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Optimizing Maritime Security Strategies: A Methodological Approach Using AHP and SWOT

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Abstract:

Purpose: *The purpose of this paper is to propose the enhancement of SWOT analysis with multicriteria decision-making technique (AHP). Therefore, the goal of applying this combined method is to improve the quantitative aspect of strategic planning regarding the best possible decision-making in the process of providing maritime security services in an unstable geoeconomic and geopolitical environment.*
Design/Methodology/Approach: *Initially, a detailed presentation of the Strengths, Weaknesses, Opportunities and Threats is made and reflected in the relevant SWOT table. The AHP approach then achieves pairwise comparisons between factors and sub-criteria SWOT in order to prioritize them using eigenvalue calculation.*
Findings: *Conclusions are drawn from this analysis regarding the weighting in relation to the priority of each SWOT group. Thus, it is then concluded which factor from a particular group is the most important due to the highest Overall Priority of Factor. And, of course, this analysis also gives us the ranking in priorities of the other factors based on the Overall Priority Factor. In addition, this analysis enables us to assess the consistency of our findings.*
Practical implications: *The practical implications relate primarily to the possibility for Law Enforcemnts Agensies/Naval Forces and Shipping Companies as well to use the methodology in question in effective decision -making management, in order to optimize Maritime Security Strategies.*
Originality/Value: *The contribution is twofold: First, using SWOT's calculations of factors and sub-criteria, an approach could be implemented regarding the support and documentation of critical decisions at strategic and operational level, since each qualitative element acquires a quantitative dimension in dealing with shipping risks and threats. Second, the results of the work could be used to synthesize a set of appropriate alternative strategies to protect international shipping activity in high-risk areas given geopolitical and geo-economic conditions.*

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1. Introduction

This paper examines the combined application of SWOT methodology and Analytical Hierarchical Procedure – AHP, based on which the multicriteria dimension of Maritime Security as a pillar of Geopolitical/Geoeconomic component of international maritime transport is highlighted. In particular, the following are highlighted:

The SWOT analysis is possible to produce an analysis of the qualitative characteristics of geopolitical, geoeconomic and maritime security osmosis, which are grouped according to their origin into characteristics related to the internal environment of international maritime activity and characteristics related to its external environment, such as geopolitical and geoeconomic data on sea routes. threats and opportunities at specific times.

However, the SWOT approach does not rank characteristics / factors based on importance, so their analysis won't lead us to the best possible strategic planning result.

Thus, taking into account the aforementioned fact (the lack of specification of the importance ranking for SWOTs in relation to the geopolitics and geoeconomics of maritime security), the purpose of this paper is to propose the reinforcement of SWOT analysis with multicriteria decision-making technique and in particular with that of the Analytical Hierarchy Process (AHP) (Kharti and Metri, 2016), in order to compare the best possible strategies and to weigh/prioritize alternative

actions/strategies. Therefore, the Analytical Hierarchical Process is a tool through which the weaknesses of SWOT analysis are mitigated and reduced (Kurtilla *et al.,* 2000).

2. Literature Review

The analysis of Strengths, Weaknesses, Opportunities and Threats (SWOT) is a widely used tool that examines Strengths and Weaknesses (internal factors) of a particular activity together with Opportunities and Threats (external factors) of the environment in which it is an actor (Houben *et al.,* 1999, Kangas *et al.,* 2001, 2003).

SWOT analysis gathers and organizes information regarding the external and internal environment of an organization within which it operates immediately and, in the future, (Osuma and Aranda, 2007). Another model of SWOT analysis is Threats, Opportunities,Weaknesses, and Strengths (TOWS) Strategic Alterative Matrix (Table 1).

Table 1. *Strategic Alternative Matrix*

	Internal Strengths (S)	Internal Weaknesses (W)
External Opportunities (O)	SO: "Maxi-Maxi" Strategy. Strategies thatuse strengths to maximize opportunities	WO: "Mini-Maxi" Strategy. Strategies that minimize weakness by taking advantage of opportunities
External Threats (T)	ST: "Maxi-Mini" Strategy. Strategies that use strengths to minimize threats	WT: "Mini-Mini" Strategy. Strategies that minimize weakness and avoid threats

Source**:** *Weihrich (1982)*

AHP was introduced by Saaty in 1980 (Saaty, 2003; 2008) and is one of the most effective tools for making complex decisions. Thus, this multicriteria methodology can facilitate the decision-maker by categorizing and prioritizing the building blocks of a problem by comparing them in pairs and then synthesizing them into a single result (Triantaphyllou and Mannn, 1995). Therefore, the aim of applying this combined method is to improve the quantitative aspect of strategic planning in relation to the subject matter in question (Tuzmen and Sipahi, 2011; Saaty and Vargas, 1996).

