A Threat to Maritime Trade: Analysis of Piracy Attacks Between 2015 and 2022 and the Period of COVID-19

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Abstract

More than 80 percent of world trade is transported by sea. Maritime piracy negatively affects international maritime transport and trade. The aim of the study is to analyze maritime piracy attacks between 2015-2022 and during the coronavirus disease-2019 (COVID-19) period. In the study, a literature review, main reasons and statistics for piracy and armed robbery attacks, international efforts to combat maritime piracy were examined and maritime piracy attacks were analyzed in 2015-2022 and the COVID-19 period. The results of the main findings are as follows; the most piracy attacks occurred in 2015, the most attacks were occurred in March-April-May majority of attacks occurred between the hours 24:00-04:00, the most attacks occurred in South East Asia, the most types of attacks against to ships was boarded. Marshall Islands-flagged ships were the most attacked. There is a weak statistical relationship between the piracy attacks by months and regions and between the piracy attacks by years and type of attacks. There is no statistical relationship between other variables.

Keywords: Maritime security, Maritime piracy, Maritime trade, Chi-square test

1. Introduction

International maritime trade amounted to 10.7 billion tons in 2021. More than 80% of the international trade of goods is transported by sea. The annual growth of international maritime trade will be estimated at 2.4% in 2023, 2.3% in 2024 and 2025, and 2.2 in 2026 [1]. The negative effects of coronavirus disease-2019 (COVID-19) on shipping and ports lead to continued disruption in supply chains, increasing production costs. Maritime piracy negatively affects ship owners, importers, exporters, carriers, crews, the environment international trade, and increases costs [2]. The International Maritime Bureau's (IMB) Piracy Reporting Center (PRC) reported that a total of 116 attacks occured in 2022. Most of these attacks occurred in Singapore Straits (48), Peru (12), Indonesia (10), Bangladesh, and Ghana (7) [3]. The highest risk region is South-East Asia with 58 attacks and respectively America (24), Africa (21), Indian subcontinent (10) and East Asia (2) [3]. Maritime piracy and armed robbery on ships increased in 2020 during the COVID-19 period. Maritime piracy increased during the pandemic period [3].

Chalk [4] analyze maritime piracy in the Southeast Asian region. The main reasons for maritime piracy can be listed as follows: economic crisis in Southeast Asia, low wages, high unemployment rates, poverty and inadequate education, inadequate coastal and port control, local law enforcement, loopholes in legal instruments demand ransom, illegal fishing activities of foreigners, and dumping nuclear and toxic wastes into the sea by foreign ships [4].

International Maritime Organization (IMO), European Union, and other relevant organizations have made legal and some regulations concerning maritime security such as the Convention for the Suppression of Unlawful Acts against the Safety of Maritime Navigation 1988, the United Nations (UN) Convention Against Illicit Traffic in Narcotic Drugs and Psychotropic Substances, 1988 (Article 17), the UN Security Council Resolutions, IMO conventions, guidances, resolutions circules and best management practices. The Djibouti Code, the Regional Cooperation Agreement on Combating Piracy and Armed Robbery against ships in Asia.

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The UN Convention on the Law of the Sea 1982 includes the number of provisions related to maritime piracy (Articles 100-107 and 110) [5].

Some of technical arrangements are those; maritime technologies such as AIS and LRIT System; security plans for ships and port facilities, technical collaboration between states. Military and naval antipiracy patrols such as NATO Combined Task Forces, and other States' naval forces combat piracy. The International Recommended Transit Corridor through the Gulf of Aden is patrolled against pirates by international naval forces. The coastguards, marine police, etc. in South East Asia countries have taken precautions to combat maritime piracy. Indonesia, Malaysia, Singapore have conducted joint naval patrols [5].

The PRC of the IMB reported that there were 1,422 attacks against ships between 2015 and 2022. The most attacks were in South East Asia (580) and respectively Africa (458), the Americas (207), Indian subcontinent (100), and East Asia (70) between 2015 and 2022 (IMB, ICC 2022). A total of 1,145 ships were boarded, 158 attempted attacks, 44 ships hijacked, and 75 fired upon between 2015-2022. All types of attacks except hijack decreased in 2022 according to the previous year [3]. Bulk carriers were the most attacked ships (429) and respectively product tanker (287), container ships (163), tanker (111), general cargo (71), LPG tanker (49), chemical tanker (62) and tug (54) between 2015-2022. The attacks on bulk carriers and all types of tankers increased in 2022 compared to 2021 [3].

IMB PRC reported 115 attacks against ships in 2022. The piracy attacks in the Singapore Straits increased in 2022 (38) compared to the previous year (35). The attacks dropped in Malacca Straits due to the measures taken by the littoral states [3].

The aim of the study is to analyze of maritime piracy attacks in 2015-2022 and the COVID-19 period using quantative methods such as the frequency distribution, the chi-square test (χ^2), which is a statistical hypothesis test, the Spearman's Rank correlation, the Phi coefficient coefficient and non-parametric correlation. In the study a literature review has been done, and main reasons and statistics of piracy attacks, international legal framework and arrangements on maritime piracy and international efforts to combat maritime piracy were examined. A statistical hypothesis test such as χ^2 was used to determines whether there is an relationship between categorical variables and null (H_0) and alternative (H_1) hypotheses are established.

2. Literature Review

There have been many studies on piracy. Pristrom et al. [6] conducted the statistical analysis of maritime piracy incidents. According to the some results of the analysis

the ships which have speed of less than 15 knots and a low freeboard are vulnerable [6]. Soğancılar [2] reviews the previous studies concerning piracy and the effects of maritime pirate incidents on international trade. Anti-piracy measures and operations have been very effective in reducing pirate attacks [7]. Mejia et al. [8] inquire whether acts of piracy are a truly random occurrence and conduct the econometric analysis. The results of the study show that both and type of vessel and flag of registry are main factors in explaining maritime piracy [8].

