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Probability Theory Analysis of Maritime Piracy and the Implications for Maritime Security Governance

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Abstract

The objective of this study was to determine the empirical probability coefficients of pirate attacks on ships in various sea regions, individual ship types, and the occurrence probability scores of trauma associated with hostage-taking, injury, death, kidnap for ransom, missing, and threats to the lives of crew members effected by pirate attacks on ships. Secondary data on the frequency of pirate attacks on ships trading in various regions of the world were obtained from the International Maritime Bureau. The data covered 10 years, that is, between 2011 and 2020, and were analyzed using the empirical probability statistical method implemented with the MATLAB software. Results showed that Southeast Asian and African waters have the highest empirical probability coefficients of 0.40 and 0.39, respectively, and are most prone to pirate attacks on ships. Trauma associated with hostage-taking of the ship's crew has the highest probability coefficient and likelihood of occurrence of 0.76 compared with other effects of piracy affecting the ship's crew. Kidnap for ransom is second with an occurrence probability of 0.15. Chemical and product tankers have the highest likelihood of a pirate attack, with an occurrence probability of 0.26, followed by bulk carriers, crude oil tankers, container vessels, general cargo ships, LPG tankers, and trawler fishing vessels, with empirical probabilities of 0.24, 0.11, 0.11, 0.06, 0.04, and 0.02, respectively. The implications for maritime security governance were discussed.

Keywords: Maritime, security, governance, piracy, ship types, ship's crew

1. Introduction

Insecurity in the maritime domains of coastal states manifests in the form of piracy, terrorism, and armed robbery attacks on ships involved in seaborne trade over the years and has a negative impact on the development potential of the blue economy subsectors of the affected coastal states. For example, reports from the International Maritime Bureau (IMB) [1] revealed a sharp increase in attacks on ships and maritime insecurity in the African trade routes, such as the coast of the Horn of Africa and the Gulf of Aden (GOA), the east coast of Africa and the Gulf of Guinea (GOG), and the west coast of Africa. This increase in attacks has a direct disruptive effect on maritime logistics, supply chain, and trade flows, which subsequently threaten the African shipping trade and commerce with the rest of the world. The situation is similar in major sea routes and maritime regions of the world. Between 2011 and 2020, the IMB [2] reported an aggregate of 2,513 pirate attacks on ships trading in all sea regions of the world, that is, an average of 251 attacks per annum. However, the report noted that not all such attacks over the period were recorded. Table 1 shows the regional spread of global attacks on ships involved in seaborne trade globally.

Table 1 shows that maritime insecurity has affected major global maritime trade routes and regions, necessitating the need for the development and deployment of serious strategies for maritime security governance. Moreover, maritime security across global sea regions and shipping routes, particularly the Southeast Asian and African regions, is seriously threatened. Furthermore, the efficient and effective flow of shipping trade and seamless supply chain operations is threatened and disrupted. The consequence

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is cost-push inflation on the prices of import and export commodities [3]. From Asia to Africa and other regions, maritime trade, logistics, and supply chain networks face security risks and are threatened by the incessant scourge of maritime insecurity that has led to increased piracy-related insurance for ships transiting through piracy hotspots and increased and unstable freight and charter rates. Martínez-Zarzoso and Bensassi [4] estimated the annual cost expenditure for combating piracy and promoting maritime security globally at between $7 billion per annum and $12 billion per annum. Table 2 shows the disaggregated cost of pirate attacks on ships involved in maritime trade.

Apart from economic consequences, maritime piracy has a set of social and health implications and effects suffered by both ship's crew and passengers affected, which include the risk cum probability of injury and/or death, kidnapping for ransom, trauma associated with hostage-taking and torture, threats to life, and assault. Reports from the IMB [2] indicate that, between 2011 and 2020, the global injury burden suffered by ship's crew affected by pirate attacks in all sea regions is 156 injured persons, whereas the death burden representing the number of crew members killed by pirates over the same period is 24 persons (Table 3).

These findings underscore the fact that the socioeconomic effects of maritime insecurity are multifarious, thus the inevitable need for anti-maritime piracy measures to remedy the spate of insecurity in global waters and limit the socioeconomic impacts.

Table 1. *Regional spread of pirate attacks on ships involved in seaborne trade globally*

Sea region/zones	(i) Aggregate attacks 2011-2020	(ii) Regional attacks as a % of global attacks	(iii) Average attack per annum
Southeast Asian region	1.016	40.4%	101.6
Far East Asian region	118	4.7%	11.8
India subregion	183	7.28%	18.2
South America	212	8.4%	21.2
Africa	974	38.8%	97.4
Middle East as well as the rest of the world	10	0.39%	1.0
Global aggregate	2,513	100%	251.3
Source: (i) was aggregated from the IMB [2]. (ii) and (iii) were calculated by the authors			

Table 2. *Total estimated disaggregated cost of piracy in 2010*

Cost type	Cost ($)
Ransoms	$148 million
Insurance premiums	$460 million to $3.2 billion
Rerouting ships	$2.4 to $3 billion
Security equipment	$367 million to $ 2.5 billion
Naval forces	$2 billion
Prosecutions	$31 billion
Anti-piracy organizations	$19.5 billion
Cost to regional economies	$1.25 billion
Total estimated cost	$7 to $12 billion per year
Adapted from [4]	

Table 3. *Effects of pirate attacks suffered by seafarers between 2011 and 2020*

Outcome/risk type	Aggregate number of crew affected in all sea regions	Average per annum
Injury burden/seriously injured	156	15.6
Killed/death	24	2.4
Kidnapped for ransom	588	58.8
Source: IMB [2] Note: Authors' calculation		

Although many coastal states and the global shipping community have over the years responded to the scourge of maritime insecurity by promoting maritime security governance through the implementation of several anti-piracy measures, including direct combative measures such as the militarization of the waterways by deploying the navies and the implementation of anti-piracy regulations/legislations, vessel rerouting strategies, the International Ship and Port Facility Security (ISPS) code, and regional collaborative strategies. The implementation of various anti-piracy measures and the promotion of maritime security governance seem to have led to a declining trend in attacks on ships in some regions; however, maritime insecurity persists in some other regions, and the rate of decline in attacks in most regions seen to be rather insignificant [5-7].