According to Saaty, making decisions in a hierarchical way should disintegrate the decision-making process into the following steps (Saaty, 2003):

- Clear description of the problem to be decided.
- Prioritization of issues, starting from the top, where the goal for which the decision is sought to be taken will be set.

- Then, at the intermediate level, the criteria that are directly related to the decision-making will be placed and at the lower level the sub-criteria or alternative scenarios that exist will be set (see ANNEX).
- A Table comparing the criteria in pairs is then constructed. This Table is completed based on the Evaluation System for Pairwise Comparisons (Table 3).
- Finally, the weightings/weights/priorities of each criterion for the final goal of making the decision are calculated, as well as the weighting of each alternative scenario for each of the criteria set and related to the decision-making.

In addition, the AHP (Analytical Hierarchical Process) facilitates the identification of interdependencies between factors, thereby enhancing the understanding of complex socio-technical systems in the maritime industry. Leveraging the insights gained from AHP, organizations can develop resilience strategies that monitor, respond, learn, and anticipate threats, ensuring a robust defense against potential challenges (Patriarca *et al.,* 2017).

3. Reseaarch Methodology

Initially, a detailed presentation of the Strengths, Weaknesses, Opportunities and Threats is made and reflected in the relevant SWOT Table. The AHP approach achieves pairwise comparisons between factors or criteria in order to prioritize them using the eigenvalue calculation. In particular, the whole methodology follows three steps:

The first step aims to identify the most important internal (strong and weak) and external (opportunities and threats) factors for strategic planning, which make up the SWOT analysis.

In particular, in relation to the Strengths, the following are mentioned:
Risk and Threat Assessments, Planning of a Shipping Company or Port Infrastructure Management Organization to deal with risks and threats, Measures for the protection of ships and/or ports (critical infrastructure) and Use of Modern Technology.

In relation to Weaknesses, the following are mentioned:
Cost of route diversion, Cost of repairing damages in case of implementation of threats, Cost for design and implementation of protection measures, Operation in adverse Geopolitical and Geoeconomic environment.

In relation to Opportunities, the following are mentioned:
International Partnerships of Law Enforcement Bodies at Sea, International Institutional Framework, Strategic and Operational Intelligence Diplomatic initiatives.

Regarding Threats, the following are highlighted:
Piracy, Attacks, Crew kidnapping, Terrorist acts, Consequences on the normal operation of the supply chain and inflationary pressures, Proliferation of weapons of mass destruction, Transportation of narcotic substances.

In the second step, comparison pairwise takes place in order to draw conclusions about the weights/weights of each SWOT team (Strengths, Weaknesses, Opportunities, Threats).

In the third step, the use of the Analytical Hierarchical Process gives us the relative priorities for each SWOT actor (i.e., elements characterizing Strengths, Weaknesses, Opportunities and Threats, e.g., S1, S2, … Sn.. W1, W2,.. Wn.. O1, O2.. On,.. T1, T2… Tn.). Then the total degree of gravity/weighting of the factor is obtained by multiplying the weights / weights of the individual factors by the weighting factor/weighting of the specific group.

This analysis is expected to draw conclusions regarding the weighting/weighting regarding the priority of each SWOT group. (Strengths, Weaknesses, Opportunities, Weaknesses and Threats). So, then we can draw a conclusion about which factor from a particular group is the most important due to the highest Overall Priority of Factor. And, of course, this analysis also gives us the ranking in priorities of the other factors based on the Overall Priority Factor. In addition, this analysis enables us to assess the consistency of our findings.

The implementation of the Analytical Hierarchy Process (AHP) in maritime safety using SWOT provides a structured approach to prioritize various factors affecting security measures. By using the AHP, actors involved in the provision of maritime safety services as well as actors in the maritime industry can systematically assess multiple criteria and sub-criteria affecting maritime safety. This prioritization allows decision-makers to allocate resources more efficiently and focus on critical vulnerabilities.