Nincic [9] research on maritime piracy and statistics of pirate attacks. As a result of the study is that social and economic difficulties in Africa are among the causes of piracy and negatively affect trade and the economy. Mohn [10] examines the dangers of maritime piracy to international trade and transport, and human society. The result of the study show that the regional cooperation of Southeast Asian countries has been very effective in the fight against piracy in the region. Flückiger and Ludwig [11] conduct 2SLS instrumental variable approach, regression analysis, data and descripive analysis. It has been estimated that plankton shock caused a 10% decrease in fish production. Shepard and Pratson [12] conduct two-stage least squares regression analysis Some findings of the study show that soft restrictions on piracy on energy exports by most Persian Gulf countries have little effect in the long run.

Daxecker and Prins [13] conduct two-stage estimation approach, two-part model, empirical Analyses, Ordinary Least Squares regression, Heckman selection model. The results show that piracy in weak states and both land area and coastline length increase capital to piracy. Okoronkwo et al. [14] research sociological discourse on maritime piracy in Nigeria. Özdemir and Güneroğlu [15] conduct quantitative analysis of maritime piracy. The results of the study show piracy attacks significantly increase costs in maritime trade between Asia and Europe. The most effective reason for piracy is economic insufficiency on the region to combat the piracy. Fu et al. [16] examined the effects of maritime piracy on global economic development in 2003 and 2008 in the Far East-Europe container liner shipping service. The findings of the study show that the international community must do more to fight against maritime piracy.

Bensasi and Martinez-Zarsorro [17] estimate the impact of maritime piracy on international trade between the main European and Asian countries in 1999-2008. The results of the analysis estimated that the cost of piracy to international trade is 24.5 billion dollars. Li and Yang [18] analyzed maritime piracy events. According to some of the research's findings, the most commonly attacked are bulk

carriers, followed by container ships. Jiang and Lu [19] analyze the maritime piracy occurred in Southeast Asia. The results of the research show that if the precautions on the ship are at the highest level and other anti-piracy measures are taken, the probability of the success of the pirate attack will decrease considerably.

Yang et al. [20] review the challenges of maritime safety analysis. Yang et al. [20] reviewed studies measuring maritime safety and risks in maritime transport and A Formal Safety Assessment. Findings from the study show that adequate risk analysis and measurement are used to support regulatory measures applicable to different areas of international shipping. Tsioufis et al. [21] used analytic hierarchy process and spatio-temporal methods to identify maritime piracy hotspots. Some findings of the analysis show that pirates attack more in areas of political instability outside the Arabian Sea and closer to the coastlines of countries facing extreme poverty.

Nwokedi et al. [22] determined the empirical probability coefficients of pirate attacks on ships, ship types and threats to crews affected by hostage-taking, injury, death, loss and pirate attacks using empirical probability statistical method. According to the results of the study; taking ship crew hostage has the highest probability of trauma relative to other trauma factors. Chemical and product tankers are most often attacked. Vespe et al. [23] analyzed diminishing impact on sea routes and ship behavior. The findings of the study show that anti-piracy efforts are effective in the Western Indian Ocean. Akan et al. [24] analyze maritime piracy attacks. The results of the analysis show that maritime piracy attacks decreased by 12.2% in 2022 compared to the previous year, with the most attacks against tankers (31.9%), followed by dry cargo ships (25.4%). The most attacks occur in the South China Sea, respectively, in the Strait of Malacca and in Africa. Nnadi et al. [25] analyzed maritime piracy in the Gulf of Guinea region between 2002 and 2015. One of the findings of the study shows that the most attacks occurred in Nigeria.

Aydın et al. [26] examine the effects of pirate attacks at the Gulf of Aden on international maritime trade and performed correlation analysis and Spearman's rho analysis. According to the results of the study, the piracy costs resulting from their actions are related to the type of attack and the experience of the ships.

Nwokedi et al. [27] analyzed the economic cost of piracy attacks to Nigeria's the global shipping industry and ocean trawler fishery sector and using the empirical probability measure. According to the findings, Nigeria's loss in the industrial trawling sector due to piracy attacks is approximately $1,275,258. This figure shows that the attacks caused significant losses to the Nigerian economy.

3. Materials and Methods

The piracy and armed robbery attacks data were obtained from IMB PRC "Piracy and Armed Robbery Against Ships" Annual Reports for in the period 2015 and 2022. The piracy attacks statistics contain 11.496 non-parametric data.

In the study, frequency distribution, the χ^2 and Cramer's value (Cramer's V) tests, Spearman's Rank correlation coefficient (Spearman's Rho), Phi coefficient and non-parametric correlation were used using statistical analysis performed with Statistical Package Programme (SPSS). The non-parametric variables include attacks years, attack months, attack hours, attack regions, type of ships attacked and ship's flag attacked The non-parametric variables have divided sub groups using the classification scale. The frequency distribution tables were presented to show the number of observations for each possible non-parametric value.

The χ^2 measures whether there is a relationship between non-parametric variables. In order to the χ^2 to be used safely, the following conditions must be met; all individual expected numbers must be 1, the minimum expected number must be at least equal to 1, and the p-value must be less than 0.05 significance level; more than 20% of the expected counts should not be less than 5 [28-31]. In the study, the significance level (α) was considered as 5%. The formula for the χ^2 test statistic is given as follows [32,33]:

where Oij= Observed value, E= Expected Value, Cal= Calculated value, Tab= Table value

$$X_{cal}^2 = \sum_{j=1}^{c} \sum_{i=1}^{r} \frac{(O_{ij} - E_{ij})^2}{E_{ij}} \tag{1}$$

If the differences between expected values and observed values are small, the χ^2 value to be calculated will be small and H_0 will not be rejected. If the differences are large, H_0, which indicates independence between the criteria, will be rejected. When applied with the χ^2 test, the observed frequencies in each response category are compared with the frequencies expected if the null hypothesis is true. If;

$$X_{cal}^2 \geq X_{tab}^2 \tag{2}$$

H_0 will be rejected. Otherwise, H_0 will be accepted [32,33].