The achievement of a secure maritime environment demands the eradication and suppression of acts of piracy and armed robbery against ships, which can be realized by maritime security governance through the deployment of knowledge-based security intelligence, technology, and legislation. The probability scores indicating the likelihood of occurrence of pirate attacks on individual ship types and in individual sea regions are an important example of a knowledge-based security intelligence needed to support current anti-piracy measures and promote maritime security governance to eradicate maritime piracy. To help the shipping industry, particularly ship operators and crew, acquire knowledge on and develop the capacity to understand the risk levels and likelihood of pirate attacks on individual ship types and the associated risks of kidnap for ransom, death, injury, torture, and hostage-taking, the empirical probability coefficients of pirate attacks on individual ships types and the coefficients of the empirical probability of risks of death, kidnap for ransom, injury, assault, torture, and hostage-taking associated with the attacks cum the probability coefficients of the likelihood of pirate attacks in various sea regions and trade routes need to be determined.

1.1. Objectives of this Study

The objectives of this study are:

(i) To determine the empirical probability coefficients of pirate attacks in Southeast Asia, the Far East, South America, Africa, the Indian subcontinent, and the Middle East as well as the rest of the world's maritime zones.

(ii) To measure the occurrence probabilities of death, kidnap for ransom, trauma associated with hostage-taking of crew members, assault, missing seafarers, and threats to the lives of seafarers following pirate attacks in global waters.

(iii) To estimate the empirical probability coefficient cum likelihood of pirate attacks on individual ship types in global sea routes.

The following constitute the research questions to be addressed in this study:

(i) What are the empirical probability coefficients of the likelihood of pirate attacks in Southeast Asia, the Far East, South America, Africa, the Indian subcontinent, and the Middle East as well as the rest of the world's maritime zones?

(ii) What are the occurrence probabilities of death, kidnap for ransom, trauma associated with hostage-taking of crew members, assault, missing seafarers, and threats to the lives of seafarers following pirate attacks in global waters?

(iii) What are the empirical probability coefficients cum likelihood of pirate attacks on individual ship types in global sea routes?

2. Literature Review

Several empirical studies have been conducted in an attempt to analyze the challenges of maritime insecurity caused by pirate attacks on ships involved in seaborne trade across global waters. For example, Ahmadi [8] reviewed the international legal regime of maritime piracy over the years to identify lacunas to legislations and legal frameworks as anti-piracy operations and policies in maritime states and used exploratory research approaches. Moreover, Ahmadi [8] recommended that dealing with maritime piracy involves coordinated and orchestrated efforts at different levels, including domestic, regional, and international. Furthermore, Ahmadi [8] noted that, although anti-maritime piracy operations have been successful in controlling and reducing piratical activities, for example, attacks on merchant vessels off the coast of Somalia have considerably reduced, the legal issues and the gaps in the international maritime piracy legal regime need to be identified. However, although the trend of attacks in most maritime domains, such as the Somali zone and the GOG, follows a decreasing trend, the rate of decrease is still insignificant and the economic impact on maritime trade and businesses is still significant [5,9]. One of the ways to accelerate the achievement of the current anti-piracy policies and further decrease the rate of attacks on ships is the determination of the ship types that are most prone to attacks, as well as the zones of most attacks and the probability and risk of attacks facing each ship type in various maritime zones and regions. This is a fact that the work presented in Ahmadi [8] did not address.

Mbekeani and Ncube [9], in a study for the African Development Bank, investigated the economic cost of maritime piracy, particularly in the African region, and determined that incidents of ship attacks in the waters of Africa are creating a challenge to maritime trade and other maritime economic opportunities. According to Mbekeani and Ncube [9], pirate attacks in the GOA have necessitated the adoption of the rerouting strategy by tanker operators to the Cape of Good Hope, which is approximately $3.5 billion in annual fuel costs. Mbekeani and Ncube [9] also noted that, although the fishery subsector is seriously hit economically by pirate attacks across the waters of Africa, in Seychelles alone, the cost of piracy is approximately 4% of the gross domestic product. The cost of piracy has increased the insurance costs and affected the development of the tourism potential of most coastal regions [9,10].

Ece and Kurt [7] analyzed maritime piracy in global waters using a quantitative approach and employed both primary data from surveys and secondary data from the IMB between 2015 and 2020 to analyze the attacks on ships in major global sea routes and regions and the frequency distribution method to examine the obtained data. The results of the study indicated that most piracy attacks occurred in 2015 (20.9%) and in March, April, and May (30.2%), with the prevalent time of attacks between 24:00 and 04:00 (29.2%). The results also indicated that most attacks occurred in Southeast Asian (42.6%) waters and the attackers in the majority of the attacks (79.1%) boarded the attacked vessels. Bulk carriers (BC) suffered the most attacks (28.6), and Marshall-Island-flagged ships were the most attacked (17.1%).

Hasan and Hasan [11] evaluated the effectiveness of the current regimes to combat piracy in the GOG. The study aimed to assess the application and shortcomings of the current arrangements in addressing the problem of piracy in the region. By employing data obtained from both secondary and primary sources, the study determined that the current anti-piracy strategies in the regions that focus more on the militarization of the waters in the regions have achieved minimal success as attacks continue over the years [11,12]. The findings support the propositions of the frustration-aggression theory and demand that the multifaceted approach requires the involvement of ship operators, coastal communities, navies of coastal states, and representatives of the government. Part of the approaches should be the economic emancipation of the youthful population in the coastal zones via meaningful employment opportunities. The involvement of the ship operators in the form of risk analysis and identification of piracy-prone zones, ship types, and information-sharing strategies is also important.

