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Ranking Seafarers' Duties towards Unmanned and Autonomous Ships in Prospective of STCW

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المستخلص

تشهد صناعة النقل البحري تحولاً جذرياً في أدوار و قدرات العاملين في البحار بسبب الإبتكار التكنولوجي السريع نحو السفن غير المأهولة والمسيّرة ذاتيًا. تُعد هذه التطورات تحولًا أساسيًا يؤثر بشكل جوهري على الطريقة التي يشارك بها البحارة في أدوارهم ومهامهم ومسؤولياتهم على متن تلك السفن. لذلك، أحدثت التقنيات الناشئة والأتمتة والرقمنة ثورة في العمليات البحرية التقليدية، مما أدى إلى ضرورة إعادة تقييم الكفاءات والمهارات اللازمة للبحارة. تمتاز هذه السفن بأنها مجهزة بأنظمة تحكم معيارية متقدمة وتكنولوجيا اتصالات عن بُعد متطورة؛ لم تستحوذ هذه السفن على خيال المجتمع البحري العالمي فحسب ، بل إستدعت أيضًا أعتبارات تنظيمية عاجلة من قبل المنظمة البحرية الدولية (IMO). بالإضافة إلى ذلك، تحمل الأتفاقية الدولية لمعايير التدريب والإجازة (إصدار الشهادات) والخفارة (النوبات الملاحية) للملاحين علي ظهر السفن (STCW) أهمية مركزية وموقرة تضمن أمتلاك البحارة المعرفة والمهارات والكفاءات اللازمة لأداء واجباتهم بشكل مؤثر وأكثر فعالية.

ومع ذلك، تنبثق نقص المعايير النموذجية الخاصة باتفاقية STCW والمصممة بشكل دقيق لمعالجة السفن غير المأهولة والمسيّرة ذاتيًا، مما يدفع إلى إجراء فحص نقدي وتحليل عميق لأدوار وقدرات البحارة في هذا السياق المتطور. وبالتالي، يُهدف هذا البحث إلى تصنيف واجبات البحارة تجاه السفن غير المأهولة والمسيّرة ذاتيًا في ظل غياب الإرشادات ضمن اتفاقية STCW وذلك من خلال تحليل AHP حيث تظهر النتائج أن إدارة تلك السفن تُعتبر العامل الأكثر أهمية.

ABSTRACT

The maritime industry is experiencing a transformative shift in seafarer roles and capabilities due to rapid technological innovation towards unmanned and autonomous ships. This evolution is fundamentally altering the way seafarers engage with their roles, tasks, and responsibilities onboard ships. Therefore, emerging technologies, automation, and digitalization have revolutionized traditional maritime operations, leading to a reevaluation of the competencies and proficiencies required of seafarers. These ships are equipped with sophisticated modular control systems and cutting-edge remote communication technology; these vessels have not only captured the global maritime community's imagination but have also necessitated urgent regulatory considerations by the International Maritime Organization (IMO). In addition, the Standards of Training, Certification, and Watchkeeping (STCW) Convention holds a central and time-honored significance to ensure that seafarers possess the necessary knowledge, skills, and competencies to perform their duties effectively.

However, the lack of specific STCW guidelines precisely tailored to address unmanned and autonomous ships prompts a critical and introspective examination of the roles and capabilities of seafarers in this evolving context. Hence, this paper aims to rank the duties of seafarers towards unmanned and autonomous ships in the absence of guidelines within STCW through AHP analysis. The results show that ship management is deemed the most important factor.

Keywords: Unmanned ships, Autonomous ships, STCW, Seafarers

1. Introduction

The maritime sector is experiencing a significant rise in automation and digitalization, with a growing focus on the development and interest in unmanned, remotely controlled, and autonomous vessels (Porathe et al., 2018). This wave of technological advancement is closely tied to the ongoing reevaluation of the STCW convention. The evaluation is essential to delineate the competencies and capabilities skills that will be essential for seafarers in future ship operations within the realm of autonomous shipping. It necessitates careful consideration of how seafarers' roles and duties will be shaped and enhanced in the context of unmanned and autonomous vessels (Ringbom, 2019).

