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Convention-Level Pattern Analysis of Exemptions and Equivalents in IMO Regulations using Rule-Based Pipeline

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Abstract

This study examines how flag states utilize exemptions and equivalents within the International Maritime Organization's regulatory system, using ten years of cleaned and enriched Global Integrated Shipping Information System (GISIS) notifications. Data preparation used a deterministic, rule-based pipeline that transformed semi-structured text through tokenization, regex patterning, and n-gram co-occurrence analysis. Standardized instrument references and reconstructed analytical fields were linked to metadata on ship type and size. The Analyses examined exemption intensity, cross-flag variation, convention portfolios, ship-type associations, temporal dynamics, and exploratory clustering. Results show that exemptions are concentrated in technical regimes led by International Convention for the Safety of Life at Sea, followed by International Convention for the Prevention of Pollution from Ships, International Regulations for Preventing Collisions at Sea, and International Convention on Load Lines; national portfolios are coherent rather than random; and volumes increase over the decade despite adjustment for exposure. Notification rates remain highly right-skewed, with a small subset of flags accounting for a disproportionate share of documented exemptions and equivalents. Methodologically, the paper contributes a reproducible, deterministic pipeline that normalizes instrument references, reconstructs exemption fields, and links notifications to vessel attributes, enabling exposure-adjusted cross-flag comparisons and portfolio analysis. The scope is limited to convention-level categories rather than clause- or rule-specific analyses because citation patterns in flag-state reports are fragmented and heterogeneous. Findings have implications for transparency, comparability, and the design of structured reporting in GISIS to support evidence-based oversight.

Keywords: IMO regulations, exemptions, rule-based pattern mining

1. Introduction

The International Maritime Organization (IMO) is a specialized agency of the United Nations responsible for regulating maritime transport globally. The IMO has near-universal membership, comprising 175 member states that together represent about 98% of world merchant tonnage, reflecting its central position in maritime affairs [1]. The purpose of the IMO is to strengthen safety and security at sea while preventing marine pollution through the adoption of harmonized international standards. Its primary role is to develop and maintain a comprehensive framework of international maritime regulations [2]. According to the IMO's mission statement, these regulations cover a wide range of areas related to international shipping ship safety, security, and environmental protection [2]. As part of the United Nations, IMO also began actively developing regulations aligned with the Sustainable Development Goals, including promoting and enforcing sustainable and efficient practices in the maritime sector. The IMO aims to achieve its mission through international conventions (treaties) that member states adopt and implement [2,3]. IMO's regulatory work is carried out through specialized committees and numerous technical subcommittees. Through these bodies, IMO continually updates conventions. Conventions generally cover legal, operational, and technical aspects of the subjects mentioned, in the form of guidelines, rules, and regulations. The most notable conventions, commonly referred to as the pillars of the IMO, are International Convention for the Safety of Life at Sea (SOLAS), International Convention

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for the Prevention of Pollution from Ships (MARPOL), and International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). These conventions underwent several revisions and amendments over the years, with the intention of both modernizing and expanding their content. Amendments, appendices, and annexes expanded and built on these conventions. Comprehensive amendments also come in the form of codes, e.g., the Life-Saving Appliance Code (LSA), the Code for Fire Safety Systems, or the International Maritime Dangerous Goods Code [4]. Most conventions use a tacit acceptance procedure for amendments. Under this procedure, if member states do not object within a set period, amendments enter into force automatically, accelerating updates to keep pace with industry changes.

Conventions, codes, and amendments that set minimum requirements for ships and maritime operations. However, flag states have primary legal authority over vessels registered under their jurisdiction, granting them the right to enforce maritime laws aboard these ships within their territorial waters and exclusive economic zones. Since IMO consists of these member flag states, these states negotiate and adopt the conventions and regulations. Once adopted, these instruments do not apply directly to ships until they are ratified and implemented by member states. When a country ratifies an IMO convention, it agrees to transpose those international requirements into its national laws and to apply them to ships flying its flag.

Therefore, for IMO instruments to take effect, flag states must incorporate them into their domestic legislation. Only then can IMO rules govern ships on the State's register, enable effective port state control (PSC), and ensure compliance with obligations under the relevant IMO instruments [5]. In this way, IMO conventions become binding rules for ships worldwide, ensuring that maritime regulations are consistent across countries. Still, in a way, IMO and PSC only set minimum standards for ships, and flag states have the utmost authority to enforce stricter rules and regulations on vessels under their jurisdiction.

Importantly, United Nations Convention on the Law of the Sea (UNCLOS) establishes the duty of flag states to ensure their ships conform to international safety and pollution standards. UNCLOS provides the legal foundation by requiring states to adopt laws and regulations for ships flying their flag that are at least as effective as generally accepted international rules. Under UNCLOS Article 94 and related provisions, every flag State must effectively exercise jurisdiction over its ships, ensuring they are constructed, equipped, manned, and operated in conformity with "generally accepted international rules and standards". Similarly, for marine environmental protection, UNCLOS Article 211 (2) obliges flag States to adopt laws "at least as effective as" the international rules established by the competent organization. In practice, this means that even if a State has not ratified a particular IMO convention, it may be bound by UNCLOS to enforce equivalent standards on its fleet [6]. Flag States are thus the primary enforcers of IMO regulations over their vessels; IMO has no supranational police powers and no authority to enforce conventions.

UNCLOS also empowers coastal and port states to enforce certain international rules in their waters or ports. To bolster compliance, UNCLOS and IMO conventions provide for complementary enforcement by port and coastal States. Many IMO instruments authorize PSC, allowing inspectors in foreign ports to verify visiting ships' certificates and conditions and to detain vessels that present clear hazards or serious deficiencies [7]. Flag States often rely on recognized organizations (ROs), typically classification societies, to carry out survey and certification functions on their behalf [8]. Essentially, IMO creates the standards, and UNCLOS, together with the conventions, compels states to implement and enforce them, making IMO a key instrument of global maritime governance.

Despite the goal of uniformity, IMO conventions incorporate a degree of flexibility through provisions on exemptions and equivalents. These clauses recognize that one-size-fits-all rules may not suit every scenario, allowing administrations limited discretion to depart from strict compliance in defined circumstances. IMO treaties commonly include equivalence provisions, such as provisions that permit a flag administration to accept fitting, material, appliance, or apparatus, or other provision as an alternative to those prescribed by the conventions [9]. In such cases, the flag state must ensure that the ship meets any supplementary safety measures it deems adequate and must obtain the consent of destination states that the ship will visit. Critically, any novel-feature exemption must be notified to the IMO with details and justification, which are then circulated to all member governments [9]. This transparency aims to prevent abuse and inform the international community.

The Global Integrated Shipping Information System (GISIS) now serves as a repository for such notifications across various instruments. However, there has been no comprehensive empirical analysis of GISIS records to discern trends in the use of exemptions and equivalents. This study addresses this gap by leveraging GISIS notifications to examine the incidence and characteristics of exemptions granted under IMO conventions. The analysis investigates how flag states employ these mechanisms across registry sizes, regulatory instruments, vessel functions, and over time, by focusing on IMO convention schemes and assessing the implications for the consistency, integrity, and effectiveness of the global maritime regulatory framework.

2. Materials and Methods

The dataset used in this study was sourced from the IMO GISIS exemption database, which contains detailed records of 12,510 notifications of exemptions or equivalent arrangements granted by flag administrations and reported to the IMO between 2015 and August 2025. After data preparation, this number was reduced to 6,360 records. Each record includes the ship's flag state, name, IMO number, authority conferred by, exemption from or equivalence to, and date of notification, where available. Additional data, such as Automatic Identification System (AIS)-derived ship type, gross tonnage (GT), summer deadweight tonnage (DWT), merchant fleet size by country, and the conventions related to exemptions and the specific regulation or rule under which each exemption was granted, are retrieved by the author using different methodologies. The raw data were irregularly formatted and required substantial cleaning (Figure 1).

The dataset was prepared through a structured cleaning and enrichment workflow. Records were deduplicated using the IMO number combined with a text fingerprint, and rows with empty analytical fields were removed. Pre-processing normalized textual content through Unicode cleaning, lowercasing, whitespace compression, and the correction of recurrent typographical variants that could impede pattern recognition. Missing vessel attributes were populated using open APIs and controlled web scraping to retrieve ship type, size, and age from external databases keyed by IMO numbers. Conflicts among sources were resolved by a fixed priority policy that considered institutional reliability and record recency, yielding a single value per field. During integration, conflicts among sources were resolved by a priority policy that considered institutional reliability and record recency, yielding a single coherent value per field. Outliers were screened through logical consistency rules and range checks, and suspect entries were queued for manual audit.