It should be noted in relation to the above coefficients that intermediate values of 2,4,6,8 indicate a compromise, while the inverse values of all weighting values mean that if, for example, criterion S compared to criterion W gets the value 2 or 3, then criterion W compared to criterion S gets the value 1/2 or 1/3.

The next figure illustrates the composition of the SWOT table and the process of the Analytical Hierarchical Process which offers us the possibility of a) breaking down the information into a hierarchy of alternatives and criteria, b) synthesizing the information to define the relative arrangement of the sub criteria and c) the information can be compared in order priorities to be determined.

Table 2. *SWOT Matrix of the Maritime Security issue*

Internal Environment	
STRENGTHS	WEAKNESSES
S1. Risk and Threat Assessments S2. Planning of a Shipping Company or Port Infrastructure Management Organization to address risks and threats, S3. Measures for the protection of ships and/or ports (critical infrastructure) S4. Use of Modern Technology S5. Staff / Crew Training	W1. Diversion cost W2. Cost of repairing damages in case of threats occurring W3. Cost for planning and implementation of protection measures W4. Operating in an unfavorable or unstable Geopolitical and Geoeconomic environment W5. Increased energy cost W6. Increased risk premiums W7. Increased labor costs in HRA (High Risk Areas)
External Environment	
OPPORTUNITIES	THREATS
O1. International Collaborations of Law Enforcement Bodies at Sea, O2. International Institutional Framework, Strategic and Operational Intelligence O3. Diplomatic Initiatives	T1.Piracy T2. Attacks T3. Crew kidnapping, T4. Manifestation of terrorist acts T5. Consequences for the normal operation of the supply chain and inflationary pressures. T6. Proliferation of weapons of mass destruction T7. Drugs Trafficking and Transportation

Source: *Own study.*

Table 3. *Saaty's Intensity of Importance*

Intensity of Importance	Definitions
1	Equally important
3	Moderately more important
5	Much More important
7	Immenesely more importantEntitely more important
9	Entirely more important
2,4,6,8	Interior values

Source: *Saaty, T.L.(1980)*

3.1 Pairwise Comparisons of SWOT Matrix Criteria- Normalized Arithmetic Mean Method

Table 4. *Pairwise Comparisons of SWOT Matrix Criteria*

GOAL: Maritime Security in Modern Geopolitical and	**STRENGHTS**	**WEAKNESSES**	**OPPORTUNITIES**	**THREATS**

Geoeconomic Environment				
STRENGHTS	**1**	**5**	**2**	**4**
WEAKNESSES	**1/5**	**1**	**½**	**½**
OPPORTUNITIES	**½**	**2**	**1**	**2**
THREATS	**¼**	**2**	**½**	**1**

Source: *Own study.*

The analysis is carried out by using the Octave software for the necessary calculations as follows:

$$A=\begin{pmatrix} 1 & 5 & 2 & 4 \\ 1/5 & 1 & ½ & ½ \\ ½ & 2 & 1 & 2 \\ ¼ & 2 & ½ & 1 \end{pmatrix} \qquad A^2=\begin{pmatrix} 4 & 22 & 8,5 & 14,5 \\ 0,775 & 4 & 1,65 & 2,8 \\ 1,9 & 10,5 & 4 & 7 \\ 1.15 & 6.25 & 2.5 & 4 \end{pmatrix}$$

Sum of each row A^2:
49
9,225
23,4
13,9
95,525
Normalization of the sum
0,512
0,096
0,245
0,147

Consequently, the results obtained show that:
STRENGHS are the most important criterion with 51.2%
OPPORTUNITIES are the second important criterion 24.5%
THREATS are the third important criterion with 14.7%
WEAKNESSES are the fourth important criterion with 9.6%

However, the CI (Consistency Index, Saaty 1980) should be calculated in relation to the results obtained, i.e. whether the results of the paired comparisons are continuous.

This indicator shall be calculated as follows: CI= $(\lambda max-n)/(n-1)$, where λmax is the maximum eigenvalue of the criteria comparison matrix (=A).