Nwokedi et al. [13] estimated the economic cost of output losses as a result of death and injury caused by maritime piracy and armed robbery in the ocean trawler fishery subsector of Nigeria and the global maritime industry and as economic justification for investment in remedial measures and policies against attacks in the subsector. The study used an ex post facto design approach where secondary data were obtained and analyzed using the gross output and empirical probability models to determine the output losses due to death and injuries to human capital caused by pirate attacks in the maritime industry [13]. The study developed a model for the estimation of output losses due to death and injury based on the relationship between the empirical probability coefficients of each risk type, the per capita output of the economy, and the number of maritime workers exposed to pirate attacks in any given economy [13].

Knyazeva and Korobeev [14], in the study entitled “Maritime Terrorism and Piracy: The Threat to Maritime Security,” established the distinctive features of piracy and maritime terrorism. By employing secondary data from the databases of the International Maritime Organization and IMB, the study determined the maritime regions prone to piracy and terrorist attacks. The authors opined that the anti-piracy approaches, policies, and measures cannot work in the case of combating maritime terrorism because available evidence indicates that the acts are committed with different intentions and motivated by different purposes [14,15].

Özdemir and Güneroğlu [16], in the study entitled “Quantitative Analysis of the World Sea Piracy using fuzzy AHP and fuzzy TOPSIS Methodologies,” investigated the factors causing piracy incidents and the most significant practical and applicable solutions to the problem. The expert opinions on the criteria set were analyzed by applying fuzzy AHP and fuzzy TOPSIS techniques to determine the significance level and ranking of the alternatives. Among all criteria, economic insufficiency received the maximum score as the most effective cause of sea piracy, whereas the geographic location of the canals and straits that are in risky regions of the world was identified as the least effective factor.

In a different study, Livingstone et al. [17] examined global maritime piracy, its impact on seafaring, and the factors shaping confrontational outcomes of piracy. The objective of the study was to determine the factors that affect the crew members’ attitude toward their job, including piracy, as well as the determinants of the success and failure of global maritime piracy, particularly the role of crew members. The study employed primary data obtained through surveys. The results of the study indicated that the fear of being captured (kidnapped) at sea by pirates significantly influence seafarers’ decision to move from working onboard ships to landside jobs. The study recommended that shipping industry employers should conduct a thorough appraisal of the effects of maritime piracy on recruitment efforts and develop policies to mitigate these effects to ensure improvement in seafarers’ productivity.

Finally, Helmick [18] assessed the key cost impacts of global piracy and armed robbery attacks on global supply chain operations and discussed strategies that can be employed to evade, deter, and mitigate this threat. The study identified the implications of piracy and armed robbery for supply chain partners to include seafarer abuse, injury, or death; the need for premium crew compensation; the payment of hostage ransoms; elevated insurance premiums; delayed cargo delivery; reduced cargo value; higher fuel costs; security equipment expenses; and the need for embarked security teams. Moreover, the study identified the implementation of best management practices as one of the strategies that can be used to address the threat of piracy to supply chain security without specific mention of particular best management strategies [18,19].

The current study overcame the gap of non-identification of specific empirically based anti-piracy strategies by developing occurrence probability coefficients of pirate attacks in specific regions and on individual ship types, which are important empirical information for evading and deterring pirate attacks, and the impacts on supply chain security.

The most important alternative to offering a solution to this problem was established as "providing support to local and regional authorities in risky regions", whereas the least important alternative was confirmed as "providing rehabilitation to individuals or groups whose actions tend to fuel pirate attacks".

The question of what constitutes in empirical terms the probability coefficients of pirate attacks on ship types (bulkers, tankers, general cargo vessels, passenger vessels, and cruise ships) involved in seaborne voyages in various sea regions seems currently lacking. Similarly, the available empirical literature has not tried to investigate what constitutes the occurrence probability coefficients and likelihood occurrence of death, kidnap for ransom, missing, trauma, assault, and threats to life associated with pirate attacks on crew members.

3. Data and Methods

The secondary data on the frequency of global pirate attacks on individual ship types between 2011 and 2020 was obtained from the IMB. The time series data on the spread of attacks on ships in global waters in various regions, such as the Southeast Asian region, Far East, Indian subcontinent, South America, Africa, and the Middle East as well as the rest of the world, covering 10 years, that is, between 2011 and 2020, were also obtained. Frequency data on the effects of the pirate attacks suffered by ship's crew, consisting of injury to crew, death/killed, kidnapped for ransom, assaulted, trauma/hostage, missing crew, and threats to life, covering the period between 2011 and 2020 were also obtained. Each category of the dataset was analyzed using the empirical probability statistical method implemented with the MATLAB software.

3.1. Empirical Probability

Probability theory deals with chance or stochastic processes. Empirical probability measures the likelihood that an event may occur based on historical data. The empirical probability coefficient is a numerical value or score that measures the likelihood that some events will occur based on past and/or historical data. Pirate attacks on ships are a stochastic occurrence, and pirate attacks on a given ship in the maritime zones, that is, Southeast Asia, Far East region, Indian subcontinent, South American region, Africa, and the Middle East as well as the rest of the world, are a mutually exclusive stochastic event [20]. Therefore, frequency data on global attacks spread across the identified piracy-prone maritime zones can be employed as the basis for estimating the empirical probability coefficients of pirate attacks in each zone. The empirical probability P_e of an event e is expressed as follows:

$$P_e = \frac{F}{N}, \qquad (1)$$

where F is the frequency/number of successful occurrences in the past, N is the aggregate frequencies representing the number of possible outcomes, and P_e is the empirical probability coefficient showing the likelihood of occurrence of event e.