After the initial data population and preparation, specific IMO conventions related to exemptions were identified. Convention identification followed a deterministic, rule-based pipeline supported by a two-track discovery phase and a subsequent normative validation phase. Conventions were primarily identified through structural cues and domain-specific terms. Rule development proceeded in two parallel stages. First, a data-oriented discovery step was applied after strict normalization and tokenization into simple classes (WORD, NUM, ROMAN, SLASH, and COMMA). Word-based and type-based bigram and trigram counts were computed and ranked using pointwise mutual information (PMI), the log-likelihood ratio, and the t-score to identify stable cues such as ANNEX+ROMAN, RULE+NUM, and ROMAN+SLASH+NUM. Unsupervised data mining methods, including n-gram collocation statistics and the PrefixSpan frequent sequential pattern mining algorithm, were applied to induce short sequential templates from type sequences and to identify recurrent, ordered patterns indicative of specific conventions. This highlighted pattern sequences that mark SOLAS chapter and clause paths, and "Annex" with a Roman numeral combined with "Regulation" and a number that mark MARPOL annex references. In

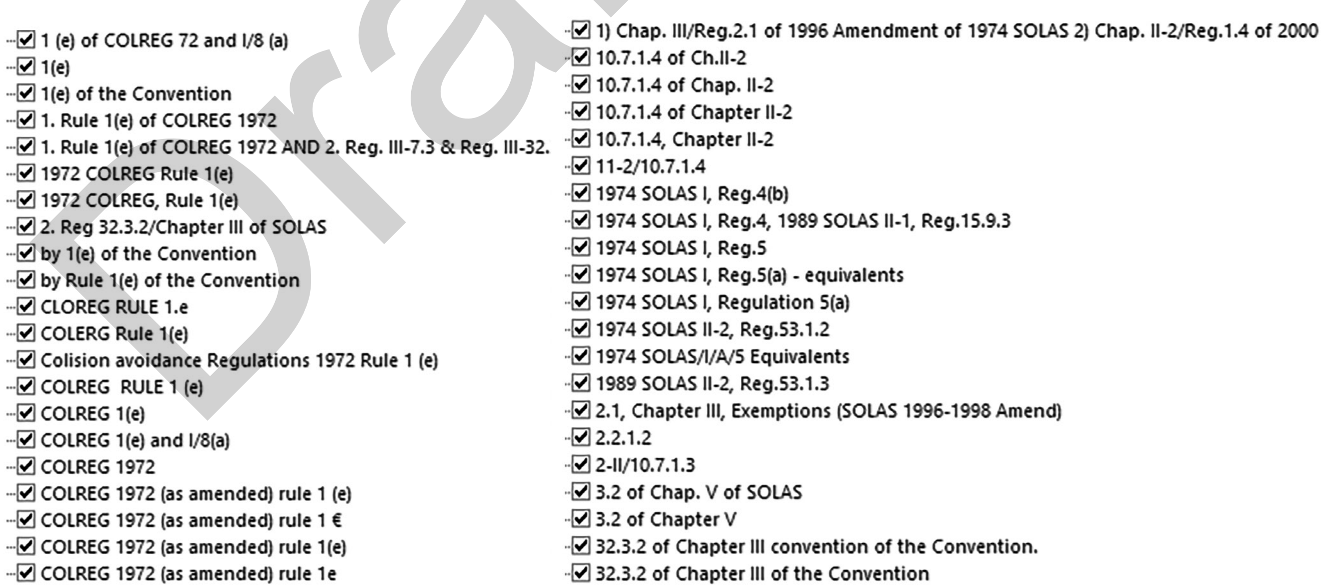

Figure 1. *Irregularities in the reporting format and data*

COLREG: International Regulations for Preventing Collisions at Sea, SOLAS: International Convention for the Safety of Life at Sea parallel, expert-guided authoring sets produced pattern families that reflect instrument-specific drafting habits. These expressions capture SOLAS chapter markers with clause paths (e.g., II-1/12.1), MARPOL annexes with regulation numbers (e.g., Annex I, Regulation 14.3), and International Regulations for Preventing Collisions at Sea (COLREG) provisions in rule and parenthetical forms (Table 1). All patterns from both routes were verified against one another and against the structures of the official instruments and relevant IMO reference pages. Synonymous names and frequent variants were incorporated into a maintained lexicon, and regex capture groups were aligned. Negative contexts that produced false matches were blacklisted.

A deterministic, rule-based pipeline was developed to ensure that every stage of processing exemption data remained methodical and verifiable. Citation formats and numbering conventions vary widely across IMO instruments; this variability makes automated machine learning classifiers unreliable and difficult to evaluate. In the context of regulatory analysis, interpretability is essential because each link between the raw text and its corresponding legal reference must be clearly understood and traceable. The pipeline was constructed in two main stages. In the discovery phase, families of regular expressions and lexical patterns were derived from tokenized text using collocation statistics and n-gram co-occurrence analysis. These patterns were aligned with the official structure of each convention to standardize references to annexes, chapters, and rules. Ambiguous entries, such as those citing only "Annex Reg. 5," were resolved through contextual cues and a fixed precedence policy that governed the "Authority conferred by" and "Exempted from/Equivalent to" fields. The validation phase involved a stratified manual audit that spanned multiple years, conventions, and high-volume flags. This audit evaluated the precision of instrument assignments, the accuracy of annex disambiguation, and the consistency of vessel metadata linkages. All corrections were documented, and the complete rule lexicon, precedence policy, and codebook were included in the Supplement to allow independent replication. This deterministic approach provides a consistent and verifiable data transformation framework suitable for regulatory analytics. It enables reliable quantitative comparison of exemption activity across conventions and flag administrations while preserving the full interpretability of each derived label.

After validation, production labeling was performed using the lexicon and validated families of regular expressions within a deterministic pipeline. Conventions were assigned directly when exact lexicon matches were present; otherwise, they were assigned by structural expressions and regex. Named codes [e.g., International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF),

Table 1. *Rule examples from the data labeling*

Cue type	Example cue	Context condition	Final assignment	Note
Explicit rule	Rule 1(e)	None	COLREG	Deterministic match
Structural pattern	Chapter II-2/10.7.1.3	None	SOLAS	Chapter+Roman numeral is a strong indicator
Annex+context	Annex IV Reg. 14	Emission, fuel oil, OWS, NOx, SOx	MARPOL	Use MARPOL when emission or oil context is present
Annex+lights	Annex I+masthead light, sternlight, horizontal distance, Rule 21/23	Navigation light terminology	COLREG	COLREG Annex I disambiguation
ICLL pattern	Article 6(2), Regulation 39, freeboard, bow height	None	ICLL	Load line terminology
IGF numbering	6.7.2.x, 5.11.x, low-flashpoint fuel	None	IGF Code	Codes have priority
Code name	ISM, ISPS, Intact Stability, SPS, MODU, IGC, IBC, HSC/DSC	None	Respective Code	DSC treated under HSC family
Generic SOLAS cue	LRIT, VDR, watertight doors, gyro compass	None	SOLAS	Equipment and monitoring terms
Generic COLREG cue	Collision regulations, Rule <number>	None	COLREG	Generic rule phrasing

COLREG: International Regulations for Preventing Collisions at Sea, SOLAS: International Convention for the Safety of Life at Sea, MARPOL: International Convention for the Prevention of Pollution from Ships, OWS: Oily water separator, ICLL: International Convention on Load Lines, IGF: International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels, ISM: International Safety Management Code, ISPS: International Ship and Port Facility Security Code, MODU: Code for the Construction and Equipment of Mobile Offshore Drilling Units IGC: International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, IBC: International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, HSC: The International Code of Safety for High Speed Craft, DSC: Code of Safety for Dynamically Supported Craft, LRIT: Long-range identification and tracking, VDR: Voyage Data Recorder

International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code), International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, International Safety Management Code (ISM), International Ship and Port Facility Security Code (ISPS), International LSA] were mapped by exact lexical matches and given precedence over conventions. Each record was labeled independently of both input fields and then reconciled under a transparent precedence policy. When the two fields indicated different codes, the record was flagged for manual review. When they indicated different conventions, the record was marked as a multiple-convention case. Otherwise, the single surviving label was retained.

Table 2 presents several example step outcomes. Representative patterns included: SOLAS chapter markers with Roman numerals and clause formats (II-1, II-2, V) and equipment terms governed by SOLAS (e.g., Long-range identification and tracking, Voyage Data Recorder, watertight doors); MARPOL Annex identifiers in fuel, emissions, or oil-handling contexts, and terms such as Oily water separator, sludge, and Marine Environment Protection Committee references; COLREG "Rule n" formulations and Annex I navigation-light terminology, such as masthead light, sternlight, and horizontal distance; International Convention on Load Lines (ICLL) terminology concerning freeboard and bow height, including references such as Regulation 39 or Article 6(2); and STCW, when explicit instrument names or canonical article structures were present. Because the expressions "Annex", "regulation", and "of the convention" occur across regimes, disambiguation and unknown rules were applied. For example, navigation-light contexts were mapped to COLREG, emissions and oil-pollution contexts were mapped to MARPOL, and bow or freeboard heights were mapped to ICLL.