Calculation of λmax:

$$A=\begin{pmatrix} 1 & 5 & 2 & 4 \\ 0{,}2 & 1 & 0{,}5 & 0{,}5 \\ 0{,}5 & 2 & 2 & 2 \\ 0{,}250 & 2 & 0{,}5 & 1 \end{pmatrix}$$

From the mentioned Matrix is calcuated the sum of each column and the columns are normilized:

0,51	0,50	0,50	0,53
0,10	0,10	0,125	0,07
0,26	0,20	0,25	0,27
0,13	0,20	0,125	0,13

The Average of each row is then calculated:

$$W=\begin{pmatrix} 0{,}510 \\ 0{,}090 \\ 0{,}245 \\ 0{,}146 \end{pmatrix}$$

Then, is calculated thw product A*W

$$A*W=\begin{pmatrix} 2{,}0340 \\ 0{,}3875 \\ 0{,}9720 \\ 0{,}5760 \end{pmatrix}$$

We divide each AW element by its W counterpart, and we have:

2,034/0,510= 3,988
0,3875/0,090= 4,306

Similarly, and for the rest :
3,967
3,945

Mean: 4,0515 = λmax
Consequently, CI = (4,0515-4)/ (4-1) = 0,0171

In order to confirm if this result is acceptable, the consistency ratio (=CR) given by the formula CR=CI/RI must be calculated, where RI (random consistency index) is the indicator of randomly generated weights, and its values are given as:

Table 5. *Random Index*

n	1	2	3	4	5	6	7	8	9	10
RI	0,00	0,00	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

Source: *Saaty and Forman (1993).*

This Table came about as follows: Saaty created iterative tables of binary comparisons whose elements were chosen at random from the values of the "fundamental scale" (1/9, 1/8, 1/7.... 1,2 ... 8,9). The average consistency index (CI) of these random tables is the "random consistency index" (RI). A CR value of 0,1 or less is acceptable. In this case the CR is 0.0171/0.90= 0.019. So, the results are acceptable because CR < 0.1.

3.2 AHP to STRENGHS (Pairwise Comparisons of STRENGTHS Sub-Criteria)

In order to make pairwise comparisons of the sub criteria of STRENGTHS, WEAKNESSES, OPPORTUNITIES and THREATS respectively, the MATLAB software is used with the eigenvalue method for the tables of pairwise comparisons.

The steps are as follows:

- The comparison table is initially inserted,
- The eig command is then used to find all eigenvalues and corresponding eigenvectors of this array. In this step the software returns to us all eigenvalues in the comparison table in the variable values. Each column contains a number (the rest are zeros), which is one of the eigenvalues. We keep the largest of the real eigenvalues (hence λmax). We also do not consider complex eigenvalues. So, in the following comparisons we are interested in the eigenvector which is the first column of the vectors table.
- We will normalize this vector and thus the weights/ priorities are being derived using the command: weights =vector(:,1)/sum(vector(:,1),1)
- The degree of consistency of the comparisons made is calculated, using the appropriate RI from the above mentioned Saaty RI table.

Table 6. *Pairwise comparisons of STRENGTHS sub-criteria*

STRENGHS	Risk and Threat Assessments	Planning to address risks and threats	Protection measures for Ports / Ships	Use of Modern Technology	Staff/Crew Training
Risk and Threat Assessments	1	1/2	1/5	1/2	1/6
Planning to address risks and threats	2	1	1/6	1/5	1/6
Protection measures for Ports / Ships	5	6	1	3	2
Use of Modern Technology	1	5	1/3	1	1/5
Staff/Crew Training	6	6	1/2	5	1

Source: *Own study.*

Results

Calculations by MATLAB software result that the sub criterion: Measures for the protection of ships and/or ports (critical infrastructure) has the highest weight/ priority (40.07%), followed by Staff Training sub criterion (35.52%,) while the weighting scores for the rest of the sub-criteria are the following: Use of Modern Technology (12,96%), Planning encountering Risks and Threats (6,02%) and Risk and Threat Assessment (5,42%) respectively.

Furthermore, the results are acceptable as CR = 0,0724.