The IMB (2021) divided the global maritime zones prone to insecurity challenges into six regions consisting of Southeast Asia, the Far East region, the Indian subcontinent, the South American region, Africa, and the Middle East as well as the rest of the world. The empirical probability coefficient showing the likelihood that a vessel trading or on a voyage in each of the regions may be attacked by pirates can be estimated using Equation (1) modified as follows:

For example, the empirical probability P_e of pirate attacks in the Southeast Asia region is expressed as follows:

$$P_{e1} = \frac{FSEA}{N}, \qquad (1a)$$

where $FSEA$ is the frequency of attacks in the waters within the Southeast Asian region between 2011 and 2020 and N is the aggregate global attacks on ships involved in seaborne trade between 2011 and 2020.

The empirical probability coefficients showing the likelihood of pirate attacks in the remaining regions of the Far East region, Indian subcontinent, South American region, Africa, and the Middle East as well as the rest of the world are expressed as follows:

For the Far East region, the empirical probability:

$$P_{e2} = \frac{FFER}{N}, \quad (1b)$$

For the Indian subcontinent:

$$P_{e3} = \frac{FISC}{N}, \quad (1c)$$

For the South American region:

$$P_{e4} = \frac{FSAR}{N}, \quad (1d)$$

For African waters:

$$P_{e5} = \frac{FAFR}{N}, \quad (1e)$$

For the Middle East as well as the rest of the world:

$$P_{e6} = \frac{FMEW}{N}, \quad (1f)$$

where *FFER*, *FISC*, *FSAR*, *FAFR*, and *FMEW* denote the frequencies of attacks in the Far East, Indian subcontinent, South American region, Africa, and the Middle East as well as the rest of the world between 2011 and 2020.

Based on the rules of probability theory, the following expression can be derived:

$$\sum P_{e1} + P_{e2} + P_{e3} + P_{e4} + P_{e5} + P_{e6} = 1 .$$

Similarly, the IMB [2] indicated that the attacks are spread over a total of 28 ship types, which include accommodation barge (AB), BC, cement carriers (CC), container ships (CS), dredger (D), drilling rig (DR), Floating production storage and offloading (FPSO), general cargo ships (GCS), heavy lift vessel (HLV), ore carrier (OC), passenger ships (PS), pipe layer vessel (PLV), pleasure craft (PC), refrigerated cargo ship (RCS), research vessel (RV), supply ship (SS), support vessel (SV), tanker/asphalt/bitumen (TAB), RORO, tanker bunkering (TB), tanker/chemical/product (TCP), tanker-crude oil (TCO), LNG tanker, LPG tanker, trawler fishing vessel (TFV), tug/offshore tug, vehicle carrier (VC), and yachts [20].

We determined the empirical probability coefficients of pirate attacks on individual ship types (P_{st}) over the period by employing the frequency of attacks on each ship type between 2011 and 2020 and the aggregate attacks on all ship types, that is:

$$P_{st} = \frac{ST_f}{N}, \quad (2)$$

where ST_f is the frequency of attacks on a given ship type (*ST*) over the period and *N* is as defined previously.

For example, the empirical probability coefficient of pirate attacks on ABs P_{AB} over the period is expressed as:

$$P_{AB} = \frac{AB_f}{N}. \quad (3)$$

Based on the rules of probability theory, the aggregate empirical probably coefficients ($P_{staggregate}$) of global attacks on all 28 ship types must not be equal to 1 [20,21], that is:

$$P_{staggregate} = \frac{ST_{faggregate}}{N} = 1.$$

Therefore:

$$\sum \frac{AB_f}{N}_t + \frac{BC_f}{N} + \frac{CC_f}{N} + \frac{CS_f}{N} + \frac{D_f}{N} + \frac{DR_f}{N} + \frac{FPSO_f}{N} + \frac{GCS_f}{N} +$$

$$\frac{HLV_f}{N} + \frac{OC_f}{N} + \frac{PS_f}{N} + \frac{PLV_f}{N} + \frac{PC_f}{N} + + \frac{RCS_f}{N} + \frac{RV_f}{N} + \frac{SS_f}{N} +$$

$$\frac{SV_f}{N} + \frac{TAB_f}{N} + \frac{RORO_f}{N} + \frac{TB_f}{N} + \frac{TCP_f}{N} + \frac{TCO_f}{N} + \frac{LNG_f}{N} + \frac{LPG_f}{N} +$$

$$\frac{TFV_f}{N} + \frac{TUG_f}{N} + \frac{VC_f}{N} + \frac{YACHTS_f}{N} = 1,$$

where $\sum \frac{AB_f}{N}_t$ is the empirical probability coefficient of pirate attacks on AB ship types between 2011 and 2020 and

$\frac{BC_f}{N}, \frac{CC_f}{N}, \frac{CS_f}{N}, \frac{D_f}{N}, \frac{DR_f}{N}, \frac{FPSO_f}{N}, \frac{GCS_f}{N}, \frac{HLV_f}{N}, \frac{OC_f}{N}, \frac{PS_f}{N}, \frac{PLV_f}{N},$

$\frac{PC_f}{N}, \frac{RCS_f}{N}, \frac{RV_f}{N}, \frac{SS_f}{N}, \frac{SV_f}{N}, \frac{TAB_f}{N}, \frac{RORO_f}{N}, \frac{TB_f}{N}, \frac{TCP_f}{N}, \frac{TCO_f}{N},$

$\frac{LNG_f}{N}, \frac{LPG_f}{N}, \frac{TFV_f}{N}, \frac{TUG_f}{N}, \frac{VC_f}{N}, \frac{YACHTS_f}{N}$

are the respective empirical probability coefficients of pirate attacks on individual ship types, that is, BC, CC, CS, Ds, DRs, floating production, storage and off-loading ships, GCS, HLVs, OCs, PS, PLVs, PCs, RCSs, RVs, SSs, SVs, TAB, RORO vessels, TB, TCP, TCO, LNG tanker, LPG tanker, TFVs, tugs/offshore tugs boats, VCs, and yachts [20].