This methodological choice was necessitated by structural limitations of the IMO GISIS Exemptions interface, heterogeneity of its underlying documents, and irregularities in reporting and writing (Figure 1). The IMO portal provides tabular downloads for exemption records, yet these exports omit vessel attributes such as ship type and size, and exclude the detailed grounds for exemptions and the explicit convention or code clauses relied upon by authorities. The substantive justifications are contained in the application files and letters uploaded by the authority. Those appear templated but, in practice, depart from a consistent standard, with rules cited using divergent phrasing, numbering styles, and capitalization, and key terms embedded in narrative text rather than in dedicated fields. Accessing these requires record-by-record navigation on the GISIS website, which prevents direct, automated ingestion at scale and precludes immediate quantitative analysis. Under these constraints, a principled approach that systematically extracts, normalizes, and reconciles legal references from semi-structured narratives is essential to render the data analyzable and produce replicable labels for instruments and clauses.

Automation of data cleaning, enrichment, and convention labeling was implemented in Python. Data preparation and analytical manipulation were performed using the pandas library. Text normalization and tokenization were performed using "re" and "regex" regular-expression libraries. Fine-grained text parsing and tokenization were handled by the spaCy library. During rule discovery, unsupervised data mining methods were applied. N-gram (bigram/trigram) collocation statistics, PMI, t-score, and log-likelihood ratio G-test were computed with SciPy; spaCy was used for tokenization and count extraction (NumPy for vectorization where needed), and sequential patterns were mined from type sequences using the PrefixSpan algorithm via the "prefixspan" package. This methodological flow is shown in Figure 2.

Table 2. *Rule outcomes by step*

Step	Input	Condition or operation	Output or label	Reported metric
Dual-field reconciliation	Authority label, exempted label	If both present and different: prefer Code, else fixed priority list; two different Codes → Multiple Codes; two different Conventions → Multiple Conventions	Single instrument label	Conflict count, multi-label count
Annex disambiguation	"Annex" cues	Emission or oil context → MARPOL; navigation light terminology → COLREG	Final instrument	Count of Annex-driven corrections
Unknown pass 1	Unassigned records	List unique phrases, derive new pattern lexicon	Expanded matcher	Unknown count baseline
Unknown pass 2	Expanded matcher	Add pattern cues, n-gram clusters, IGF 6.7.2.x style numbering, re-run	Reduced Unknown	Unknown counts by exempt and authority
Outputs	Final labels and rule fields	Produce versioned files	Corrected finals	Coverage, sensitivity, conflict rate

MARPOL: International Convention for the Prevention of Pollution from Ships, COLREG: International Regulations for Preventing Collisions at Sea, IGF: International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels

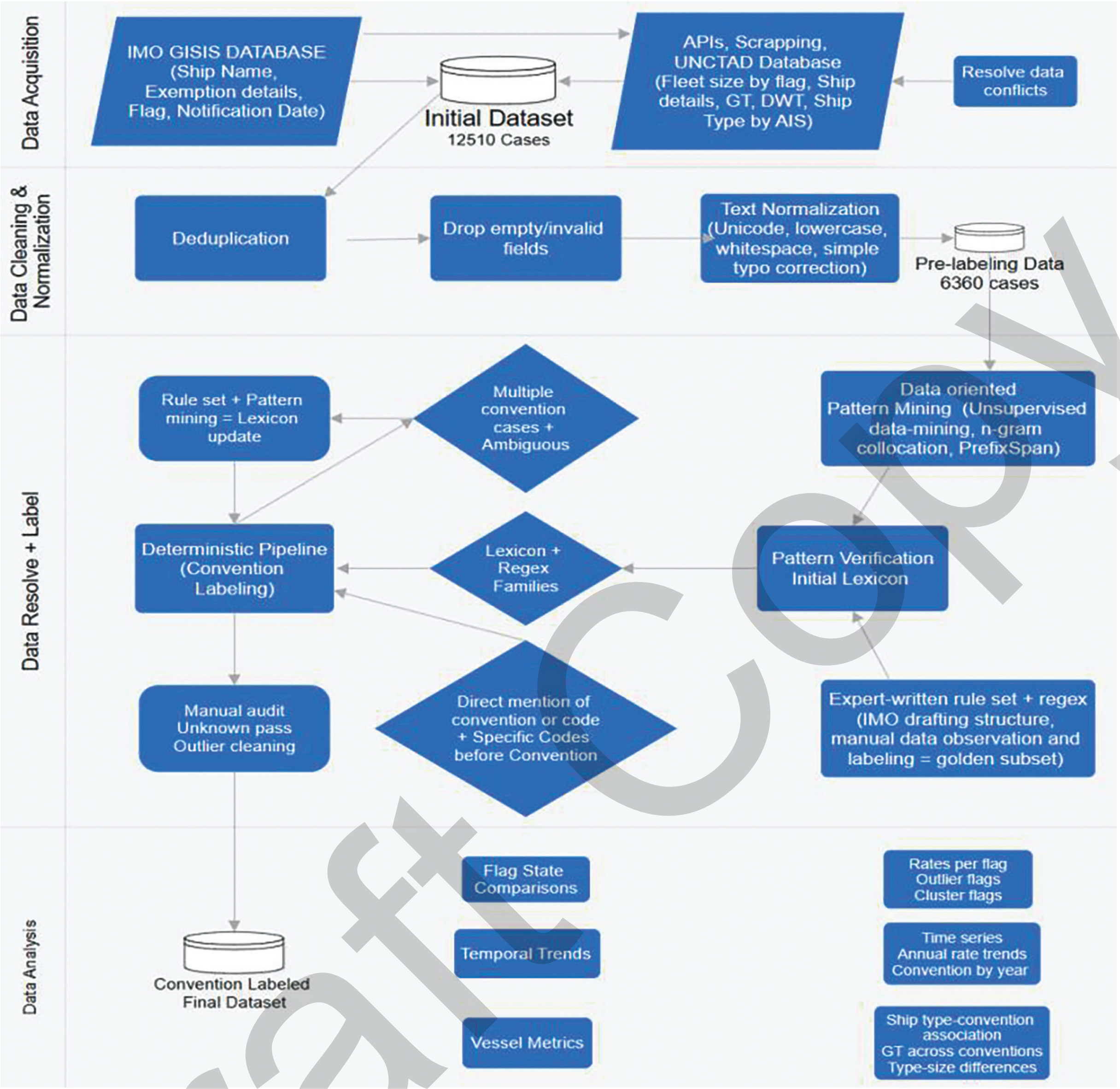

Figure 2. *Flowchart of the research*

IMO: International Maritime Organization, UNCTAD: UN Trade and Development, GT: Gross tonnage, DWT: Deadweight tonnage, AIS: Automatic Identification System

Data analysis procedures were organized to quantify exemption rates, concentration and inequality, cross-flag differences, association structures, temporal trends, ship-size contrasts, divergence from global patterns, and exploratory clusters. The annual exemption rate for each flag was defined as 1,000 times the count of reported exemptions in a calendar year divided by the merchant fleet size in that year. This rate served as the primary outcome for cross-flag comparisons. Concentration across flags was summarized using the Herfindahl-Hirschman Index (HHI), its normalized variant, and the Gini coefficient; Lorenz curves were produced to visualize distributional inequality. Differences in exemption rates between flags were tested using Pearson chi-square tests of homogeneity after verifying expected cell counts of at least five, and Wilson score intervals were reported for single-flag proportions. The false discovery rate was controlled using the Benjamini-Hochberg procedure.

To stabilize rate estimates for small fleets, an empirical Bayes beta-binomial model was applied. Shrinkage-adjusted rates and 95 percent control limits were plotted on funnel plots to distinguish sampling variability from systematic differences. Association structures were examined in two contingency settings: flag (by convention) and ship type (by convention). Each table was analyzed using a chi-square test of independence; Cramér's V was reported as an effect size, and standardized residual heatmaps were used to identify influential cells, with cell-level inference adjusted using false discovery rate control.

Temporal dynamics were evaluated with Kendall's tau tests applied to monthly exemption counts and annual exposure-adjusted rates, with exact or continuity-corrected p-values selected according to series length and the presence of ties. Differences in GT across conventions were assessed with the Kruskal-Wallis test, and epsilon squared was used as a rank-based effect size. Pairwise explorations were assessed using Dunn-type contrasts with Benjamini-Hochberg adjustments. Divergence between the convention mix of each flag and the global mix was quantified using the Jensen-Shannon distance. For exploratory structural analysis, a feature matrix was constructed from positive, statistically significant standardized residuals in the flag-by-convention table. Cosine similarities between flags were then computed, and agglomerative clustering with average linkage was performed. Dendrogram cut levels were chosen to balance within-cluster coherence and between-cluster separation, and the resulting groups were used solely for descriptive interpretation.