Cramer's V and Phi coefficient values dispread between 0 and 1 and Spearman's Rank correlation coefficient (Spearman's Rho) value dispread between -1 and 1 [20].

The formulas for the Cramer's V test statistic, Spearman's Rho test as equation, and the Phi coefficient (φ) are given below [28,31,32,34,35].

Cramer's V test was used to determine whether an relationship exists between two categorical variables [28]. The Cramer's V test statistic is determined as:

$$V = \sqrt{\frac{x^2}{n*(k-1)}} \qquad (3)$$

Spearman's Rho was used to measure the strength between two variables [34,36]. The formula of Spearman's Rho test is determined as:

$$rs = 1 - \frac{6\sum di^2}{n(n2-1)} \qquad (4)$$

The Phi coefficient (φ) is used to measure the association between the two variables. The Phi coefficient (φ) is determined as:

$$\varphi = \sqrt{\frac{x^2}{n}} \qquad (5)$$

In the study, the non-parametric correlation was also used to measure the association between the two non-parametric variables. The correlation matrix was created to summarize the data for more advanced analysis.

3.1. Data Presentation

Frequency distributions of maritime piracy attacks by years, regions, types of attacks, months and type of ships attacked are given in the tables below (Tables 1-5).

Table 1. Frequency distribution of piracy attacks by years

Attacks by years	Frequency	Percent (%)	Total cumulative percent (%)
2015	250	17.4	17.4
2016	195	13.6	31.0
2017	185	12.9	43.8
2018	202	14.1	57.9
2019	161	11.2	69.1
2020	196	13.6	82.7
2021	132	9.2	91.9
2022	116	8.1	100.0
Total	1.437	100.0	
Source: IMB ICC 2015-2022 Annual Reports			

Table 2. Frequency distribution of piracy attacks by regions

		2015	2022	2020	2022	Frequency	
Attacks by regions	Frequency	Percent (%)	Total cumulative (%)	2020	2021	2022	Total
Africa	436	30.3	30.3	86	37	3	126
South East Asia	632	44.0	74.3	64	58	61	183
Indian subcontinent	103	7.2	30.3	11	2	10	23
America	224	15.6	97.1	30	35	42	107
Far East	35	2.4	99.5	4	0	0	4
Others	7	0.5	100.0	1	0	0	1
Total	1.437	100.0		196	132	116	444
Source: IMB ICC 2015-2022 Annual Reports							

Table 3. Frequency distribution by types of piracy attacks

		2015	2022	2020	2022	Frequency	
Types of piracy attacks	Frequency	Percent (%)	Total cumulative (%)	2020	2021	2022	Total
Attempted	158	11.0	11.0	19	13	4	36
Fired upon	73	5.1	16.1	11	4	1	16
Hijack	41	2.9	18.9	3	1	0	4
Boarded	1.165	81.0	99.9	163	114	111	388
Total	1.437	100.0		196	132	116	444
Source: IMB ICC 2015-2022 Annual Reports							

Table 4. Frequency distribution of piracy attacks by months

Attacks by months	Frequency	2015 Percent (%)	2022 Total cumulative (%)	2020 2020	2022 2021	Frequency 2022	Total
December-January-February	373	26.0	26.0	52	39	40	131
March-April-May	425	29.6	55.5	61	33	29	123
June-July-August	290	20.2	75.7	31	30	20	81
September-October-November	349	24.3	100.0	52	30	27	109
Total	1.437	100.0		196	132	116	444
Source: IMB ICC 2015-2022 Annual Reports							

Table 5. Frequency distribution of type of ships attacked

Type of ships attacked	Frequency	2015 Percent (%)	2022 Total cumulative (%)	2020 2020	2022 2021	Frequency 2022	Total
NA	1	0.1	0.1	-	-		-
Fishing ships	21	1.5	1.5	6	3	0	9
General cargo	74	5.1	6.7	12	4	5	21
Bulk carrier	431	30.0	36.7	52	47	49	148
Container	160	11.1	47.8	26	30	10	66
Tanker	113	7.9	55.7	10	5	9	24
Chemical tanker	63	4.4	60.1	9	3	6	18
Product tanker	281	19.6	79.6	41	20	14	75
LPG tanker	56	3.9	83.5	5	4	2	11
Refrigerated vessel	18	1.3	84.8	4	1	0	5
Vehicle carrier	16	1.1	85.9	0	2	7	9
Tug	64	4.5	90.4	4	3	8	15
Others	138	9.6	100.0	27	10	6	43
Total	1.437	100.0		196	132	116	444
Source: IMB ICC 2015-2022 Annual Reports							

The most attacks occurred in Indonesia and respectively Nigeria as shown in Table 1S.

The most attacks occurred between the hours 24:00-04: and respectively 04:00-08:00 between the period of 2015 and 2020 as given in Table 2S.

Marshall Islands-flagged ships are most commonly attacked and respectively Panama-flagged ships between the period of 2015 and 2022 as given in Table 3S.

3.2. Chi-square Test

χ^2 concerning piracy attacks for the period in 2015-2022 are given in the following:

3.2.1. The Chi-square test piracy attacks by years and regions

Most attacks occurred in Africa in 2018 (87), and respectively South East Asia in 2015 (181), Indian subcontinent in 2015 and 2017 (20), the Americas in 2022 (42), in the Far East (16) in 2016 as shown in Table 6 [3]. Piracy attacks decreased in all regions except the Americas during the COVID-19 period.