Simultaneously, the introduction of autonomous ships presents legal challenges and questions regarding how seafarers' duties will be redefined and what adaptation will be required in international and national regulations. As these ships become a reality, understanding how the legal framework can effectively accommodate and regulate their use while upholding the rights and responsibilities of seafarers is paramount. Moreover, integrating safety measures and ensuring compliance with conventions like the Convention for Safety of Life At Sea (SOLAS) are vital elements in aligning the deployment of autonomous ships with seafarers' duties and maintaining a high standard of maritime safety.

Each state must effectively exercise its authority over administrative, technical, and social issues and take the required steps for ships flying their flag to maintain maritime safety. A law stipulates that every vessel must have a master and officers who are trained in maritime, navigation, communications, and engineering. These specifications were acknowledged by flag nations for conventional ships. These flag states responsibilities were undoubtedly established for traditional ships with a master and his crew. However, in the context of Maritime Autonomous Surface Ships (MASS), these criteria may pose significant challenges regarding seafarers' duties and capabilities, demanding a reevaluation within the framework of STCW. There are some issues with how these clauses are interpreted in relation to unmanned ships. The most severe view would be that unmanned ships are prohibited because there is no qualified master and officers present, making them unlawful. Then, it is up to the flag state to forbid the unmanned ships. It would not be advisable to accept this interpretation because it is the most antiquated (Boviatsis et al., 2022). This integration of legal perspectives and evolving technologies necessitates a careful examination of how seafarers' roles align with the changing landscape of maritime autonomy under the context of STCW.

Because there is no longer a need for the master and officers to be in command of an autonomous ship, this might be a potential resolution. As a result, the clause referring to this particular responsibility would no longer be applicable. For unmanned and autonomous ships in particular, this interpretation would be the most intriguing. Another option is for the Shore Control Center (SCC) to interpret these responsibilities by analogy. According to this view, the ship's operator would be regarded as the master, and he would be required to fulfill the obligations and responsibilities of a master. However, a shore-based vessel controller's duties will likely differ from those of the ship's master. Additionally, given the radically different working environment and circumstances, it would not be the ideal approach to merge the shore-based ship controller with the ship's master when considering the various responsibilities in other conventions (Van Hooydonk, 2014).

The significance of Maritime Autonomous Surface Ships (MASS) concerning the competence criteria of seafarers at a global level should not be underestimated. As we transition towards highly automated, remotely controlled, or autonomous solutions, the established routines of ship operations and the roles, duties, and responsibilities of key shipboard senior staff will undergo radical transformation compared to traditional shipboard organization (Kitada et al. 2018). The continuation of these roles might even be at risk (Sharma et al. 2019). The manner in which ships and their seafarers adapt to these evolving work dynamics holds critical implications for the safety and dependability of ship operations. The knowledge, skills, and ability (KSA) as stipulated in the STCW, which have historically ensured safe and efficient operations, may not retain the same relevance or effectiveness with increased automation (Sharma et al. 2019). Thus, it is imperative to re-identify and ranking the STCW duties in this new context to effectively harness the potential of autonomous shipping.

Based on the demonstrated deficiency in STCW guidelines regarding unmanned and autonomous ships, the current study aims to rank the duties and capabilities of seafarers towards unmanned and autonomous ships in view of STCW by applying AHP analysis.

2. The Legal Status of an Unmanned and Autonomous Merchant Ship

First, the IMO disclosed the results of the regulatory scope research for using maritime autonomous surface ships (MASS), which were released on June 3, 2021, and which defined Degrees of Autonomy to be four degrees, namely (IMO, 2021)

1. **Degree One**: despite some operations being automated and unattended, seafarers remain present on board and in charge of the vessel's operation and navigation.
2. **Degree Two**: crew staff aboard remotely operated ships have the ability to operate the ship entirely from an SCC, giving them complete control.
3. **Degree Three**: ships that can be remotely operated but have no crew members aboard—operation of the ship from an SCC without workers.
4. **Degree Four**: without the aid of an SCC, a fully autonomous ship's operating system is suitable for independent navigation and operation.