3. Findings

Before a more comprehensive data analysis, descriptive statistics also revealed some key findings. Tables 3 and 4 show the descriptive statistics and frequency distributions of the variables. Exemptions were concentrated in the cargo and tanker segments, which together accounted for about 62% of notifications, with the passenger and special craft segments contributing smaller shares. Within the detailed AIS breakdown, the most frequent classes were general cargo ships, bulk carriers, and container ships.

Most referenced exemptions were to SOLAS, followed by MARPOL, COLREG, and ICLL. Six specific code mentions were identified, the most prominent being the IGC Code.

Table 3. *Ship type distributions*

Ship type (Detailed)	Frequency	%	Cumulative %	Ship type	Frequency	%	Cumulative %
General cargo ship	1156	18.1	18.1	Cargo	2803	43.8	43.8
Bulk carrier	626	9.8	27.9	Tanker	1147	17.9	61.8
Container ship	554	8.7	36.6	Other type	903	14.1	75.9
Offshore supply ship	378	5.9	42.5	Passenger	459	7.2	83.1
Supply ship	373	5.8	48.3	Special craft	423	6.6	89.7
Chemical/oil products tanker	288	4.5	52.8	Tug	287	4.5	94.2
Passenger (Cruise) ship	249	3.9	56.7	Dredger	154	2.4	96.6

Table 4. *Convention-code level distributions*

Convention/Code	Frequency	%	Cumulative %
SOLAS	3896	60.9	60.9
MARPOL	765	12.0	72.9
COLREG	698	10.9	83.8
ICLL	348	5.4	89.3
IGC Code	261	4.1	93.4
LSA Code	140	2.2	95.5
IGF Code	76	1.2	96.7
MODU Code	52	0.8	97.5
IBC Code	35	0.5	98.1
SPS Code	33	0.5	98.6
STCW	32	0.5	99.1

COLREG: International Regulations for Preventing Collisions at Sea, SOLAS: International Convention for the Safety of Life at Sea, MARPOL: International Convention for the Prevention of Pollution from Ships, ICLL: International Convention on Load Lines, IGC: International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, LSA: International Life-saving Appliance Code, IGF: International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels, MODU: Code for the Construction and Equipment of Mobile Offshore Drilling Units, IBC: International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, SPS: Code of Safety for Special Purpose Ships, STWC: International Convention on Standards of Training, Certification and Watchkeeping for Seafarers

Vessel sizes exhibited wide dispersion, with a median summer DWT of 6,626 tons and a maximum of 499,124 tons. At the upper tail, the largest DWT case was the Pioneering Spirit, a split-hull crane vessel designed for single-lift installation and removal of large offshore platforms. This was followed by the 380-meter crude-oil tanker SA OCEANIA and other crude-oil tankers. By GT, the largest was the floating liquefied natural gas terminal CORAL SUL FLNG, followed by the cruise vessels Icon of the Seas, Star of the Seas, and Utopia of the Seas; the latter were granted identical exemptions. At the small vessel end of the distribution, the tug SVITZER BOXER was the smallest instance observed, followed by several offshore supply ships and small passenger vessels, all of which displayed exemption patterns consistent with their vessel types.

The named vessels cited in the dataset represent upper-tail cases that illustrate the range of exemption practices, rather than generalizable patterns. They include large cruise vessels and gas carriers with complex technical systems that require equivalence approvals. Each case aligns with the conventions governing its primary design features, for example, SOLAS fire-safety exemptions for passenger ships or IGC-based provisions for gas carriers. These cases confirm that exemptions tend to cluster within function-specific regulatory regimes.

3.1. Findings Based on Flag States

Exemption rates per 1,000 ships are concentrated among a limited number of flags, as indicated by the Gini coefficient and the normalized HHI. Total exemption counts are dominated by a few very large registries because of their fleet sizes. This is confirmed by the Lorenz curve, which shows substantial inequality and by a Gini coefficient of 0.752 and an HHI of 0.061. Liberia accounts for 1,112 of 6,379 notifications, representing 17.4%. The top five flags account for 43.8 percent, and the top ten flags account for 60.6 percent. Reaching 80 percent of all exemption notifications requires only 20 flags (Table 5).

The comparative analysis of exemption rates across flags reveals statistically significant differences. The global average exemption rate was 6.5%, and the chi-square test of homogeneity indicated that this rate was not evenly distributed across countries (χ^2=15963.7, df=90, p<0.001). A sensitivity analysis restricted to countries with fleets larger than 100 vessels yielded similar results [χ^2(68)=14,748.6, p<0.001]. Wilson confidence intervals (CIs) and multiple testing

Table 5. *Exemption frequencies and rates by fleet size*

Flag (from highest count of exemption to lowest)	Exemption frequency	Exemption rate to fleet size	Flag (from highest % of exemption-fleet size to lowest)	Exemption frequency	Merchant fleet size	Notifications per 1,000 ships
Liberia	1112	0.1743	Bahrain	149	159	94
Russian Federation	685	0.1074	Gibraltar	85	96	89
Palau	349	0.0547	Luxembourg	121	152	80
Republic of Korea	348	0.0546	Palau	349	565	62
Bahamas	303	0.0475	Slovenia	4	7	57
Panama	271	0.0426	Oman	27	50	54
Singapore	239	0.0375	Lebanon	22	46	48
Antigua and Barbuda	208	0.0331	Switzerland	6	15	40
China	177	0.0277	Faroes, Denmark	36	91	40
United Kingdom	172	0.027	Vanuatu	103	295	35
Barbados	170	0.0266	Barbados	170	491	35
Germany	151	0.0237	Brunei Darussalam	32	96	33
Bahrain	149	0.0234	Antigua and Barbuda	208	676	31
Malta	130	0.0204	Jordan	10	34	29
Norway	127	0.0204	Seychelles	8	29	28
Luxembourg	121	0.019	Germany	151	602	25
Indonesia	108	0.0169	Bahamas	303	1251	24
Vanuatu	103	0.0161	Russian Federation	685	3007	23
Türkiye	97	0.0152	United Kingdom	172	794	22
Hong Kong	87	0.0136	Liberia	1112	5562	20

adjustments further showed that a substantial proportion of countries (approximately 70 percent) significantly deviated from the global average. These findings demonstrate that exemption practices are inconsistent across flag states and vary considerably between countries (Tables 5 and 6).

Funnel plot analyses identified a number of flag states with levels of exemption that were significantly higher than expected. These outliers included small-fleet registries such as Gibraltar, Luxembourg, Bahrain, and Oman, where more than 50 percent of their national fleets were exempted. However,

Table 6. *Flag-level divergence and overrepresented cases in exemption bases*

Jensen-Shannon divergence (JSD) rank	Flag	n	JSD bits	Top convention	Observed	Expected	Std. Resid.
1	Marshall Islands	87	0.453	MARPOL	1	10.48	-2.93
2	China	177	0.299	COLREG	113	20.05	20.76
3	Russian Federation	685	0.264	MARPOL	437	82.48	39.04
4	Cyprus	81	0.262	SOLAS	35	49.18	-2.02
5	Luxembourg	121	0.247	ICLL	45	6.84	14.59
6	Brazil	43	0.231	MARPOL	3	5.18	-0.96
7	Saudi Arabia	48	0.227	SOLAS	46	29.14	3.12
8	Malta	130	0.217	IGC Code	37	5.23	13.90
9	Malaysia	33	0.211	SOLAS	12	20.03	-1.79
10	Brunei Darussalam	32	0.205	SOLAS	19	19.43	-0.10
11	United Kingdom	172	0.188	IGC Code	37	6.91	11.44
12	Vanuatu	103	0.185	SOLAS	100	62.53	4.74
13	Denmark	50	0.184	SOLAS	31	30.35	0.12
14	India	54	0.183	COLREG	18	6.12	4.80
15	Indonesia	108	0.168	SOLAS	101	65.57	4.38
16	Bahrain	149	0.166	SOLAS	142	90.46	5.42
17	Türkiye	97	0.157	COLREG	39	10.99	8.45
18	Saint Vincent and the Grenadines	39	0.155	SOLAS	33	23.68	1.92
19	Republic of Korea	348	0.150	SOLAS	325	211.27	7.82
20	Palau	349	0.149	MARPOL	129	42.02	13.42
21	Antigua and Barbuda	211	0.148	SOLAS	160	128.10	2.82
22	Germany	151	0.146	COLREG	30	17.10	3.12
23	Hong Kong, China	87	0.142	COLREG	28	9.86	5.78
24	Australia	36	0.131	SOLAS	22	21.86	0.03
25	Gibraltar (United Kingdom)	94	0.122	SOLAS	67	57.07	1.31
26	Faroes, Denmark	36	0.116	SOLAS	23	21.86	0.24
27	Singapore	239	0.115	IGC Code	29	9.61	6.26
28	Panama	272	0.082	ICLL	38	15.38	5.77
29	Norway	130	0.081	ICLL	16	7.35	3.19
30	Barbados	170	0.080	SOLAS	134	103.21	3.03
31	Bahamas	303	0.072	LSA Code	29	6.27	9.07
32	Liberia	1112	0.037	STCW	32	6.19	10.37