Using Equation (2) and the respective frequencies of pirate attacks on the identified individual ship types over the period, the study estimated the empirical probability coefficients of all individual ship types.

3.2. Limitations of the Study

The data used in this study was obtained from the IMB piracy reports. Some pirate attacks in the industry may go unreported according to general public opinion. Therefore, the accuracy of these estimations and findings of the study may be influenced to a large extent by the accuracy of the data used.

4. Results and Discussion

The results of this study presented in Table 4 indicate the empirical probability coefficients of pirate attacks in each of the six sea regions between 2011 and 2020. For example, the highest likelihood/probability of occurrence of pirate attacks on ships occurred in 2015 in Southeast Asian waters, with an empirical probability coefficient of 0.58. This finding indicates that the likelihood of pirate attacks on ships on Southeast Asian sea routes is highest in 2015, with an empirical probability score that is close to 1, indicating that it is approximately 58% likely that ships trading within that region in 2015 will experience attacks by pirates.

The results shown in Table 4 also provide answers to research question (i) identified in Section 1.1. The average empirical probability coefficient of pirate attacks between 2011 and 2020 in the sea routes in Southeast Asia, Far East Asia, Indian subcontinent, South America, Africa, and the Middle East as well as the rest of the world is 0.40, 0.05, 0.07, 0.08, 0.39, and 0.004, respectively. The Southeast Asian sea region has the highest probability (0.40) of global occurrence probability, the African sea routes have the second-highest occurrence probability of pirate attacks of 0.39, and the Middle East as well as the rest of the world has the least occurrence probability (0.004) of attacks on ships. Notably, the aggregate occurrence probability coefficients is 0.4+0.05+0.07+0.08+0.39+0.004=1, which indicates the non-violation of the probability rule of the sum of probabilities of a sample. The results also show that the likelihood/occurrence probability of pirate attacks on ships is $P_{e1} > P_{e5} > P_{e4} > P_{e3} > + P_{e2} > P_{e6}$. This finding indicates that the likelihood/occurrence probability of pirate attacks in Southeast Asian sea routes (P_{e1}) is the highest globally, followed by the occurrence probability in African routes (P_{e5}), South America (P_{e4}), the Indian subcontinent (P_{e3}), Far East, and the Middle East as well as the rest of the world (P_{e6}). The closer the probability score is to 1, the greater the certainty of the occurrence of attacks in the region. Meanwhile, the farther the coefficient of probability score of a region is to 1, the less the likelihood of pirate attacks in the region. For example, Southeast Asian sea routes with a probability coefficient of 0.40 are closer to those with 0.004, and the occurrence of pirate attacks on ships in the region is most likely than in the Middle East region with an occurrence probability coefficient of 0.004, which is far from 1. The implications for maritime security governance is that ship operators trading in the Southeast Asian and African sea regions with the highest occurrence probabilities should develop and deploy more sophisticated anti-piracy measures and shipboard security defense mechanisms than those operating in the less piracy-prone regions with negligible occurrence probabilities, such as the Middle East, Far East, and Indian subcontinent. Similar to the implementation strategy of the ISPS code maritime security instrument, the global sea regions identified are ranked in three orders or levels of maritime security based on the empirical probability coefficients and the likelihood of pirate attacks on ships over the years. The purpose of the ranking is to guide authorities on the prioritization of maritime security governance strategies and anti-piracy measures. The security levels can be used to determine the intensity of implementation of security and anti-piracy strategies and the level of sophistication of such strategies (Table 5).

Table 4. *Empirical probability coefficients of piracy in various sea regions between 2011 and 2020*

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Average
Year	0.18	0.52	0.49	0.57	0.58	0.37	0.42	0.30	0.33	0.32	0.40
SE Asia = P_{e1}	0.05	0.02	0.05	0.03	0.13	0.08	0.02	0.04	0.03	0.02	0.05
Far East Asia = P_{e2}	0.04	0.05	0.09	0.14	0.09	0.09	0.08	0.09	0.03	0.05	0.07
Indian subcontinent = P_{e3}	0.06	0.04	0.07	0.02	0.03	0.14	0.13	0.14	0.18	0.16	0.08
S. America = P_{e4}	0.67	0.38	0.30	0.23	0.14	0.33	0.32	0.43	0.44	0.45	0.39
Africa = P_{e5}	0.005	-	-	0.01	0.004	0.01	0.02	-	-	-	0.004
Middle East (as well as the rest of the world) = P_{e6}	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Global aggregate											

Table 5. *Ranking the maritime zones in decreasing order of occurrence probability of pirate attacks*

Security level/ rank(s)	Sea regions	Empirical probability coefficient(s)	Remarks
Security level 1	Southeast Asia	0.04	Deploy the most intensified maritime security and anti-piracy measures
	Africa	0.39	
Security level 2	South America	0.08	Deploy more serious anti-piracy measures than is implemented in security level 3
	Indian subcontinent	0.07	
Security level 3	Far East	0.005	Deploy less sophisticated anti-piracy measures than needed in security levels 1 and 2
	Middle East as well as the rest of the world	0.004	
Source: Authors' calculation			

The occurrence probability scores show the proneness of ships to attacks in the regions between 2011 and 2020. The ships trading in the waters in Southeast Asia and Africa are far more prone to pirate attacks than in other regions. The findings of the study corroborate the findings of Özdemir and Güneroğlu [16] and Coggins [19] who agreed that the Southeast Asian region poses the greatest risk for piracy and armed attacks on ships involved in seaborne trade. However, their study approaches are different as they did not employ a probability approach such as that used in the current study and which present a novel and simple but empirically based approach toward analyzing the incidents of piracy in global maritime domains. The probability approach analysis is considered better because the spatial distribution of pirate attacks on ships is a stochastic occurrence.