3.3 AHP to WEAKNESSES (Pairwise comparisons of sub-criteria of WEAKNESSES)

Table 7*. Pairwise comparisons of sub-criteria of WEAKNESSES*

WEAKNESSES	Diversion cost	Cost of restoring damages in case of threats occurring	Costs for planning and implementation of protection measures	Operating in an unfavorable or unstable Geopolitical and Geoeconomic environment	Increased energy cost	Increased risk premiums	Increased labor costs in HRA
Diversion cost	1	3	1/5	1/5	1/2	1/4	1/2

Cost of restoring damages in case of threats occurring	1/3	1	1/6	1/6	1/2	1/5	1/2
Costs for planning and implementation of protection measures	5	6	1	1	6	2	7
Operating in an unfavorable or unstable Geopolitical and Geoeconomic environment	5	6	1	1	6	2	7
Increased energy cost	2	2	1/6	1/6	1	1/5	1/2
Increased risk premiums	4	5	1/2	1/2	5	1	7
Increased labor costs in HRA	2	2	1/7	1/7	5	1	7

Source: *Own study*

Results

Calculations by MATLAB software result that the sub criterion: Cost for planning and implementation of protection measures & Operation in an unfavorable or unstable Geopolitical and Geoeconomic environment, have the highest weight (29.64%) followed by the sub-criterion: Increased risk premiums by 21%., Increased Labor Costs in HRA (6,03%), Increased energy cost (5,27%), Diversion Cost (5,09%) and Cost of restoring damages in case of treats occurring (3,33%) respectively.

Furthermore, the results are acceptable as CR = 0,0731<1.

3.4 AHP to OPPORTUNITIES (Pair-wise comparisons of OPPORTUNITIES sub -criteria)

***Table 8**. Pair-wise comparison of OPPORTUNITIES sub- criteria*

OPPORTUNITIES	International Law Enforcement Cooperation at Sea	International Institutional Framework	Diplomatic Initiatives
International Law Enforcement Cooperation at Sea	1	2	3
International Institutional Framework	1/2	1	2
Diplomatic Initiatives	1/3	1/2	1

***Source:** Own study*

Results

Calculations by MATLAB software result that the sub criterion: International Law Enforcement Cooperation at Sea has the highest weight /priority (53.96%), followed by the sub criterion: International Institutional Framework, Strategic and Operational Intelligence (29.7%). respectively. The results are acceptable as CR=0,0079<0,1.

3.5 AHP to THREATS (Pair-Wise comaprisons of THREATS sub-criteria)

***Table 9**. Pair-wise comparisons of THREATS sub -criteria*

THREATS	Piracy	Attacks	Crew Kidnapping	Manifestation of terrorist acts	Consequences for the normal operation of the supply chain and inflationary pressures.	Proliferation of weapons of mass destruction	Transportation of narcotic substances
Piracy	1	1/3	2	1	1/3	1/2	1/2
Attacks	3	1	1	2	4	3	1
Crew kidnapping	1/2	1	1	1	1/2	1	1/3

Manifestation of terrorist acts	1	1/21	1	1	3	1	1/2
Consequences for normal operation of the supply chain and inflationary pressures.	3	1/4	2	1/3	1	1/5	1/5
Proliferation of weapons of mass destruction	2	1/3	1	1	1	1	1/3
Transportation of narcotic substances	2	1	3	2	2	3	1

Source: *Own study*

Results

The sub criterion: Assaults, has the highest weight (24.09%), followed by the sub criterion: Transport of Narcotic Substances (22.92%).
The results are acceptable as CR= 0.077<0,1

Table 10*. Overall Priority Scores of SWOT Factors*

SWOT GROUP	SWOT GROUP Priorities	Sub-Criteria	Priority weightings of each sub criterion within SWOT groups	Overall weighting of priorities for each sub-criterion
STRENGHTS	**0,510**	Risk and Threat Assessments	0,0542	0,028
		Shipping company planning to address risks and threats	0,0602	0,03
		Taking measures for the protection of ships and /or of critical port infrastructures	**0,4007**	**0,20**
		Use of Modern Technology	0,1296	0,067
		Staff training	0.3552	0,18
WEAKNESSES	**0,090**	Diversion cost	0,0509	0,0046