COLREG: International Regulations for Preventing Collisions at Sea, SOLAS: International Convention for the Safety of Life at Sea, MARPOL: International Convention for the Prevention of Pollution from Ships, ICLL: International Convention on Load Lines, IGC: International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, LSA: International Life-saving Appliance, STWC: International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, Std. Resid.: Standardized residual

Empirical Bayes-adjusted rates confirmed that many of the extreme percentages observed among very small fleets were statistically insignificant. In contrast, large registries, such as those of the United States, the Marshall Islands, Panama, and China, reported exemption rates significantly below the global benchmark. After adjustment, the relative ranking of countries with high rates persisted across several registries with medium-sized fleets, reinforcing the interpretation that the observed variation is not solely attributable to sample size.

Three patterns emerged from this analysis. First, large open registries such as Liberia and the Russian Federation contribute disproportionately to the absolute number of exemptions due to the size of their fleets. Second, a group of medium-sized fleets, including Palau, Antigua and Barbuda, and the Bahamas, combines moderate fleet sizes with relatively high exemption rates. Third, several major trading nations with large fleets, including China and Singapore, exhibit comparatively low exemption rates, positioning them below the global mean despite their fleet size (Tables 5 and 6).

Table 6 shows the Jensen-Shannon distances that indicate substantial departures from the global exemption mix among flags with n≥30. The largest divergences are in the Marshall Islands, China, the Russian Federation, Cyprus, and Luxembourg. In each case, the single most overrepresented cell explains a large share of the deviation: Russian Federation in MARPOL (Observed=437; Expected=82.48; StdResid=39.04), China in COLREG (Observed=113; Expected=20.05; StdResid=20.76), Luxembourg in ICLL (Observed=45; Expected=6.84; StdResid=14.59), Malta in IGC Code (Observed=37; Expected=5.23; StdResid=13.90), and Palau in MARPOL (Observed=129; Expected=42.02; StdResid=13.42). These concentrated excesses confirm that national exemption mixes are specific to flags rather than random realizations of the global distribution.

Figure 3 displays only those flag-convention cells that remain significant after Benjamini-Hochberg correction ($q<0.05$) and have expected counts (E)≥5. Color intensity encodes the standardized Pearson residuals; thus, larger values indicate stronger overrepresentation relative to the expectation under independence. A small set of hotspots dominates the map. These findings support the previous analysis results of Jensen-Shannon distances with several additions. These

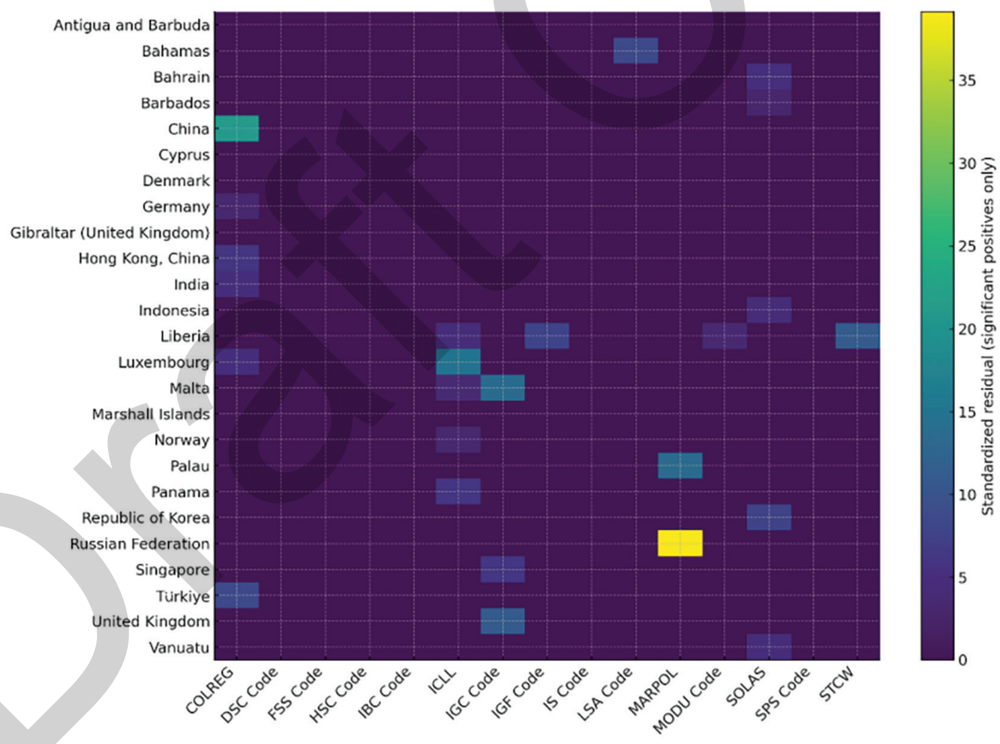

Figure 3. Flag-convention distribution heat map

COLREG: International Regulations for Preventing Collisions at Sea, DSC: Code of Safety for Dynamically Supported Craft, FSS: Fire Safety Systems Code, HSC: The International Code of Safety for High Speed Craft, IBC: International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, IGC: International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, ICLL: International Convention on Load Lines, IGF: International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels, IS: International Code on Intact Stability, LSA: International Life-saving Appliance Code, MARPOL: International Convention for the Prevention of Pollution from Ships, MODU: Code for the Construction and Equipment of Mobile Offshore Drilling Units, SOLAS: International Convention for the Safety of Life at Sea, SPS: Code of Safety for Special Purpose Ships, STWC: International Convention on Standards of Training, Certification and Watchkeeping for Seafarers additions (in addition to the results of Table 5) are: United Kingdom in IGC Code (37 vs 6.91, 11.44), Republic of Korea in SOLAS (325 vs 211.27, 7.82), Bahamas in LSA Code (29 vs 6.27, 9.07), and Liberia in STCW (32 vs 6.19, 10.37). This once again confirms that national exemption portfolios are concentrated in a few legal themes rather than evenly distributed across conventions.

Figure 4 shows that the bipartite clustering of flag-convention patterns reveals coherent communities that reflect shared legal emphases rather than overall volume. The feature matrix uses only cells with positive standardized residuals that remain significant after Benjamini-Hochberg correction and replaces all others with zero. Cosine similarity and average linkage, applied to 21 qualifying flags, produce a small set of stable groups. One community is MARPOL-centric, anchored by the Russian Federation and Palau. A second community centers on the IGC Code, with Malta and the United Kingdom as prominent members. A third community, as defined by ICLL, is exemplified by Luxembourg. A broader SOLAS-leaning group includes the Republic of Korea and several medium-sized registries. Figure 4 shows a clear separation among these clusters, indicating that exemption portfolios cluster around a few recurring legal themes. This structure aligns with the divergence and cell-level results reported earlier and supports the interpretation that national portfolios are systematically specialized rather than diffuse.

3.2. Findings by Time of Exemption Notification

Notification timing differs significantly across legal bases when examined at the year level. A Kruskal-Wallis test on notification dates, coded as elapsed time, shows a strong between-group separation ($H=506.62$, $p<0.001$, epsilon-squared=0.077), indicating that the central year and the spread of notifications vary by convention. A contingency test of convention-by-year counts also rejects the null hypothesis of independence ($\chi^2=1490.60$, $df=140$, $p<0.001$), with Cramér's $V=0.153$, consistent with a small to moderate association between legal basis and the distribution of notifications across years. Median notification years and interquartile ranges, as reported in the timing summary table, show earlier, more concentrated activity for some regimes and later, more diffuse activity for others. Year-over-year trends, computed for each convention using Kendall's tau on annual counts (Table 7), confirm heterogeneous temporal dynamics: several conventions exhibit monotonic increases over the study period, while others remain flat. Taken together, these year-level results indicate that timing is not uniform across legal bases; differences in when exemptions are filed are systematic and align with each convention's distinct role and uptake over time.