The results shown in Table 6 provide answers to research question (ii) identified in Section 1.1. Notably, the probability scores of each pirate attack are associated with the effects and outcome types in each of the years covered in the study between 2011 and 2020. The occurrence probabilities indicate the respective likelihood of occurrence and risk of assault, trauma/hostage, injury, kidnap for ransom, death/killed, missing, and threats to life facing the ship's crew as a result of pirate attacks each year between 2011 and 2020. The results indicated that the average occurrence probability coefficient of assault, trauma associated with hostage-taking of crew members, injury to crew, kidnap for ransom, death/killed, missing crew members, and threats to the lives of crew members is 0.01, 0.76, 0.04, 0.15, 0.01, 0.001, and 0.03, respectively. The sum of the average probabilities is also 1, which indicates the non-violation of the probability rule of the sum of probabilities of a sample. This finding is similar to the findings of Nwokedi et al. [13] who reported that trauma associated with hostage-taking of crew members constitutes most of the outcomes of piracy attacks on ships suffered by crew members of fishing boats attacked in Nigerian waters.

This finding indicates that the ship's crew faces trauma associated with hostage-taking of crew members as the highest risk suffered by the crew associated with pirate attacks on ships. With the empirical probability coefficients of 0.76>0.15>0.04>0.03>0.01>0.001, the likelihood of a ship's crew suffering trauma as a result of being taken hostage by pirates is far higher than being injured, killed, kidnapped for ransom, assaulted, threatened, and going missing. The probability of being kidnapped for ransom has

Table 6. *Occurrence probability of the outcomes/effects of pirate attacks suffered by crew*

Effect/outcome type/year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Average
Assaulted	0.01	0.01	-	0.002	0.04	0.02	0.03	-	0.01	0.03	0.01
Trauma/hostage	0.89	0.88	0.82	0.92	0.81	0.64	0.48	0.59	0.28	0.18	0.76
Injured	0.05	0.04	0.05	0.03	0.04	0.03	0.03	0.03	0.03	0.05	0.04
Kidnap for ransom	0.01	0.04	0.09	0.02	0.06	0.26	0.39	0.34	0.64	0.70	0.15
Killed/death	0.01	0.01	0.003	0.01	0.003	-	0.02	-	0.01	-	0.01
Missing	-	-	-	0.002	0.003	-	-	-	-	-	0.001
Threatened	0.03	0.02	0.03	0.02	0.04	0.04	0.05	0.04	0.03	0.04	0.03
Aggregate	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Source: Authors' calculation											

Table 7. *Ranking the effects suffered by crew members affected by pirate attacks in decreasing order of occurrence probability*

Outcome types/ effects	Occurrence probability coefficient(s)	Levels/rank(s)	Remarks
Trauma/hostage	0.76	Rank 1	Most dominant effect of attack suffered by ship's crew between 2011 and 2020
Kidnap for ransom	0.15	Rank 2	Second-ranked outcome suffered by the crew
Injury	0.04	Rank 3	Third most outcome/effect of attacks on ships suffered by ship's crew
Threatened	0.03	Rank 4	-
Killed/death	0.01	Rank 5	
Assaulted	0.01		
Missing	0.001	Rank 6	Least effect suffered by the ship's crew
Source: Authors' calculation			

a coefficient of 0.15 and has the second-highest likelihood/probability of occurrence associated with pirate attacks on ships in global waters, followed by the occurrence probability of injury to crew members (0.04) and threats to life (0.03). Assault on crew members and death have the same occurrence probability coefficient of 0.01, whereas missing crew has the lowest occurrence probability of 0.001, indicating the least chance of occurrence. Based on the results shown in Table 6, we ranked the outcomes and effects of pirate attacks on ships affecting crew members in decreasing order of occurrence probability. This finding corroborates the findings of Livingstone et al. [17] that kidnapping a ship's crew for ransom significantly influences seafarers to change from onboard jobs to shore-based jobs. Even though the study did not proceed to estimate the occurrence probability of kidnapping for ransom, it is identified as a significant effect of pirate attacks on ships affecting crew members (Table 7).

The implication for maritime security governance is that the deployment of shipboard security measures and defense strategies should focus more on averting trauma associated with hostage-taking of crew members, kidnapping a ship's crew for ransom, and injury, which has the highest occurrence probability and likelihood.

Table 8 provides answers to research question (iii) identified in Section 1.1. The table shows the empirical probability coefficients of global pirate attacks on individual ship types between 2011 and 2022. The average empirical probability coefficient, which indicates the occurrence probability of

Table 8. *Empirical probability scores of pirate attacks on individual ship types between 2011 and 2020*