As seen in Table 6 the differences between the observed frequencies and the expected frequencies are quite large.

Null (H_0) and alternative (H_1) hypotheses are given as follows;

H_0: There is no statistical relationship between piracy attacks by years and regions.

H_1: There is a statistical relationship between piracy attacks by years and regions.

The Pearson χ^2 value=285.925 and 31.3% of expected counts <5 as given in Table 7. P-value (0.00) < the significance level (α=0.05), but the minimum expected count <1 (0.57). Therefore, the χ^2 test can not be used safely.

3.2.2. The chi-square test between month of attack and region of attack

The most of the attacks occurred in Africa (134), South Asia (193), and the Americas (64) occurred between March and

Table 6. Crosstabulation for piracy attacks by years and regions (2015-2022)

Attacks by years/ regions	Count % within attack year/Expected count	Africa	South East Asia	Indian subcontinent	Americas	Far East	Others	Total
2015	Count	35	181	20	8	5	1	250
	Expected count	75.9	110.0	17.9	39.0	6.1	1.2	250.0
	% attack year	14.0%	72.4%	8.0%	3.2%	2.0%	0.4%	100.0%
2016	Count	62	72	17	27	16	1	195
	Expected count	59.2	85.8	14.0	30.4	4.7	0.9	195.0
	% attack year	31.8%	36.9%	8.7%	13.8%	8.2%	0.5%	100.0%
2017	Count	56	79	20	24	2	4	185
	Expected count	56.1	81.4	13.3	28.8	4.5	0.9	185.0
	% attack year	30.3%	42.7%	10.8%	13.0%	1.1%	2.2%	100.0%
2018	Count	87	64	19	29	3	0	202
	Expected count	61.3	88.8	14.5	31.5	4.9	1.0	202.0
	% attack year	43.1%	31.7%	9.4%	14.4%	1.5%	0.0%	100.0%
2019	Count	70	53	4	29	5	0	161
	Expected count	48.8	70.8	11.5	25.1	3.9	0.8	161.0
	% attack year	43.5%	32.9%	2.5%	18.0%	3.1%	0.0%	100.0%
2020	Count	86	64	11	30	4	1	196
	Expected count	59.5	86.2	14.0	30.6	4.8	1.0	196.0
	% attack year	43.9%	32.7%	5.6%	15.3%	2.0%	0.5%	100.0%
2021	Count	37	58	2	35	0	0	132
	Expected count	40.1	58.1	9.5	20.6	3.2	0.6	132.0
	% attack year	28.0%	43.9%	1.5%	26.5%	0.0%	0.0%	100.0%
2022	Count	3	61	10	42	0	0	116
	Expected count	35.2	51.0	8.3	18.1	2.8	0.6	116.0
	% attack year	2.6%	52.6%	8.6%	36.2%	0.0%	0.0%	100.0%
Total	Count	436	632	103	224	35	7	1437
	Expected count	436.0	632.0	103.0	224.0	35.0	7.0	1437.0
	% attack year	30.3%	44.0%	7.2%	15.6%	2.4%	0.5%	100.0%

Table 7. The chi-square test for the piracy attacks by years and regions (2015-2022)

	Value	df	Asymp. sig. (2-sided)
Pearson chi-square	285.925[a]	35	0.000
Likelihood ratio	301.818	35	0.000
Linear-by-Linear relationship	6.680	1	0.010
Phi (Approx. sig.)	0.446		0.000
Cramer's V (Approx. sig.)	0.199		0.000[b]
Spearman correlation	0.031		0.237[c]
Number of valid cases	1.437		
[a]15 cells (31.3%) have expected count less than 5. The minimum expected count is 0.57.			
[b]Approx. sig.			
[c]Based on normal approximation			

May. The most of the attacks occurred Indian subcontinent (47) and Far East (15) between December and February in the period of 2015 to 2022 as shown in Table 4S [3]. As seen in Table 4S, the differences between the observed frequencies and the expected frequencies are small.

H_0: There is no statistical relationship between the piracy attacks by months and region.

H_1: There is statistical relationship between the piracy attacks by months and regions.

The Pearson χ^2 value=52,318, 16.7% of expected counts <5 as given in Table 5S. The test result shows that the p-value (0.00) <α=0.05, the minimum expected count >1 (1.41). Therefore, H_0 is rejected, H_1 is accepted. There is statistical relationship between the month of attack and the region of attack. Cramer's V value (0.110) and Phi value (0.191) confirm that there is a weak statistical relationship between month of attack and region of attack. The Spearman correlation coefficient value of -0.013 confirms that there is a negative association between month of attack and region of attack.

3.2.3. The chi-square test piracy attacks between hours and regions

The piracy attacks in Africa, Indian subcontinent, Americas and Far East were occurred between the hours 24:00-04:00. The most attacks in South Asia were occurred between the hours 16:00-20:00 during the COVID-19 period between 2020 and 2022, and the differences between the observed frequencies and the expected frequencies are small as seen in Table 6S. According to the results of χ^2 for the piracy attacks by hours and regions; χ^2=252.044, p=0.000, Likelihood ratio=261.331, p=0.000, Phi=0.419, p=0.000 (Approx. Sig.-2-sided), Cramer's V=0.187, p=0.000 (Approx. Sig.-2-sided), Spearman's correlation: 0.021, p=0.000 (Asymp. Sig.-2-sided). 28.6% of expected counts <5 and the minimum expected count =0.11.

H_0: There is no statistical relationship between the piracy attacks by hours and regions, H_1: There is statistical relationship between the piracy attacks by hours and regions.