On November 21, 2021, the IMO published the fifth iteration of the MASS UK Industry Conduct Principles and Code of Practice. This version divided six degrees of automation into the same levels amount (UK INDUSTRY, 2021):

- **Level 0**: When a crew on board controls each phase of navigation, including vessel command, monitoring and reacting to the navigational environment, and executing dynamic navigation tasks as a backup, there is no need for automation. Because of this, there is no remote control of any type, and all mechanical parts, including radar, are used to facilitate navigation, which is only done by the ship's master.
- **Level 1**: the ship's master is in charge of the remaining navigational responsibilities and is predicted to watch for and respond to any threats while the steering automation system steers the vessel with steering assistance.
- **Level 2**: In the case of partial automation, a navigation automation system directs the automation and steering of the ships. The remaining navigating duties and keeping an eye on the system are the shipmaster's responsibility. Up to this level, the ship's navigation is not done using remote controls (incorporating Degree 1 of the IMO's previous study).
- **Level 3**: When a navigation system, like as collision avoidance, is used conditionally, the shipmaster is still available to intervene and address any issues that may occur. After this level, installing remote-control systems is viable with no change to the minimum labor or qualification requirements (incorporating Degree 2 of the IMO's previous study).
- **Level 4**: High automation, where the navigation automation system performs all dynamic navigational activities, including backup procedures, immediately and without awaiting the shipmaster's response. Only specific navigational elements require human involvement (incorporating Degree 3 of the IMO's previous study).
- **Level 5**: whereby the navigation automation system handles and fully automates all dynamic navigation duties (incorporating Degree 4 of the IMO's previous study).

The navigation automation system aids the ship's navigation in the first three stages of automation because it is obvious that the vessel does not have a remote control fitted (Poornikoo, 2022). Any navigational mistakes are therefore solely the ship's master's fault. Because the ship's master is eventually accountable for responding to system issues, the third degree of automation is necessary even though the navigation is performed by the installed navigation automation system. When a ship is automated to Level 4, the navigation automation system is accountable, and the master is solely responsible for the specific navigational tasks that have been assigned to them. At this point, responsibility is only transferred to the SCC. At Level 5, there is also no risk related to the human element. Only those automated systems that are specifically designed for ships (Choi, 2022).

3. Adapting Seafarer Roles in the Era of Evolving Maritime Operations

The maritime industry is witnessing a transformative shift in the dynamics of seafarer roles and responsibilities within the realm of maritime operations. Traditionally, seafarers have been the linchpin of ship operations, responsible for a multitude of tasks vital for safe and efficient maritime transportation. However, with the integration of advanced technologies and the emergence of autonomous shipping, the nature of seafarer roles is evolving. Automation and digitalization are reshaping the functions aboard ships, challenging the conventional reliance on a significant human presence for operation. Seafarers are now expected to adapt to and integrate with automated systems, necessitating a shift in their competencies and skill sets. They are becoming operators of sophisticated technologies, coordinators of autonomous systems, and overseers of safety measures. This evolution demands a proactive approach to revising training, certification, and operational frameworks, as outlined by the STCW convention. The STCW needs to reflect these changing dynamics, ensuring that seafarers are adequately prepared and capable of navigating this new era of maritime operations (Shahbakhsh et al., 2022)

4. Duties and Capabilities of Seafarers

The ship's master carries significant legal responsibilities in both private and navigational realms. Primarily, they are tasked with crew management, navigation, and crucial safety decisions for the vessel. Their authority involves various obligations, with ensuing responsibilities in case of non-compliance. Furthermore, the ship's master holds a legal duty to represent the ship owner, albeit with diminishing scope due to evolving regulations and technological advancements. The rise of unmanned and autonomous ships has altered the landscape, enabling direct task commissioning and contractual agreements between the shipowner and the SCC manager, reducing the former captain's once-essential role. These transformations highlight the evolving nature of seafarers' duties and responsibilities in the maritime industry.