Ship type/year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Average
Accommodation barge	-	0.02	-	-	-	0.005	-	-	-	0.005	0.003
Bulk carrier	0.23	0.15	0.20	0.23	0.35	0.27	0.21	0.29	0.29	0.26	0.24
Cement carrier	-	0.01	-	0.004	-	-	0.006	-	-	-	0.002
Container ship	0.14	0.11	0.11	0.08	0.12	0.05	0.13	0.09	0.12	0.12	0.11
Dredger	0.002	0.01	-	-	-	0.005	-	-	-	-	0.002
Drilling rig/ship	0.002	0.01	-	-	-	-	-	0.005	-	0.005	0.003
FPSO/FSO	-	0.01	-	-	0.008	-	-	-	-	0.005	0.003
General cargo	0.09	0.05	0.07	0.06	0.06	0.06	0.07	0.03	0.04	0.07	0.06
Heavy lift vessel	0.05	0.01	-	0.004	-	0.02	-	0.005	-	-	0.005
Ore carrier	-	0.01	-	-	0.004	0.005	-	0.005	-	-	0.003
Passenger ship	0.002	0.01	-	0.004	0.004	-	-	-	0.006	-	0.003
Pipe layer barge/vessel	-	0.01	-	-	0.004	0.02	-	-	-	0.01	0.005
Pleasure craft	0.002	0.01	-	-	-	-	-	-	0.006	-	0.002
Refrigerated cargo ship	0.009	0.02	0.008	-	0.01	0.005	0.01	0.03	-	0.02	0.01
Research ship	-	0.01	-	0.008	-	0.01	0.01	-	0.006	0.005	0.005
Supply ship	0.002	0.03	0.02	0.01	0.008	0.02	0.04	0.03	0.01	0.04	0.02
Support ship	-	0.01	-	0.004	-	0.005	0.01	0.01	0.006	0.02	0.006
Tanker/asphalt/bitumen	0.002	0.01	0.01	0.02	-	0.005	0.006	0.005	-	0.005	0.006
RORO	0.007	0.02	0.004	0.008	-	-	-	0.01	-	-	0.006
Tanker bunkering	-	0.02	-	0.008	0.004	0.005	0.006	-	-	0.005	0.005
Tanker/chemical/product	0.22	0.20	0.31	0.36	0.23	0.29	0.25	0.25	0.27	0.27	0.26
Tanker-crude oil	0.15	0.10	0.15	0.10	0.07	0.07	0.12	0.08	0.12	0.07	0.11
LNG tanker	-	0.02	-	0.004	-	0.005	0.02	0.02	0.01	0.005	0.007
LPG tanker	0.01	0.04	0.03	0.05	0.06	0.05	0.06	0.03	0.04	0.02	0.04
Trawler fishing	0.03	0.02	0.02	0.01	0.008	0.005	0.006	0.06	0.03	0.03	0.02
Tug/offshore tug	0.07	0.07	0.07	0.03	0.04	0.07	0.06	0.06	0.04	0.04	0.06
Vehicle carrier	0.02	0.01	-	0.008	0.004	0.01	-	0.005	0.01	-	0.008
Yacht	0.009	0.005	-	-	-	-	-	-	0.006	-	0.003
Aggregate probability	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Source: Authors' calculation											

pirate attacks on individual ship types, shows that chemical and petroleum product tankers have the highest likelihood/occurrence probability of pirate attack with a coefficient of 0.26, followed by BC with an occurrence probability coefficient of 0.24. Crude oil tankers and CS each with a probability score of 0.11 have the third-highest likelihood of pirate attacks over the period. This finding indicates that chemical and product tankers, BC, crude oil tankers, and container vessels are the most pirate-targeted ship types. The implication for maritime security governance is that operators of ship types, such as chemical and product tankers, BC, crude oil tankers, container vessels, and general cargo vessels, with the most likelihood of pirate attacks should optimize the implementation of anti-piracy strategies needed to ensure the protection of the ship, trade, and crew against pirate attacks. The implementation of anti-piracy and maritime security measures for such ship types with a higher likelihood of pirate attacks should be intensified. Figure 1 shows the ranking of the individual ship types in decreasing order of likelihood of pirate attacks. The findings of the study are consistent with the findings of Helmick [18] who determined that pirate attacks on individual ship types disrupt supply chain security and could threaten the supply of the commodity types carried by affected ships in global markets.

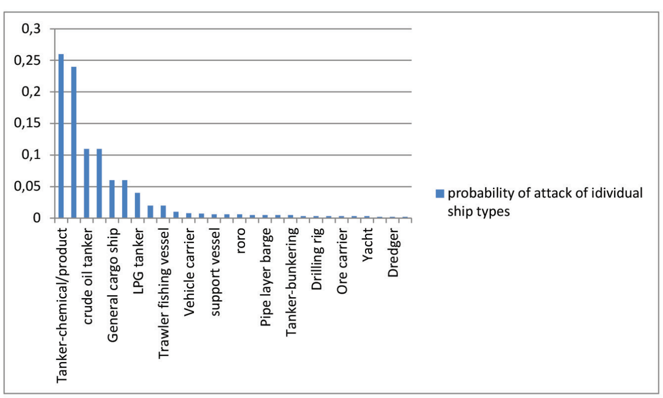

Figure 1. *Ranking of individual ship types in decreasing order of likelihood of pirate attacks*

5. Conclusion

The findings of this study indicate that the empirical probability coefficients of pirate attacks in various sea regions are disproportionate, with Southeast Asian and African waters having the highest occurrence probability scores and being most prone to pirate attacks on ships. Trauma associated with hostage-taking of the ship's crew has the highest occurrence probability coefficient than any other outcome/effect of pirate attacks suffered by the ship's crew, followed by kidnap for ransom with an occurrence probability of 0.15. For individual ship types, chemical and product tankers with an occurrence probability of 0.26 have the highest likelihood of pirate attacks, followed by BC, crude oil tankers, container vessels, GCS, LPG tankers, and TFVs with occurrence empirical probabilities of 0.24, 0.11, 0.11, 0.06, 0.04, and 0.02, respectively. Dredgers have the least likelihood of pirate attacks with an empirical probability of 0.002. The implications for maritime security governance are that sea regions, individual ship types, and outcomes/effects of pirate attacks on seafarers with higher occurrence probabilities should be prioritized when implementing anti-piracy measures. Moreover, the higher the occurrence probability coefficient of pirate attacks, the more the need for stricter implementation of anti-piracy measures in such regions, ship types, and the control of pirate attack outcome/effect types on the crew.

6. Recommendations

For maritime security governance, in the deployment of anti-piracy measures, the maritime zones and individual ship types having the highest occurrence probability scores should be prioritized and focused more upon. The ship's crew should also be trained to guard against the effects of pirate attacks suffered by crew members by prioritizing the deployment of shipboard security and defense mechanism against the outcome types with the most occurrence probabilities and likelihood such as trauma/hostage and kidnap for ransom.