Table 7 shows the exemption intensity over time. Monthly exemption notifications exhibit a clear, monotonically increasing trend over the 128-month study window. The overall series shows Kendall's tau of 0.578 with $p<0.001$, indicating a moderate increase in volume over time. Positive and statistically significant trends are also present for the top five conventions: SOLAS (tau=0.521, $p<0.001$), MARPOL (tau=0.455, $p<0.001$), COLREG (tau=0.539, $p<0.001$), ICLL (tau=0.408, $p<0.001$), and IGC Code (tau=0.354, $p<0.001$).

The magnitudes suggest that COLREG and SOLAS exhibit the steepest month-to-month gains among individual

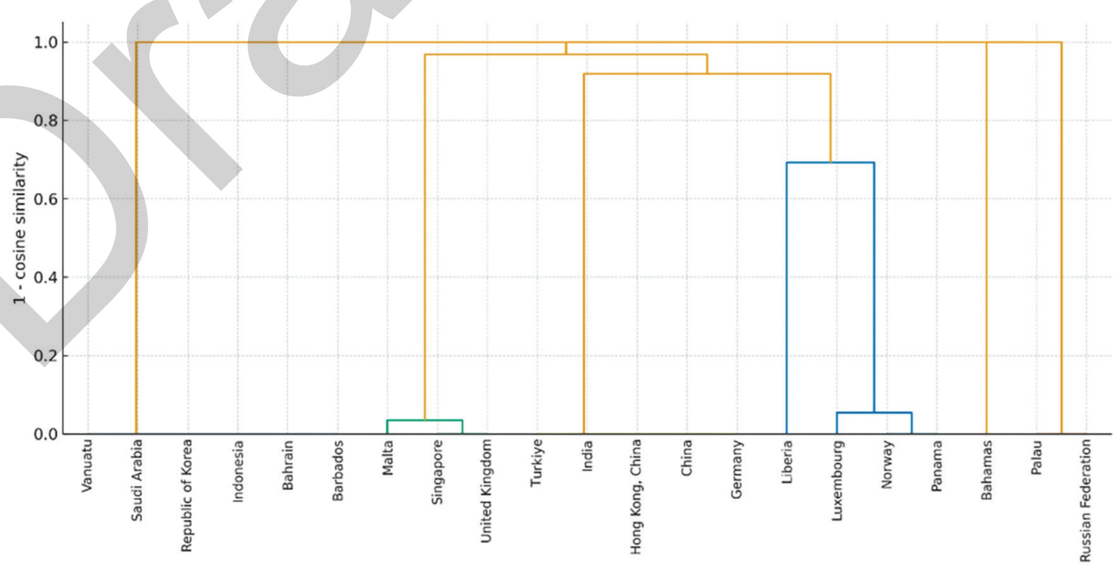

Figure 4. *Flag similarity based on exemption overrepresentations*

regimes, while IGC Code rises more gradually (Figure 5). Overall, the increase in exemption activity is broad-based across legal bases rather than concentrated in a single convention. Annual exemption intensity by flags, adjusted for exposure, also increases over time. Rates were computed as 1,000 × (exemptions divided by the corresponding world- or country-level merchant fleet size) for each year from 2015 to 2025. The global series exhibits a clear monotonically increasing trend. A Kendall's tau of 0.673 ($p=0.003$) over 11 years indicates a moderate to strong increase that cannot be attributed to fleet expansion alone. Among large registries, the Bahamas exhibits a significant rise in the rate (tau=0.636, $p=0.006$), and Liberia shows a similar pattern (tau=0.564, $p=0.017$). China and Antigua and Barbuda show non-significant increases.

3.3. Findings by Vessel Characteristics

Analysis of the "Ship type × Convention" interaction (Figure 6) shows that ship type and the legal basis for exemptions are not independent. The chi-square test indicates a significant association [$\chi^2(252)=3799.70$, $p<0.001$] with Cramér's V=0.207, indicating a moderate effect. Standardized residuals reveal concentrations above expectations, particularly for tankers under the IGC Code, dredgers under the ICLL, and special craft and tugs under COLREG. The pattern remains after controlling the false discovery rate across cells. Cooler cells in the heatmap indicate combinations that occur less often than expected, suggesting that exemption bases are specialized by ship function.

GT distributions differ significantly across conventions (Figure 7; Kruskal-Wallis $H=1053.15$, $p<0.001$). The IGC Code shows that exemptions grounded in gas-carrier provisions are concentrated among very large ships with the highest GT levels. SOLAS and ICLL occupy a mid-to-upper range, with a broad dispersion consistent with heterogeneous fleets. MARPOL and COLREG cluster at lower tonnages, consistent with exemptions that apply to smaller vessels. This size stratification across legal bases is clearly visible in the box plot and aligns with the functional specialization of the underlying regulations.

Unadjusted comparisons show no significant difference in average GT between high-rate and low-rate exemption-reporting flags. The Geometric mean of GT is 10,238 for high-rate group vs 10,632 for low-rate group (Welch $t=-0.536$, $p=0.592$, Hedges' g on the log scale=-0.022). However, after adjusting for ship-type composition, the difference becomes positive and statistically significant. The ship-type FE regression yields a multiplicative effect of 1.085 on GT for high-rate flags relative to low-rate flags (95% CI 1.036 to 1.136, $p=0.00006$). This means that within ship types, vessels under flags with high exemption rates have, on average, about 8.5 percent higher GT.

4. Discussion

This section interprets the empirical results in light of existing research on maritime governance, regulatory discretion, and compliance flexibility within the IMO framework. It connects the observed exemption patterns to broader debates on harmonization, delegation, and data transparency in international maritime regulation.

This study, grounded in a cleaned and enriched dataset from the IMO GISIS Exemptions database, reveals critical insights into how flag states operationalize exemptions

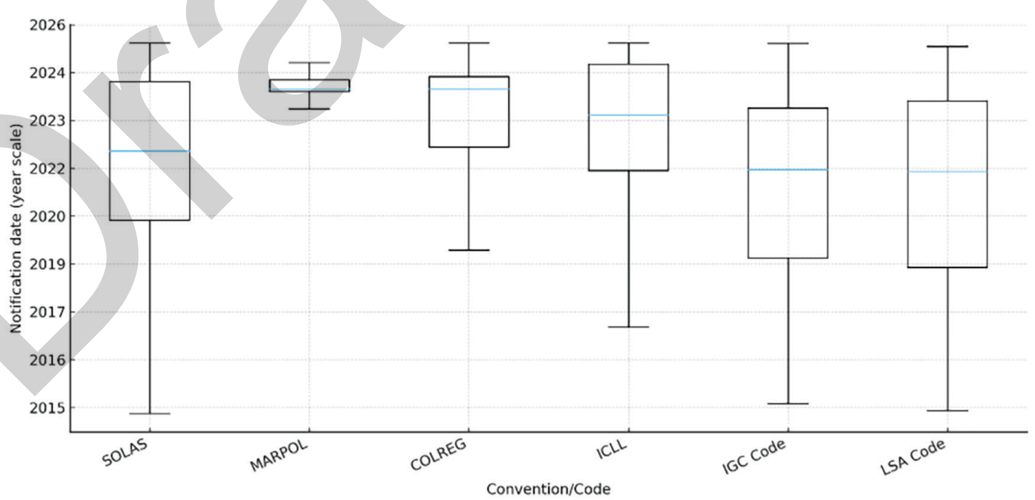

Figure 5. *Exemption notification timing by convention*

SOLAS: International Convention for the Safety of Life at Sea, MARPOL: International Convention for the Prevention of Pollution from Ships, COLREG: International Regulations for Preventing Collisions at Sea, ICLL: International Convention on Load Lines, IGC: International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, LSA: International Life-saving Appliance Code

__Table 7.__ Exemption notification intensity by time

Series (rate per 1000)	Tau	p-value	Series	Kendall tau	p-value
World overall	0.673	**0.003**	All conventions	0.578	**<0.001**
Antigua and Barbuda	0.382	0.121	SOLAS	0.521	**<0.001**
Bahamas	0.636	**0.006**	MARPOL	0.455	**<0.001**
China	0.341	0.206	COLREG	0.539	**<0.001**
Liberia	0.564	0.017	ICLL	0.408	**<0.001**
Palau	0.482	**0.046**	IGC Code	0.354	**<0.001**
Panama	0.236	0.359			
Republic of Korea	0.559	**0.02**			
Russian Federation	0.526	**0.047**			
Singapore	0.587	**0.012**			
United Kingdom	0.273	0.283			

(128 months for conventions ~ 11 years for fleet size changes)

COLREG: International Regulations for Preventing Collisions at Sea, SOLAS: International Convention for the Safety of Life at Sea, MARPOL: International Convention for the Prevention of Pollution from Ships, ICLL: International Convention on Load Lines, IGC: International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk

