1,664.6	12.12%	-	-
	Top 10	**26.10%**	**70.28%**	**9,366.7**	**68.20%**	**-**	**-**
	Top 15	**40.38%**	**78.62%**	**10,525.8**	**76.63%**	**-**	**-**
	Top 20	**48.65%**	**83.51%**	**11,471.2**	**83.52%**	**-**	**-**
	Top 25	**58.52%**	**87.48%**	**12,070.5**	**87.88%**		
	Total fleet	**100%**	**100%**	**13,735.1**	**100%**	**-**	**-**

Appendix E4: MVR by class (2017 to 2020), sorted by % MVR to total MVR

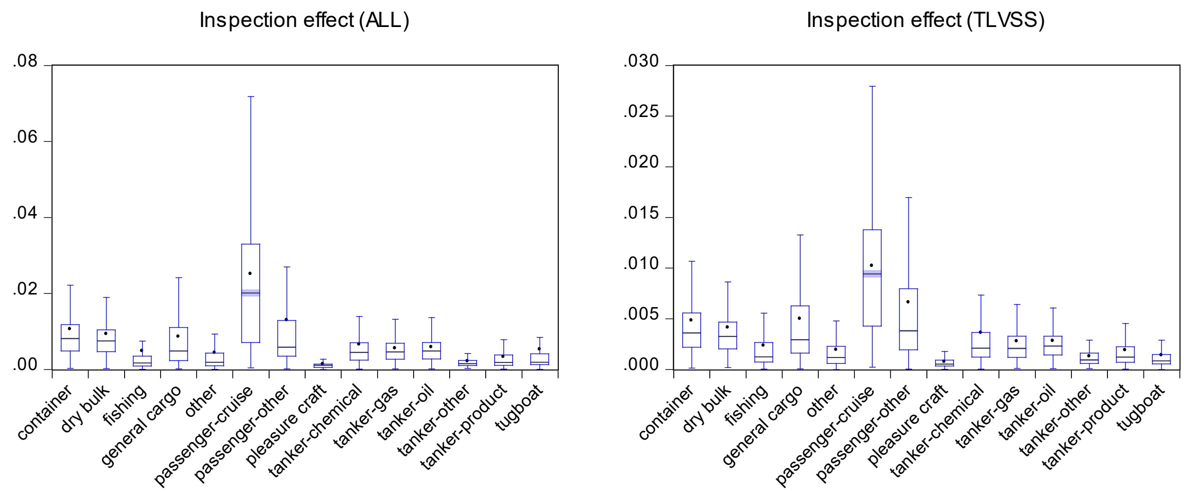
		% to Total		MVR (TLVSS)		
Nr	Class Society	Nr	GRT	USD total (millions)	% to total MVR (TLVSS)	Mean (000's)
1	DNV-GL	7.89%	19.09%	3,450.1	25.12%	357,589
2	Lloyd's Register	6.16%	16.05%	2,371.4	17.27%	314,399
3	American Bureau of Shipping	6.68%	16.67%	1,878.0	13.67%	229,870
4	Nippon Kaiji Kyokai	7.05%	18.25%	1,731.7	12.61%	200,724
5	Bureau Veritas	7.02%	8.25%	1,282.6	9.34%	149,406
6	Registro Italiano Navale	3.01%	2.79%	595.9	4.34%	161,817
7	China Classification Society	3.13%	7.38%	553.6	4.03%	144,771
8	Korean Register of Shipping	2.25%	4.51%	460.8	3.35%	167,285
9	Russian Maritime Register	2.80%	0.85%	296.2	2.16%	86,451
10	Biro Klasifikasi Indonesia	5.84%	0.59%	166.3	1.21%	23,288
11	Indian Register of Shipping	0.96%	0.64%	79.0	0.58%	67,365
12	Polski Rejestr Statkow	0.31%	0.33%	50.4	0.37%	131,574
13	Vietnam Register	1.07%	0.30%	47.8	0.35%	36,397
14	Turk Loydu	0.37%	0.06%	27.6	0.20%	60,925
15	China Corporation Register	0.17%	0.15%	25.1	0.18%	121,175
16	Russian River Register	0.18%	0.05%	19.2	0.14%	85,776
17	International Register	0.31%	0.05%	14.4	0.10%	38,273
18	International Naval Surveys	0.18%	0.04%	13.5	0.10%	62,664
19	Zianlian Chuen	0.31%	0.09%	10.1	0.07%	26,656
20	Phoenix Register of Shipping	0.13%	0.04%	9.8	0.07%	61,199
21	Croatian Register of Shipping	0.29%	0.08%	9.4	0.07%	26,126
22	Panama Maritime Documentation	0.06%	0.03%	8.2	0.06%	108,718
23	Isthmus Bureau of Shipping	0.09%	0.04%	8.1	0.06%	75,750
24	Sing-Lloyd	0.12%	0.05%	6.8	0.05%	45,036
25	Dromon Bureau of Shipping	0.12%	0.05%	6.5	0.05%	43,901
	Other	43.51%	3.58%	612.3	4.46%	-
	Top 10	**34.79%**	**78.31%**	**10,713.9**	**78.00%**	**-**
	Top 15	**51.82%**	**94.44%**	**12,786.7**	**93.10%**	**-**
	Top 20	**54.70%**	**95.91%**	**13,016.7**	**94.77%**	**-**
	Top 25	**55.81%**	**96.18%**	**13,083.7**	**95.26%**	
	Total fleet	**100%**	**100%**	**13,735.1**	**100%**	**-**