The test result shows that the p-value (0.00) <α=0.05, but the minimum expected count <1 (0.11). Therefore, the χ^2 can not be used safely.

3.2.4. The chi-square test between attack years and attack types

The most ships attempted (16.3%) and respectively fired upon (8.9%) in 2018. The most ships hijacked and boarded in 2015 as shown in Table 8. The attacks have dropped significantly due to preventive measures, anti-piracy operations and armed guards on board ships [3]. All type of attacks decreased in the COVID-19 period (2020-2022) as shown in Table 8. Most ships were boarded between 2015 and 2022.

χ^2=62.412, p=0.000, Likelihood ratio=73.942, p=0.000, Phi=0.208, p=0.000 (Approx. Sig.-2-sided), Cramer's V=0.120, p=0.000 (Approx. Sig.-2-sided), Spearman's correlation=0.072, p=0.006 (Asymp. Sig.-2-sided).

3 cells (9.4%) have expected count less than 5. The minimum expected count is 3.31.

As seen in Table 8, the differences between the observed frequencies and the expected frequencies are small. H_0: There is no statistical relationship between the piracy attacks by years and type of attacks; H_1: There is a statistical relationship between the piracy attacks by years and type of attacks. 9.4% of expected counts <5 as given below Table 8. P-value (0.00) <α=0.05, but the minimum expected count >1 (3.31). Therefore, H_0 is rejected, H_1 is accepted. There is a statistical relationship between the year of attack and the region of attack. Cramer's V value (0.120) and Phi value (0.208) confirm that there is a weak statistical relationship between the year of attack and the region of attack. The Spearman correlation coefficient value of 0.072 confirms that there is a very weak association between year of attack and region of attack.

3.2.5. Chi-square test between attack types and attack regions

The most attacks occurred were boarded in Africa (290), in South East Asia (549), in Indian subcontinent (95), in the Americas (197) and in the Far East (31) between 2015 and 2022 as given in Table 9.

χ^2=207.936, p=0.000, Likelihood ratio=178.652, p=0.000, Phi=0.380, p=0.000 (Approx. Sig.-2-sided), Cramer's V=0.220, p=0.000 (Approx. Sig.-2-sided), Spearman's correlation: 0.195, p=0.006 (Asymp. Sig.-2-sided).

7 cells (29.2%) have expected count less than 5. The minimum expected count is 0.20.

29.2% of expected counts <5 as given below Table 9. P-value (0.00) <α=0.05, but the minimum expected count is less than 1 (0.20). Therefore, the χ^2 can not be used safely.

3.2.6. Non-parametric correlation

Non-parametric correlation measure the association between the two variables [34,35]. The correlation matrix was created to summarize the data for more advanced analysis. The correlation matrix shows a global view of the more or less strong relationship between the variables [36-38].

The correlation between some variables indicate little or no association. These are the correlation between type of ship attacked and flag of ships attacked (0.140); between flag of ships attackted and month of attack (0.043); between year of attack and hour of attack (0.178); between type of attack and year of attack (0.072); between year of attack and type of attack (0.064); between year of attack and region of attack (0.068); between region of attack and type of attack (0.122) as given in Table 10.

The correlation between some variables indicates strong negative association such as between flag of ships attacked

and year of attack (-0.082); between flag of ships attacked and type of attack (-0.020); between flag of ships attacked and region of attack (-0.065); between type of ship attacked and type of attack (-0.013), between type of ships attacked and region of attack (-0.078) as given in Table 10.

4. Results and Discussion of Findings

The purpose of the study is to help stakeholders take effective anti-piracy measures against pirate attacks by revealing the attacks by years, months, and hours, regions, type of ships attacked and ship's flag attacked, or whether there is a relationship between these parameters between 2015 and 2022 and the COVID-19 Period. The results of the frequency distributions are as follows;

There were 1,437 piracy and armed robbery attacks between 2015 and 2022. The most piracy attacks occurred in 2015 (17.4%) between 2015 and 2022. Maritime piracy

attacks decreased by 32.7% in 2020 and by 12.2% in 2022 according to the previous year [35]. The annual report of IMB PRC shows 13% decrease in overall attacks in 2022 compared to 2021 [21]. The attacks decreased respectively between 2021 and 2022 during the COVID-19 period as given in Table 1. According to the study conducted by Akan et al. [24] most piracy attacks occurred in 2015 (13.3%) between 2010 and 2020 These results confirm the analysis results.

The region with the most attacks is South East Asia (44.0%) and respectively Africa (30.3%), America (15.6%), Indian subcontinent (7.2%) and Far East (2.4%) between the period of 2015 and 2022. The region with the most attacks is South East Asia (183) and respectively in Africa (126) and America (107) between 2020 and 2022 during the COVID-19 period as given in Table 2. The attacks in Africa drastically decreased in 2020-2022. The almost attacks increased in

Table 8. Crosstabulation for the piracy attacks by years and type of attacks (2015-2020)