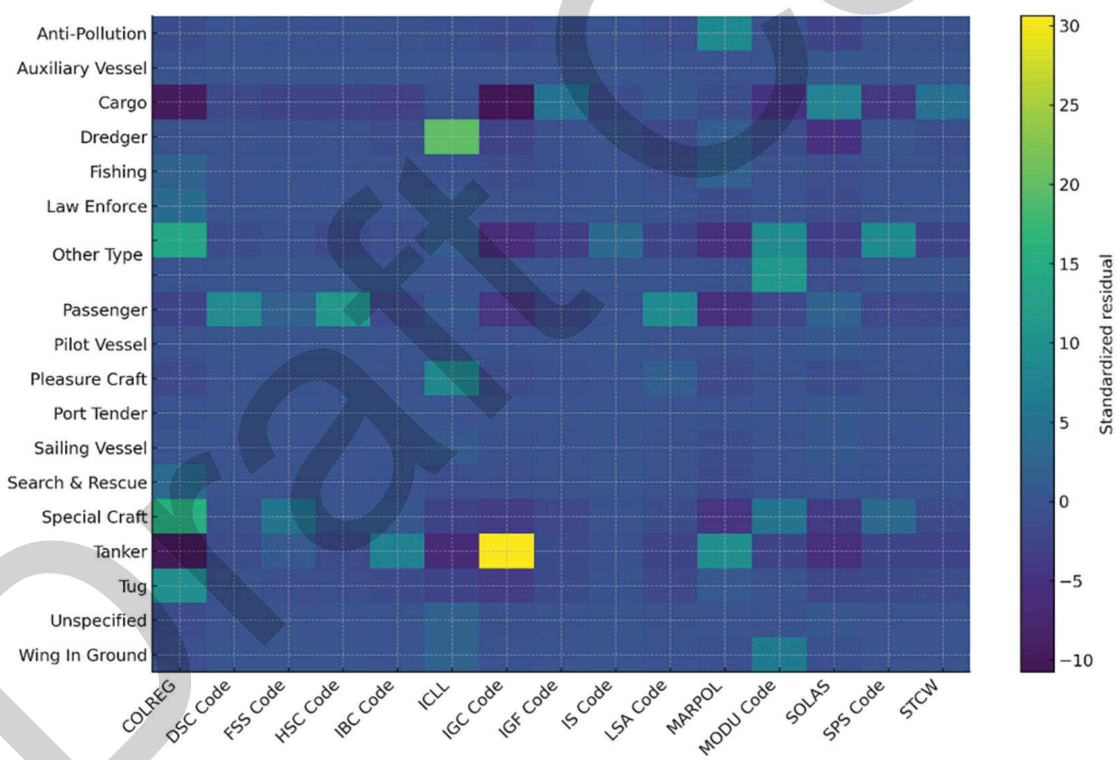

__Figure 6.__ Heatmap of standardized residuals for ship type-convention

COLREG: International Regulations for Preventing Collisions at Sea, DSC: Code of Safety for Dynamically Supported Craft, FSS: Fire Safety Systems Code, HSC: The International Code of Safety for High Speed Craft, IBC: International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk, ICLL: International Convention on Load Lines, IGC: International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, IGF: International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels, IS: International Code on Intact Stability, LSA: International Life-saving Appliance Code, MARPOL: International Convention for the Prevention of Pollution from Ships, MODU: Code for the Construction and Equipment of Mobile Offshore Drilling Units, SOLAS: International Convention for the Safety of Life at Sea, SPS: Code of Safety for Special Purpose Ships, STWC: International Convention on Standards of Training, Certification and Watchkeeping for Seafarers

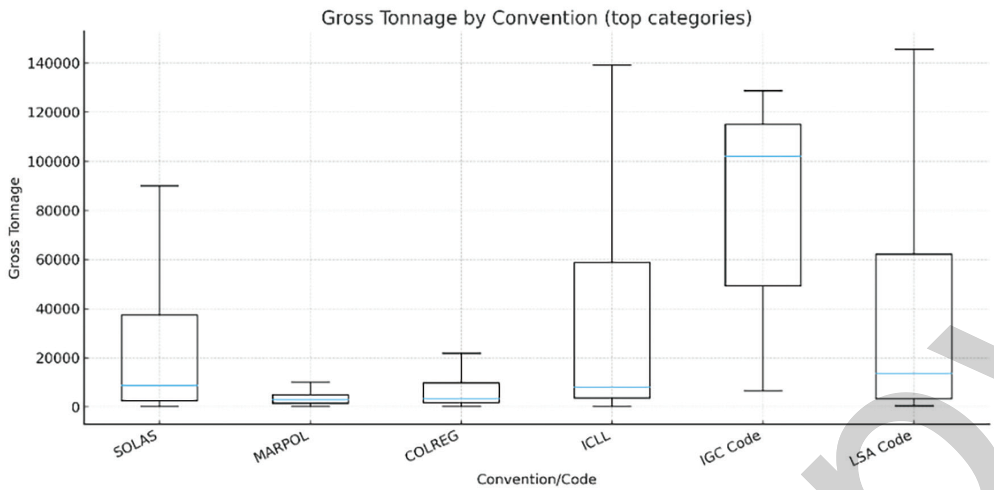

Figure 7. *Gross tonnage by convention*

SOLAS: International Convention for the Safety of Life at Sea, MARPOL: International Convention for the Prevention of Pollution from Ships, COLREG: International Regulations for Preventing Collisions at Sea, ICLL: International Convention on Load Lines, IGC: International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, LSA: International Life-saving Appliance Code

and equivalencies under IMO conventions. The findings demonstrate that despite the harmonizing role of the IMO, significant heterogeneity persists in the way exemptions are granted, interpreted, and implemented across flag administrations. This variation often stems from administrative discretion, inconsistent application of legal clauses, and the structural limitations of the GISIS database itself.

These findings confirm earlier research showing that flag states retain considerable discretion in applying IMO conventions, even when bound to incorporate them into national law [10,11]. However, the present results extend that evidence by revealing how such discretion operates in practice through measurable exemption activity. Prior analyses focused on legal interpretation and administrative delegation, while this study demonstrates how those mechanisms manifest empirically across conventions and vessel types [12].

The results indicate that exemptions and equivalents are not marginal curiosities. They operate as routine components of the compliance architecture, with most references tied to technical regimes led by SOLAS, followed by MARPOL, COLREG, and ICLL. This pattern is consistent with the flexibility inherent in IMO instruments, as exemplified by MARPOL Annex VI Regulation 4, which recognizes “equivalent methods” (most prominently exhaust gas cleaning systems) subject to published testing, survey, and verification guidelines. In practice, what might seem discretionary is administered through structured, guidance-driven procedures. These findings show that the normalization of equivalents and exemptions is a routine compliance tool. These are not used as simple waivers of the regulations, but have become a normalized instrument of compliance in the maritime sector. This trend reflects the broader evolution toward adaptive and performance-based regulation within the IMO framework, where compliance is judged against functional outcomes rather than fixed design prescriptions. Similar shifts have been observed in safety and environmental management studies that highlight the growing role of risk-based discretion and outcome-oriented governance in maritime regulation [13-15].

Two structural signals support this interpretation: concentrations, by legal locus, that track ship function (e.g., emissions/energy matters under MARPOL Annex VI; low-flashpoint fuel systems under the IGF Code), and steadily rising notification activity and exposure-adjusted rates. Together, these patterns are consistent with the administration’s creation of documented, objective-based alternatives to meet codified safety and environmental goals. This interpretation is consistent with recent literature that frames maritime compliance as the outcome of multi-level governance, in which flag, coastal, and port states share regulatory responsibilities, with PSC acting as an increasingly salient backstop to flag implementation [13-15].

Exemptions and equivalents rise in step with a system in which IMO sets outcome-oriented standards and flags implement them, often via clarifications, Unified Interpretations, or goal-based pathways [12,13]. Tacit acceptance procedures and the “no-more-favourable-treatment” principle further promote convergence of outcomes while leaving room for documented alternatives [10]. This governance architecture is consistent with our empirical finding that exemptions are now routine tools to meet objectives rather than rare dispensations.

ROs function as pivotal gatekeepers in this context. Formal delegation frameworks and RO codes establish standardized evidentiary expectations, which in turn support template-based equivalency packages for recurring cases [16,17]. In contexts where flag-state inspection capacity is limited and at-sea enforcement is costly, documentary controls and construction or retrofit verifications become the path of least resistance, which aligns the observed concentration of notifications in the cargo and tanker segments with governance realities [18,19]. This pattern is consistent with comparative findings on the role of classification societies in mediating between global rules and national implementation [17,20,21]. These studies emphasize that delegation to ROs amplifies national variation by translating international standards into context-specific technical decisions.