7. Suggestions for Further Studies

Given the empirical probability coefficients determined, further studies must be conducted to forecast and extrapolate the numbers of likely attacks on ships in various regions, individual ship types, and the quantum of kidnapping for ransom, trauma, death of crew members, physical injury, and assault in the future. Further studies will provide information on the deployment of anti-piracy measures to proactively prevent the attacks and the associated effects.

Authorship Contributions

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8. References

[1] International maritime bureau, (IMB, 2020) Piracy and armed robbery against ships. Retrieved from: https://www.icc-ccs.org/reports/2020_Annual_Piracy_Report.pdf. [Accessed on 23/03/2021].

[2] International maritime bureau, (IMB, 2015) Piracy and armed robbery against ships. Retrieved: https://www.hellenicshippingnews.com/wp-content/uploads/2016/02/2015-Annual-IMB-Piracy-Report-ABRIDGED.pdf. Accessed on 23/03/2021.

[3] B. S. Essienand, and T. Adongoi, "Sea piracy and security challenges of maritime business operators in Bayelsa state Nigeria: An Empirical study," International journal of humanities and social science, vol. 5, pp. 213-211, Feb 2015.

[4] I. Martínez-Zarzoso, and S. Bensassi, "The Price of Modern Maritime Piracy," Defense and Peace Economics, vol. 24, pp. 397-418, Oct 2013.

[5] N. E. Ogwo, D. N. Dike, T. C. Nwokedi, and J. C. Mbachu, "The Influence of Economic Growth on Trend of Sea Piracy and Armed Robbery Attacks against Ships in Nigeria," Hmlyn J Human Cul Stud, vol. 3, pp. 21-28, Feb 2022.

[6] K. U. Nnadi, T. C. Nwokedi, I. A. Nwokoro, O. C. Ndikom, G. C. Emeghara, and C. Onyemechi, "Analysis of Maritime Piracy and Armed Robbery in the Gulf of Guinea Maritime Domain," Journal of ETA Maritime Science, vol. 4, pp. 271-287, Oct 2016.

[7] N. J. Ece, and H. Kurt, "Analysis of Maritime Piracy by using Qualitative Methods," Mersin University Journal of Maritime Faculty, Vol. 3, pp. 37-50, Dec 2021.

[8] M. Ahmadi, "Maritime piracy operations: Some legal issues," Journal of International Maritime Safety, Environmental Affairs, and Shipping, Vol. 4, pp. 62-69, Jul 2020.

[9] K. K. Mbekeani, and M. Ncube, "Economic Impact of Maritime Piracy," Africa Economic Brief, vol. 2, Jul 2011.

[10] D. Broohm, "Maritime Security Governance: A New Strategy Management To Avoid Piracy in the Gog And its Legal Guarantee," Advances in Social Sciences Research Journal, vol. 8, pp. 405-437, Oct 2021.

[11] D. Hasan, and S. Hasan, "Effectiveness of the Current Regimes to Combat Piracy in the Gulf of Guinea: An Evaluation," African Journal of Legal Studies, vol. 10, pp. 35-65, Aug 2017.

[12] C. J. Nwalozie, "Exploring Contemporary Sea Piracy in Nigeria, the Niger Delta and the Gulf of Guinea," Journal of Transportation Security, vol. 13, pp. 159-178, Aug 2020.

[13] T. Nwokedi, C. U. Odumodu, J. Anyanwu, and D. Dike, "Frustration-Aggression-Theory Approach Assessment of sea Piracy and Armed Robbery in Nigerian Industrial Trawler Fishery Sub-Sector of the Blue Economy," Journal of ETA Maritime Science, vol. 8, pp. 114-132, Jun 2020.

[14] N. A. Knyazeva, and A. I. Korobeev, "Maritime terrorism and piracy: The threat to maritime security," Mediterranean Journal of Social Sciences, vol. 6, pp. 226-232, Nov 2015.

[15] N. J. Ece, (2012). "The Maritime Dimension of International Security: Piracy Attacks", in Uzuner, F.,B. (Ed), NATO Science for Peace and Security Series - E: Human and Societal Dynamics, Maritime Security and Defense Against Terrorism, IOS Press, Amsterdam, Netherlands pp. 33-49.

[16] Ü. Özdemir, and A. Güneroğlu, "Quantitative Analysis of the World Sea Piracy by Fuzzy AHP and Fuzzy TOPSIS Methodologies" International Journal of Transport Economics, vol. 44, pp. 427-448, 2017.

[17] D. C. Livingstone, L. Justin, A. Mawuli, and B. Mazen, "Global maritime piracy: Impact on seafaring and the factors shaping confrontational outcomes," Journal of Transportation Security, vol. 14, pp. 307-324, Dec 2021.

[18] J. S. Helmick, "Maritime Piracy and the Supply Chain," Global Supply Chain Security, pp. 17-34, 2015.

[19] B. L. Coggins, "Global patterns of maritime piracy, 2000-09: Introducing a new dataset," Journal of Peace Research, vol. 49, pp. 605-617, Jul 2012.

[20] T. C. Nwokedi, and K. U. Nnadi, "Estimating the Theoretical and Empirical Probability Coefficients of Oil Pipeline Transport Infrastructure Failure Modes in Nigeria's Coastal Ecosystem: Panacea for Non Optimal Deployment of Pipeline Safety and Security Management Systems," LOGI– Scientific Journal on Transport and Logistics, vol. 9, pp. 35-50, 2018.

[21] M. Flückiger, and M. Ludwig, "Economic shocks in the fisheries sector and maritime piracy," Journal of Development Economics, vol. 114, pp. 107-119, May 2015.