Granting the SCC manager equal authority to the ship's master may not be wise. The employment contract between the shipowner and the SCC could restrict urgent situation handling, aligning with the new Belgian Maritime Code's suggestions (Van Hooydonk, 2014). The ship's master also acts as the cargo owners' agent, with the authority to seek court permission for cargo sale if the consignee rejects delivery. However, determining responsibility without a captain on board and an uncooperative consignee is complex. Delegating this to a local agency could be more suitable, considering the SCC manager's likely distance from the ship, cargo, and consignee and limited involvement in cargo handling.

In the realm of unmanned and autonomous ships, there's a growing concern surrounding the traditional roles of ship captains. Existing mandates, like the requirement for a captain's physical presence during port or river entries according to Article 64 M.C., pose challenges for unmanned vessels where no onboard presence is expected. Similarly, Article 74 of the Merchant Marine Code, emphasizing the captain's responsibility for a voyage, might shift to the (SCC) due to their critical role in ensuring safe and timely arrivals, necessitating legal provisions to define their criminal culpability. Regulations like Article 77 M.C. regarding passenger and crew evacuation lose relevance without a physical onboard presence, presenting a shifting landscape of duties and capabilities. Additionally, assisting mariners and vessels in need, a vital duty outlined in Articles 62 and 63 of the Criminal and Disciplinary Code, requires reevaluation and potential new rules when unmanned and autonomous ships encounter vessels in distress. These changes underscore the evolving duties and responsibilities of seafarers in the context of advancing maritime technology and autonomous vessels.

5. Maritime Security in the Age of Unmanned and Autonomous Ships

In maritime law enforcement, seafarers hold critical responsibilities in verifying suspect ships' nationality and conducting inspections as per Article 110(2) UNCLOS regulations. However, when dealing with suspicious unmanned vessels, their roles become more challenging due to the absence of a crew or a master to assist in vital procedures and ensure safety during boarding (Allen, 2018). The emergence of unmanned ships raises questions about the possibility of utilizing remote or virtual methods to establish nationality and inspect cargo without physically boarding. While remote identification of a ship's nationality is feasible through hull marks, the legal implications of determining the nationality of ships using digital means need careful consideration (Schmitt, 2017).

In this evolving landscape, automated technologies enable remote inspections, presenting possibilities for both unmanned and traditional manned ships. However, the legality of remote or virtual exercises depends on adherence to specified safeguards (Article 8bis of the SUA Convention, 2005). Challenges arise when verifying unmanned ships due to the absence of personnel to verify essential credentials, potentially affecting the validity of remote exercises (Schmitt, 2017). Careful consideration of these aspects is crucial for maritime law enforcement actions involving unmanned ships. In this evolving landscape, seafarers' roles must adapt and align with advancements to ensure effective compliance and enforcement.

6. Research Methodology

The Analytic Hierarchy Process (AHP) is used to rank the duties and capabilities of seafarers towards the unmanned and autonomous ships within the view of STCW. AHP is a method that establishes priority scales based on expert judgment and measurements through pairwise comparisons. It has been one of the methods for multiple criteria decision-making that is most frequently used (Russo and Camanho, 2015).

In conducting the AHP with pairwise comparisons completed through a questionnaire distributed to 25 experts, the cumulative session making process is unfolded through a structured sequence. Initially, a comprehensive questionnaire is meticulously designed based on the hierarchy of criteria and sub-criteria, encompassing paired comparisons for each element. A panel of 25 experts, selected based on their subject expertise, is then invited to partake in the AHP analysis by having their insights provided through the questionnaire. This questionnaire, along with clear, understandable, and unambiguous instructions, is shared with the experts through online electronic means, and the criteria and sub-criteria are independently evaluated and compared in pairs, with numerical values denoting the relative importance of one item over the other being assigned.