		Cost of restoring damages in case of threats occurring	0,0333	0,003
		Cost planning and implementation of Protection measures	**0,2964**	**0,026**
		Operating in an unfavorable or unstable Geopolitical and Geoeconomic environment	**0,2964**	**0,026**
		Increased energy cost	0,0527	0,0047
		Increased risk premiums	0,21	0,02
		Increased labor costs in HRA	0,0603	0,0054
OPPORTUNITIES	**0,245**	International Collaborations of Law Enforcement Agencies at Sea	**0,5396**	**0,13**
		International Institutional Framework, Strategic and Operational Intelligence	0,297	0,073
		Diplomatic initiatives	0,1634	0,04
THREATS	**0,146**	Piracy	0,0921	0,013
		Attacks	**0,2409**	**0,035**
		Crew kidnapping	0,0989	0,014
		Manifestation of terrorist acts	0,1262	0,02
		Impact on the normal functioning of the supply chain and inflationary pressures	0,0976	0,014
		Proliferation of weapons of mass destruction	0,1152	0,017
		Transportation of narcotic substances	0,2292	0,033

Source: *Own study*

The results of the last column of the table 10 are obtained by multiplying the priorities of SWOT elements by the respective weights of priorities within the SWOT teams. For example, 0.028 is derived from the product 0.510*0.0542=0.028.

The results presented in the Table above lead to the following conclusions:

- Regarding the criteria / in each SWOT group, the most weight/priority is given to STRENGTHS (51%), followed by OPPORTUNITIES (24.5%), THREATS (14.6%) and WEAKNESSES (9%).
- Regarding the sub-criteria in SWOT, the greatest weight and priority/importance is the Taking of Measures for the protection of ships and/or critical port infrastructures with 20% in the STRENGHS criterion.
- Other sub-criteria that are relevant in terms of their weight in the overall weighting of priorities of each sub-criterion in order are International Partnerships of Law Enforcement Agencies at Sea (13%) in the criterion OPPORTUNITIES, followed by the sub-criterion Attacks (3.5%) in the criterion THREATS and in the same ranking are the sub-criteria: Cost for design and implementation of protection measures & Operation in an

unfavorable or unstable Geopolitical and Geoeconomic environment (2.6%) of the criterion WEAKNESSES.

However, methodologically, the results from the Benefit-Cost analysis should be examined (if we indicatively set the costs in monetary units, Table 11), as these results should be ultimately taken in account concerning the rankings of priorities for the planning of policies and strategies for making final decisions.

Table 11. *Calculation of Benefit-Cost ratio*

SWOT Sub Criteria	Priorities	Cost in Monetary Units	Normalization Cost	Benefit-Cost Analysis (Priorities/Cost Normalization)
Taking measures for the protection of ships or critical port infrastructures	0,20	550	0,164	1,219
Costs for planning and implementation of protection measures	0,026	500	0,149	0,174
Operating in an unfavorable or unstable Geopolitical and Geoeconomic environment	0,026	700	0,208	0,125
International Collaborations of Law Enforcement Agencies at Sea	0,13	850	0,254	0,518
Attacks	0,035	750	0,224	0,156

Source: *Own study.*

Thus, it finally emerges that the Taking of Protection Measures for ships or critical port infrastructure, is preferred as the first priority since it presents the largest Benefit-Cost ratio (1,219), while in second place is the Cost for Planning and Implementing protection measures with a Benefit-Cost ratio (0,174).

4. Conclusions

1. The implementation of the multicriteria decision-making method AHP in combination with SWOT, is a useful tool since from this analysis conclusions are drawn about the gravity / weighting regarding the priority of each SWOT group. (Strengths, Weaknesses, Opportunities, Weaknesses and Threats) and alternative scenarios/sub-criteria, directly related to the issue of Maritime Security.

2. We can then draw conclusions about which factor in a particular group is the most important due to the higher overall priority score. Subsequently, this analysis also gives us the ranking in priorities of the other factors / sub-criteria based on the Overall Priority Factor.

3. However, this analysis also enables us to assess the consistency of our findings. Thus, the results could be used to synthesize a set of appropriate alternative strategies for the protection of international shipping activity in high-risk areas given the geopolitical and geo-economic conditions, both by state or international bodies and even by shipping companies operating on these (high-risk) sea routes.

4. Finally, the possibility of calculating the benefit-cost ratio highlights the priorities and weights of alternative strategies/actions directly related to maritime security.

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ANNEX

Figure: *AHP & SWOT in Maritime Security*