A notable gap persists due to the absence of public oversight or standardized transparency metrics for exemption practices. While port-state control regimes have been extensively analyzed as feedback systems for flag performance, the upstream processes of exemption approval and documentation remain largely unexamined [22]. By systematizing and analyzing GISIS notifications, this study begins to address that gap and to demonstrate that regulatory discretion can be captured and compared quantitatively across conventions. The results therefore extend earlier concerns about normative ambiguity [17], reframing them as measurable differences in documentation and reporting structures rather than solely as doctrinal uncertainty.

Another core finding is that many exemptions are granted on the basis of inconsistent or vague regulatory references, necessitating sophisticated rule-based extraction to identify the underlying legal basis. This reflects a lack of standardized language, transparent reporting protocols, and replicability. The study's pattern-mining methods helped expose hidden discrepancies and interpretive drift in the referencing of rules such as SOLAS II-2/10.7.1.3 and MARPOL Annex I Reg. 14. The inconsistencies revealed in this study mirror the RO-centered delegation challenges in comparative implementation. Particularly under the RO Code, classification societies act under varying oversight conditions, often amplifying national divergences through their interpretation and technical approval practices. Findings are consistent with critiques that several IMO instruments lack structured and searchable metadata for inspection, impeding meaningful comparisons [13,18].

The results indicate a strong concentration of notifications across flags. Inequality measures are high, and a small number of flags account for most records, reflecting both exposure effects in very large registries and substantive heterogeneity in granting or reporting exemptions. Exposure-adjusted rates confirm that differences across countries are uneven and that many flags diverge markedly from the global mean. The analyses correct for extreme percentages among micro-fleets while leaving numerous medium-sized outliers intact, indicating genuine variation rather than sampling noise. Exemption practices are uneven across flags, and some administrations make more extensive and more specialized use of permissible flexibility than others. In substantive terms, that specialization often tracks practical risk and technology: tankers engaging the IGC Code, dredgers interacting with load-line geometry, and tugs and special craft operating under COLREG lights and arrangements, all of which point to function-specific regulatory tailoring rather than indiscriminate leniency. This pattern reflects a system that is both fragmented and interconnected. Different countries may enforce rules differently and to varying degrees, yet their actions are still shaped by international oversight and market pressures exerted through PSC regimes [15,22].

These disparities correspond with previous findings that flag-state performance varies systematically with administrative capacity, oversight intensity, and registry model [2023]. However, the present study extends this line of research by demonstrating that these differences emerge not only in inspection outcomes but also in the upstream stage of regulatory interpretation. This shows that heterogeneity in compliance does not begin with enforcement, but is embedded in how flag administrations operationalize exemptions and equivalents within their national systems.

Beyond their volume, flags exhibit distinct legal emphases. National exemption portfolios are concentrated in a few conventions or codes, for example, MARPOL for some flags, IGC for others, and ICLL for a smaller group of flags. Clustering of overrepresented cells reveals coherent communities that are not explained by size alone. This indicates that specialization is tied to both fleet composition and administrative guidance. The literature reports a consistent finding: instruments differ in technical scope and administrative pathways, and national authorities channel operational problems through the most relevant legal bases, creating persistent portfolio signatures visible in comparative data [14].

Furthermore, the clustering of exemptions around specific instruments (e.g., SOLAS and MARPOL) and equipment-related clauses indicates that compliance flexibility is exercised more frequently in technical domains, while other regulatory areas (such as ISM/ISPS or STCW) show fewer exemptions, perhaps due to more rigid language or different delegation practices.

The association between ship type and convention is moderate but robust. Tankers are overrepresented under IGC provisions, dredgers under ICLL, and special craft and tugs under COLREG, after controlling for multiple testing. GT distributions differ across regimes: IGC exemptions cluster among very large ships, SOLAS and ICLL span the mid-to-upper ranges, and MARPOL and COLREG skew toward smaller vessels. Crucially, the simple high-rate versus low-rate flag contrast in average GT disappears once ship-type composition is controlled, after which vessels under high-rate flags carry about 8,5 percent higher GT within types. This implies that the apparent size effect is at least partly a case-mix effect rather than a general preference for larger or smaller ships. These patterns are consistent with instrument design and recent analyses that emphasize the fit between technical requirements and operational profiles in compliance behavior [13].

Finally, the upward trend in notification activity indicates that equivalence and exemptions have become more routinized as administrative tools. That trajectory strengthens the case for improved reporting templates and structured fields in GISIS to elevate analyses from the convention level to the rule level. The present study documents that rule-level references are numerous and heterogeneous, hindering comprehensive statistical modeling; therefore, investing in standardized, machine-readable rule citations would enable finer tests of doctrinal concentration and substitution across instruments.

A comparison of Flags of Convenience and traditional registries was considered but ultimately excluded from this study. The dataset is limited to convention-level categorization and does not contain the registry-type metadata required for such differentiation. Incorporating this dimension would require integration with external fleet registry data, which is beyond the scope of the present analysis. The analysis, therefore, focuses on flag-level variation within the existing dataset to ensure that observed patterns reflect documented exemption practices rather than registry classification effects.

The cumulative evidence points to a regulatory system that balances international harmonization with localized flexibility. Variations observed across flags and conventions are not anomalies but integral features of a governance model that relies on administrative discretion to adapt global standards to specific operational contexts. Rather than weakening the IMO framework, such diversity demonstrates how the regime functions through negotiated compliance and practical accommodation, albeit at the cost of transparency and comparability.

Theoretically, these findings challenge the assumption that international maritime governance is uniformly applied. Instead, flag states exploit interpretive leeway and delegation frameworks to create "micro-jurisdictions" within the broader IMO system. This regulatory pluralism undermines harmonization, particularly when exemptions become normalized rather than exceptional.

5. Study Limitations

Limitations remain, particularly the difficulty of analyzing exemptions at the rule-specific level. The heterogeneity of citations in the "Exempted from/Equivalent to" fields prevented detailed modeling of clause-level substitution. Addressing this challenge requires methodological innovation, including the application of advanced text-mining and association-rule techniques. Future research should also move beyond convention-level mapping toward predictive models that integrate flag characteristics, fleet structure, and temporal dynamics. Collaboration with classification societies and national maritime authorities will be essential to close data gaps, especially for exemptions granted under delegated authority that are not systematically reported to the IMO.

These findings build upon earlier understandings of regulatory heterogeneity in maritime governance by demonstrating that variation arises not only at the enforcement stage but also within the initial interpretation of conventions. The analysis translates governance theory into measurable patterns of compliance behavior, creating a bridge between conceptual discussions and empirical evidence drawn from global reporting data.

In summary, the global exemption system is not broken or abused, but remains opaque, uneven, and under-scrutinized. Exemptions from IMO regulation should be understood not as signs of regulatory weakness but as indicators of a system adapting to technological and operational complexity. This study contributes to making those adaptive processes visible, measurable, and accountable within international maritime governance.

6. Conclusion

This study provides one of the first systematic analyses of how flag states grant, record, and interpret exemptions under IMO conventions, revealing a fragmented yet patterned regulatory landscape. Through reconstruction and standardization of fragmented GISIS data, the analysis revealed patterns that cluster along the dimensions of flag-state portfolio, vessel type, and regulatory focus. Exemptions emerge as an increasingly normalized mode of compliance shaped by administrative discretion, technical fit, and capacity realities.

The results underline a central tension in international maritime governance. While IMO conventions aim to harmonize safety and environmental standards, the discretion retained by flag administrations, often exercised through

ROs, creates a patchwork of implementation that varies in scope and intensity. This heterogeneity, reflecting functional specialization, forms a regulatory landscape in which exemptions serve as adaptive tools that enable alignment with evolving technologies and operational constraints, while simultaneously raising concerns about transparency and accountability.

As IMO rulemaking continues to evolve toward performance-based regimes, the gap between prescriptive rules and operational realities is expected to widen. Exemptions will likely grow in frequency and complexity, increasing the need for a standardized, machine-readable exemption reporting system. A paragraph-level, cross-flag data structure would not only enhance transparency but also enable risk-based oversight and compliance benchmarking.

This research also highlights deeper structural issues. GISIS lacks bulk access, and the current reporting scope excludes RO-granted or unreported exemptions, both of which constitute critical blind spots. Addressing these limitations will require institutional reforms and improved data-sharing arrangements among classification societies and national authorities.

The policy implications are significant. Exemptions and equivalents are no longer peripheral waivers but have become central instruments for achieving compliance. Three priorities arise for future policy and research: developing a cross-instrument taxonomy of exemptions and equivalents across SOLAS, MARPOL, STCW, COLREG, and related codes; linking exemption records with PSC data to examine potential relationships with deficiencies, detentions, or safety and environmental outcomes; and mapping national exemption portfolios to distinguish proactive adaptation from regulatory avoidance.

Footnotes

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