Years	Count/Expected count/% within attack year	Attempted	Fired upon	Hijack	Boarded	Total
2015	Count	28	1	15	206	250
	Expected count	27.5	12.7	7.1	202.7	250.0
	% wit. attack year	11.2%	0.4%	6.0%	82.4%	100.0%
2016	Count	23	11	8	153	195
	Expected count	21.4	9.9	5.6	158.1	195.0
	% wit. attack year	11.8%	5.6%	4.1%	78.5%	100.0%
2017	Count	22	16	5	142	185
	Expected count	20.3	9.4	5.3	150.0	185.0
	% wit. attack year	11.9%	8.6%	2.7%	76.8%	100.0%
2018	Count	33	18	5	146	202
	Expected count	22.2	10.3	5.8	163.8	202.0
	% wit. attack year	16.3%	8.9%	2.5%	72.3%	100.0%
2019	Count	16	11	4	130	161
	Expected count	17.7	8.2	4.6	130.5	161.0
	% wit. attack year	9.9%	6.8%	2.5%	80.7%	100.0%
2020	Count	19	11	3	163	196
	Expected count	21.6	10.0	5.6	158.9	196.0
	% wit.attack year	9.7%	5.6%	1.5%	83.2%	100.0%
2021	Count	13	4	1	114	132
	Expected count	14.5	6.7	3.8	107.0	132.0
	% wit. attack year	9.8%	3.0%	8%	86.4%	100.0%
2022	Count	4	1	0	111	116
	Expected count	12.8	5.9	3.3	94.0	116.0
	% wit. attack year	3.4%	0.9%	0.0%	95.7%	100.0%
Total	Count	158	73	41	1165	1437
	Expected count	158.0	73.0	41.0	1165.0	1437.0
	% wit. attack year	11.0%	5.1%	2.9%	81.1%	100.0%

Table 9. *Crosstabulation for attack types and attack regions (2015-2022)*

Attack types/ Attack regions	Count/Expected count/% within attack hour	Africa	South East Asia	Indian subcontinent	Americas	Far East	Others	Total
Attempted	Count	66	57	8	23	4	0	158
	Expected count	47.9	69.5	11.3	24.6	3.8	0.8	158.0
	% att. typ.	41.8%	36.1%	5.1%	14.6%	2.5%	0.0%	100.0%
Fired Upon	Count	60	4	0	4	0	5	73
	Expected count	22.1	32.1	5,.2	11.4	1.8	0.4	73.0
	% att. typ.	82.2%	5.5%	0.0%	5.5%	0.0%	6.8%	100.0%
Hijack	Count	20	21	0	0	0	0	41
	Expected count	12.4	18.0	2.9	6.4	1.0	0.2	41.0
	% att. typ.	48.8%	51.2%	0.0%	0.0%	0.0%	0.0%	100.0%
Boarded	Count	290	549	95	197	31	2	1164
	Expected count	353.5	512.4	83.5	181.6	28.4	5.7	1165.0
	% att. typ.	24.9%	47.2%	8.2%	16.9%	2.7%	0.2%	100.0%
Total	Count	436	632	103	224	35	7	1437
	Expected count	436.0	632.0	103.0	224.0	35.0	7.0	1437.0
	% att. typ.	30.3%	44.0%	7.2%	15.6%	2.4%	0.5%	100.0%

Table 10. *The correlation matrix*

		A	B	C	D	E	F	G
Type of ship attacked (A)	Correlation coefficient	1	0.140**	-0.029	-0.046	-0.038	-0.013*	-0.078**
Flag of ships attacked (B)	Correlation coefficient	0.140**	1	-0.082**	0.043	0.044	-0.020	-0.065*
Year of attack (C)	Correlation coefficient	-0.029	-0.082**	1	-0.046	0.178**	0.064**	0.068**
Month of attack (D)	Correlation coefficient	-0.046	0.043	-0.046	1	0.013	0.023	-0.033
Hour of attack (E)	Correlation coefficient	-0.038	0.044	0.178**	0.013	1	-0.004	0.021
Type of attack (F)	Correlation coefficient	-0.061*	-0.054*	0.072**	0.036	-0.027	1	0.122**
Region of attack (G)	Correlation coefficient	-0.078**	-0.065*	0.068**	-0.033	0.051	0.122**	1
*Correlation is significant at the 0.01 level (2-tailed). **Correlation is significant at the 0.05 level (2-tailed)								

South East Asia by 5.2% in 2022 compared to the previous year. According to the analysis results performed by Jiang and Lu [19], the number of pirates in Southeast Asia has increased rapidly. This result is consistent with the results of this study. The main reasons for the most piracy incidents in Southeast Asia are low wages, unemployment, inadequate coastal-port surveillance, political instability and gaps in the legal system.

Frequency distribution of piracy attacks by locations is given in Table 1S. The most attacks occurred in Indonesia (21.4%) and respectively Nigeria (13.5%), the Straits of Malacca and Singapore (9.5%) and Malaysia (4.5%) between the period of 2015 and 2022 as given in Table 1S. The most attacks occurred in the Straits of Malacca and Singapore (98) and respectively, Indonesia (43) and Nigeria [33] during the COVID-19 period. The number of pirack attacks in the Singapore Strait increased in 2022 [34].

Most attacks were boarded (81%) and respectively attempted (11%), fired upon (5.1%) and hijack (2.9%) in the period 2020 and 2022. Most attacks were boarded (388) and respectively attempted (36) and fired upon (16) during the COVID-19 period as given in Table 3. The number of attacks in Vietnamese and Malaysian ports dropped between 2020 and 2021. The region with the most attacks is Southeast Asia, followed by Africa between the years 2015-2022 and in the 2020-2022 COVID-19 period.

Majority of attacks occurred in March-April-May (29.6%) and respectively December-January-February (26.0%), September-October-November (24.3%), and June-July-August (20.2%) between the period of 2015 and 2022 as given in Table 4. The most attacks occurred in December-January-February (131) and respectively March-April-May (123) during the COVID-19 period. All attacks decreased between 2020 and 2022 except in December-

January-February in 2022. According to the results of the analysis conducted by Li and Yang [18], in Southeast Asia, Most maritime pirate attacks occurred in April and May, the dry seasons when there is no wind. These results are consistent with the findings of this study. The most attacks occurred between the hours 24:00-04:00 (27.8%) and respectively 04:00-08:00 (19.5%), 16:00-20:00 (18.4%), 20:00-24:00 (15.8%), 12:00-16:00 (9.2%) and 08:00-12:00 (7.9%) between the period of 2015 and 2022 as given in Table 2S. According to the analysis results performed by Ece [39], most of the attacks occurred the hours between 24:01-04:00 and respectively between 04:01-08:00. This result is consistent with the results of this study.