Appendix E5: MVR by GRT – top 10 flag, class and owner location by MVR/GRT or Pax (2017 to 2020)

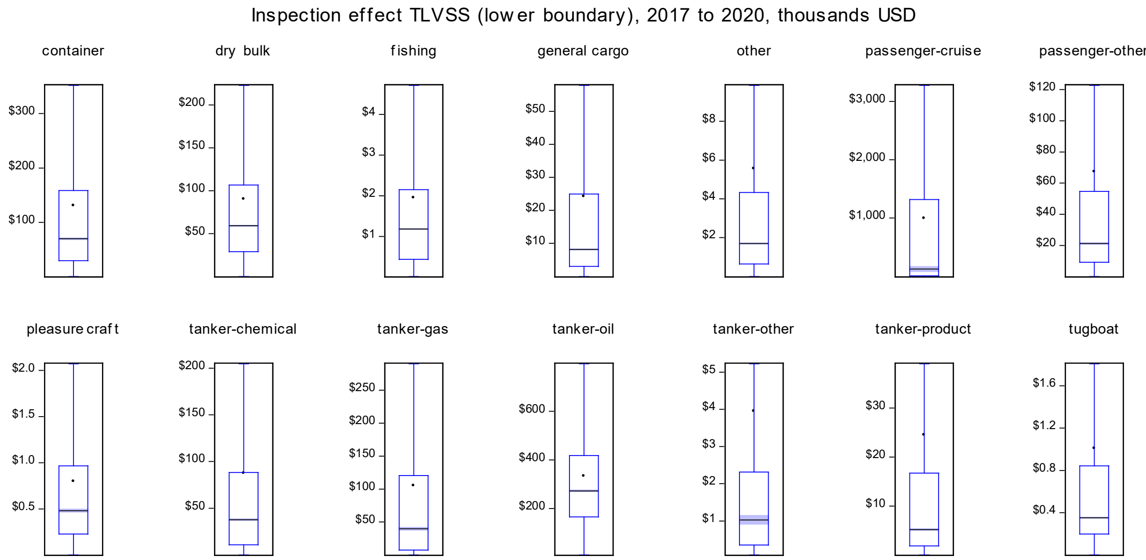
		% to total fleet		MVR (TLVSS)		
Group	**Category**	**Nr**	**Pax**	**mill USD**	**% to total**	**$ MVR/Pax**
Flag-pax	Bahamas	0.12%	6.47%	525.1	3.82%	1,797.60
Flag-pax	Bermuda	0.03%	1.73%	155.5	1.13%	1,777.65
Flag-pax	Malta	0.07%	2.92%	111.9	0.81%	1,004.27
Flag-pax	France	0.08%	1.63%	65.8	0.48%	893.89
Flag-pax	Cyprus	0.05%	1.41%	26.0	0.19%	697.70
Flag-pax	Panama	0.11%	4.07%	119.5	0.87%	550.20
Flag-pax	United Kingdom	0.10%	1.97%	68.9	0.50%	539.67
Flag-pax	Denmark (DIS)	0.02%	0.71%	16.2	0.12%	525.63
Flag-pax	Canada	0.14%	2.10%	42.7	0.31%	461.47
Flag-pax	Russia	0.07%	0.53%	5.6	0.04%	461.14
Group	**Category**	**Nr**	**GRT**	**mill USD**	**% to total**	**$ MVR/GRT**
Flag-non pax	Kenya	0.03%	0.00%	1.8	0.01%	128.26
Flag-non pax	Mauritius	0.03%	0.01%	2.5	0.02%	113.19
Flag-non pax	Russia	3.14%	0.73%	301.5	2.20%	76.92
Flag-non pax	Gibraltar	0.20%	0.15%	55.6	0.40%	55.69
Flag-non pax	Mongolia	0.13%	0.03%	11.3	0.08%	54.33
Flag-non pax	Norway	0.88%	0.15%	41.0	0.30%	53.75
Flag-non pax	Maldives Islands	0.05%	0.00%	1.0	0.01%	50.56
Flag-non pax	Cape Verde	0.02%	0.00%	0.9	0.01%	49.50
Flag-non pax	Germany	0.46%	0.58%	75.0	0.55%	49.09
Flag-non pax	Canada	0.69%	0.18%	155.8	1.13%	45.25
Class	Russian River Register	0.18%	0.05%	19.2	0.14%	143.29
Class	Maritime Bureau of Shipping	0.02%	0.00%	1.8	0.01%	130.88
Class	Columbus American Register	0.03%	0.00%	3.3	0.02%	123.37
Class	Ships Classification Malaysia	0.07%	0.00%	2.1	0.02%	107.09
Class	Hellenic Register of Shipping	0.05%	0.00%	3.4	0.02%	99.69
Class	International Naval Surveys	0.18%	0.04%	13.5	0.10%	71.37
Class	Russian Maritime Register	2.80%	0.85%	296.2	2.16%	69.99
Class	Turk Loydu	0.37%	0.06%	27.6	0.20%	53.59