According to the study conducted by Akan et al. [24] most attacks also occurred between the hours 24:00-04:00 (36.6%) and respectively 04:00-08:00 (25.4%). The results of the study are consistent with the results of this study The most attacks occurred between 24:00-04:00 (110) and then 16:00-20:00 (109) during the COVID-19 period.

Bulk carrier ships were the most attacked (30.0%), and respectively product tankers (19.6%), container ships (11.1%) between the period of 2015 and 2022 as given in Table 5. Bulk carrier ships were the most attacked (148) and respectively product tankers (75) during the COVID-19 period. Attacks against almost all types of ships except bulk carrier decreased during the pandemic. The attacks against bulk carriers increased 4.3% in 2022 compared to the previous year. The results of the study conducted by Akan et al. [24] show that tankers were the most attacked (31.9%) tanker (7.9%), chemical tanker (4.4%), product tanker (19.6%) between 2010 and 2020. These results regarding attack hours, and type of ships attacked are consistent with the results of this study. Marshall Islands-flagged ships are most commonly attacked (16.4%) and respectively Panama-flagged ships (14.4%), Singapore-flagged ships (15.0%), and Liberia-flagged ships (11.3%) in 2015-2022 as given in Table 3S. According to the statistical analysis conducted Jiang and Lu [19], the most attacked type of ship between 2010 and 2019 was bulk carriers (24.1%), followed by general cargo ships (14.9%), container ships (14.7%), and tankers (12.5%) and slowing the speed of big ships below 15 knots provides an opportunity for pirates. Singapore-flagged ships were also the most attacked (75) and respectively Marshall Islands-flagged ships (68), Liberia-flagged ships (59), and Panama-flagged ships (55) during the COVID-19 period.

The findings of χ^2 are as follows; There is a weak statistical relationship between the piracy attacks by regions and months; and there is also a weak statistical relationship between piracy attacks by years and type of attacks. There is no statistical relationship between other variables. According to findings of Cramer's V value and Phi value, there is a weak statistical relationship between the month of attack and the region of attack. The Spearman's Rho confirms that there is a very weak association between the year of attack and the region of attack. According to the non-parametric correlation results, there is little or no association between the region of attack and the month of atack. The correlation between is -0.109 which indicates There is a strong negative association between the type of ships and region of attack. According to the non-parametric correlation results; the correlation between some variables indicates little or no association.

5. Conclusion

In the study, quantitative analysis of maritime piracy attacks between 2015 and 2022 and during the 2020-2022 COVID-19 period were performed. The results of the frequency distributions are as follows; Most piracy attacks occurred in 2015. Maritime piracy attacks decreased by 12.2% in 2022 compared to the previous year. Majority of attacks occurred in South East Asia between 2015 and 2022 and the COVID-19 period. Most attacks occurred in March-April-May between 2015-2022. Most attacks occurred between the hours 24:00-04:00 in 2015-2022 and the COVID-19 period. Tankers were the most attacked in the same period. Most types of attacks against to ships were boarded between 2015 and 2022 and the COVID-19 period. The Marshall Islands-flagged ships were the most attacked in 2015-2022.

In the COVID-19 period most attacks occurred in Singapore and the Straits of Malacca. Most attacks occurred between December and February. The bulk carrier ships were the most attacked and respectively product tankers. The Singapore-flagged ships were also the most attacked.

There is a weak statistical relationship between the piracy attacks by months and regions; and there is also a weak statistical relationship between piracy attacks by years and type of attacks. According to the non-parametric correlation results; the correlation between some variables indicates little or no association.

It is thought that researching further studies on the coordinates of piracy incidents and the legal infrastructure for prosecution and criminal prosecution in case of catching pirates will contribute to the literature and anti-piracy measures.

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Table 1S. Frequency distribution of piracy attacks by locations

Attacks by location	Frequency	2015 Percent (%)	2022 Total cumulative (%)	2020 2020	2022 2021	Frequency 2022	Total
Bangladesh	49	3.4	3.4	4	0	7	11
The Gulf of Aden/Somalia	31	2.2	5.6	1	1	0	2
Indonesia	308	21.4	27.0	26	8	9	43
Malaysia	64	4.5	31.5	5	2	3	10
Nigeria	194	13.5	45.0	34	0	0	34
Vietnam	52	3.6	48.6	4	1	2	7
The Straits of Malacca and Singapore	136	9.5	58.0	24	36	38	98
Indian	53	3.7	61.7	7	1	3	11
Benin	19	1.3	63.0	11	3	4	18
Others	531	37.0	100.0	80	80	50	210
Total	1.437	100.0		196	132	116	444
Source: International Chamber of Commerce (ICC) IMB 2015-2022 Annual Reports							

Table 2S. Frequency distribution of piracy attacks by hours

Attacks by hours	Frequency	2015 Percent (%)	2022 Total cumulative (%)	2020 2020	2022 2021	Frequency 2022	Total
NA	22	1.5	1.5	0	2	0	2
24:00-04:00	399	27.8	29.3	59	32	19	110
04:01-08:00	280	19.5	48.8	31	19	16	66
08:01-12:00	113	7.9	56.6	17	10	8	35
12:01-16:00	132	9.2	65.8	23	19	11	53
16:01-20:00	264	18.4	84.2	31	35	43	109
20:01-24:00	227	15.8	100.0	35	15	19	69
Total	1.437	100.0		196	132	116	444
Source: International Chamber of Commerce (ICC) IMB 2015-2022 Annual Reports							

Table 3S. Actual and attempted piracy attacks by ship's flag attacked

Ship's flag attaccked	Frequency	2015 Percent (%)	2022 Total cumulative (%)	2020 2020	2022 2021	Frequency 2022	Total
NA	10	0.7	0.7	2	0	1	3
Europe (Exc. Malta)	42	2.9	3.6	2	28	7	37
Malta	53	3.7	7.3	7	4	7	18
USA/Cont America	4	0.3	7.6	0	0	1	1
Russia	2	0.1	7.7	0	0	2	2
Hong Kong	70	4.9	12.6	9	0	2	11
Marshall Islands	236	16.4	29.0	33	15	20	68
Antigua & Barbuda	17	1.2	30.2	1	3	0	4
Singapore	215	15.0	45.2	29	25	21	75
Panama	207	14.4	59.6	26	6	23	55
Liberia	162	11.3	70.8	31	17	11	59
Malaysia	45	3.1	74.0	1	3	3	7
Indonesia	25	1.7	74.8	4	1	0	5
Others	349	24.3	100.0	51	30	18	99
Total	1.437	100.0		196	132	116	444
Source: International Chamber of Commerce (ICC) IMB 2015-2022 Annual Reports							

Table 4S. Crosstabulation for piracy attacks by months and regions (2015-2022)

Attacks by months	Count/Expected count/% within attack months	Africa	South East Asia	Indian subcontinent	Americas	Far East	Others	Total
December-February	Count	128	120	47	62	15	1	373
	Expected count	113.2	164.0	26.7	58.1	9.1	1.8	373.0
	% w. attac. mon.	34.3%	32.2%	12.6%	16.6%	4.0%	0.3%	100.0%
March-May	Count	134	193	21	64	10	3	425
	Expected count	128.9	186.9	30.5	66.2	10.4	2.1	425.0
	% w. attac. mon.	31.5%	45.4%	4.9%	15.1%	2.4%	0.7%	100.0%
June-August	Count	70	150	16	49	4	1	290
	Expected count	88.0	127.5	20.8	45.2	7.1	1.4	290.0
	% w. attac. mon.	24.1%	51.7%	5.5%	16.9%	1.4%	0.3%	100.0%
September-November	Count	104	169	19	49	6	2	349
	Expected count	105.9	153.5	25.0	54.4	8.5	1.7	349.0
	% w.attac. mon.	29.8%	48.4%	5.4%	14.0%	1.7%	0.6%	100.0%
Total	Count	436	632	103	224	35	7	1437
	Expected count	436.0	632.0	103.0	224.0	35.0	7.0	1437.0
	% w. attac. mon.	30.3%	44.0%	7.2%	15.6%	2.4%	0.5%	100.0%
Source: International Chamber of Commerce (ICC) IMB 2015-2022 Annual Reports								

Table 5S. The chi-square test for the piracy attacks by months and regions (2015-2022)

	Value	df	Asymp. Sig. (2-sided)
Pearson's chi-square	52.318[a]	15	0.000
Likelihood ratio	50.945	15	0.000
Linear-by-Linear relationship	1.590	1	0.207
Phi (Approx. Sig.)	0.191		0.000
Cramer's V (Approx. Sig.)	0.110		0.000[b]
Spearman correlation	-0.013		0.613[c]
Number of valid cases	1.437		
[a]4 cells (16.7%) have expected count less than 5. The minimum expected count is 1.41. [b]Approx. Sig. [c]Based on normal approximation			

Table 6S. Crosstabulation for piracy attacks by hours and regions (2015-2022)

Attacks by hours	Count/% within attac. hour	Africa	South East Asia	Indian subcontinent	Americas	Far East	Others	Total
NA	Count	5	12	2	2	1	0	22
	Expected count	6.7	9.7	1.6	3.4	0.5	0.1	22.0
	% attac. hour	22.7%	54.5%	9.1%	9.1%	4.5%	0.0%	100.0%
24:00-04:00	Count	169	116	27	74	13	0	399
	Expected count	121.1	175.5	28.6	62.2	9.7	1.9	399.0
	% attac. hour	42.4%	29.1%	6.8%	18.5%	3.3%	0.0%	100.0%
04:01-08:00	Count	84	86	13	91	3	3	280
	Expected count	85.0	123.1	20.1	43.6	6.8	1.4	280.0
	% attac. hour	30.0%	30.7%	4.6%	32.5%	1.1%	1.1%	100.0%
08:01-12:00	Count	47	37	4	24	1	0	113
	Expected count	34.3	49.7	8.1	17.6	2.8	0.6	113.0
	% attac. hour	41.6%	32.7%	3.5%	21.2%	0.9%	0.0%	100.0%
12:01-16:00	Count	28	77	14	8	5	0	132
	Expected count	40.1	58.1	9.5	20.6	3.2	0.6	132.0
	% attac. hour	21.2%	58.3%	10.6%	6.1%	3.8%	0.0%	100.0%
16:01-20:00	Count	42	179	24	8	9	2	264
	Expected count	80.1	116.1	18.9	41.2	6.4	1.3	264.0
	% attac. hour	15.9%	67.8%	9.1%	3.0%	3.4%	0.8%	100.0%
20:00-24:00	Count	61	125	19	17	3	2	227
	Expected count	68.9	99.8	16.3	35.4	5.5	1.1	227.0
	% attac. hour	26.9%	55.1%	8.4%	7.5%	1.3%	0.9%	100.0%
Total	Count	436	632	103	224	35	7	1437
	Expected count	436.0	632.0	103.0	224.0	35.0	7.0	1437.0
	% attac. hour	30.3%	44.0%	7.2%	15.6%	2.4%	0.5%	100.0%
Source: International Chamber of Commerce (ICC) IMB 2015-2022 Annual Reports								