Class	Panama Maritime	0.06%	0.03%	8.2	0.06%	51.50
Class	Korea Ship Safety Technology	0.02%	0.00%	1.6	0.01%	49.29
Owner Location	Kenya	0.05%	0.00%	2.1	0.02%	107.32
Owner Location	Turkmenistan	0.04%	0.01%	4.7	0.03%	67.961
Owner Location	Portugal	0.15%	0.05%	9.4	0.07%	67.802
Owner Location	Fiji	0.03%	0.00%	2.6	0.02%	57.454
Owner Location	Bahrain	0.08%	0.01%	1.7	0.01%	54.607
Owner Location	Syria	0.02%	0.01%	1.3	0.01%	48.836
Owner Location	Malta	0.11%	0.10%	26.2	0.19%	48.541
Owner Location	Maldives Islands	0.05%	0.00%	1.2	0.01%	48.387
Owner Location	Russia	2.81%	1.20%	349.6	2.55%	44.103
Owner Location	Estonia	0.17%	0.07%	25.6	0.19%	41.127
Total for flags – passenger vessels		**0.81%**	**23.54%**	**1,137.2**	**8.28%**	**-**
Total for flags – other ship types		**5.63%**	**1.83%**	**646.4**	**4.71%**	**-**
Total classification societies		**3.78%**	**1.05%**	**377.0**	**2.74%**	**-**
Total owner location		**3.50%**	**1.44%**	**424.4**	**3.09%**	**-**

Note: for flags, owners and class societies with at least 100 vessels; owner is beneficial owner

Appendix F1: Inspection effect at ship level (percent reduction)



Appendix F2: Inspection effect by ship type (2017 to 2020), thousands USD



Appendix F3: Mean and median inspection effect by ship type (2017 to 2020), thousands USD

	ALL		TLVSS	
Ship Type	**Mean**	**Median**	**Mean**	**Median**
container	252.27	125.81	130.84	70.20
dry bulk	162.27	109.86	90.28	59.28
fishing	4.14	1.14	1.95	1.18
general cargo	42.91	11.10	24.23	8.20
other	13.37	2.65	5.56	1.71
passenger-cruise	2,979.26	347.87	994.28	128.62
passenger-other	179.59	29.98	67.29	21.25
pleasure craft	1.38	0.84	0.80	0.48
tanker-chemical	155.07	62.54	87.45	37.84
tanker-gas	178.21	72.20	105.24	39.87
tanker-oil	516.08	364.92	333.62	272.61
tanker-other	8.86	1.16	3.95	1.03
tanker-product	44.15	6.80	24.52	5.25
tugboat	3.78	0.50	1.01	0.35