The judgments/evaluations will then be made on a scale with the values 1, 3, 5, 7, and 9, i.e., criterion A versus criterion B (Saaty 1980; Podvezko 2009). The more important the corresponding criterion, the higher the value. Once the completed questionnaires are collected, the aggregated results of pairwise comparisons were meticulously analyzed to compute the relative weights for each criterion and sub-criterion using the mathematical eigenvector method, and a consensus set of weights is derived.

The measured criteria and sub-criteria are approved for unmanned and autonomous vessels by (Kim and Mallam, 2020 and Lim and Shin, 2022), which are;

Table 1: Criteria of AHP Analysis

Main Criteria	Sub-criteria
Ship Operation	**SO1**: General voyage
	SO2: Caution and Dangerous Voyage
	SO3: Determine position and navigation route
	SO4: Emergency Response
	SO5: Search and rescue
Ship Management	**SM1**: Maintain stability
	SM2: Deck and engine equipment management
	SM3: Management of shipping supplies and medicines
	SM4: Life-saving equipment and life-saving fire extinguishing management
	SM5: Compliance with international conventions
Cargo Management	**CM1**: Cargo Handling
	CM2: Care cargoes
	CM3: Cargo area hull inspection
Ability to apply task and workload management	**AAWM1**: Planning and coordination
	AAWM2: Personnel assignment
	AAWM3: Time and resource constraints
	AAWM4: Prioritization
Knowledge and ability to apply effective resource management	**KARM1**: Allocation, assignment, and prioritization of resources
	KARM2: Effective communication on board and ashore
	KARM3: Decisions reflect consideration of team experience
	KARM4: Assertiveness and leadership, including motivation
	KARM5: Obtaining and maintaining situation awareness
Knowledge and ability to apply decision-making techniques	**KADM1**: Situation and risk assessment
	KADM2: Identify and generate options
	KADM3: Select course of action
	KADM4: Evaluation of outcome effectiveness

7. Results and Finding

In this section, AHP analysis is done to rank the duties and capabilities of seafarers towards the unmanned and autonomous ships within in view of STCW, where data are collected from 25 experts in the maritime industry consisting of senior ship's captains, navigational and machinery specialists, technical superintendents, automation experts, fleet operations managers, and maritime industry association representatives. Their experience ranges from 12 to 25 years. The following part introduces the results concluded pairwise comparison methodology, a fundamental aspect of the AHP, to assess the relative importance of criteria and sub-criteria. Experts compared items in pairs to derive their judgments on importance.

Ranking of the Main Six Criteria

A pairwise comparison matrix is done through identifying the decision matrix and the weight of each criterion. This comparison is shown in Table 2.

Table 2: Values of Main Criteria

Criteria	SO	SM	CM	AAWM	KARM	KADM
SO	1.00	0.62	0.70	0.83	1.01	1.07
SM	1.62	1.00	1.09	1.37	1.60	1.79
CM	1.42	0.92	1.00	1.14	1.47	1.42
AAWM	1.20	0.73	0.88	1.00	1.19	1.21
KARM	0.99	0.63	0.68	0.84	1.00	0.99
KADM	0.93	0.56	0.70	0.83	1.01	1.00
Sum	7.170	4.448	5.058	6.007	7.276	7.482

From Table 2 the criteria weight (CW) and weighted sum vector (WSV) are calculated, where their values are shown in Table 3;

Table 3: Criteria Weight and Weighted Sum Vector of Main Criteria

Criteria	CW	WSV
SO	0.872217	5.23
SM	1.412329	8.45
CM	1.22704	7.39
AAWM	1.03505	6.22
KARM	0.854586	5.14
KADM	0.83887	5.02

From the above table, the ʎmax Random Consistency value (RC), Consistency Index (CI), and Consistency Ratio (CR) are calculated.

ʎmax= ((5.23/0.87) + (8.45/1.41) + (7.39/1.23) + (6.22/1.035) + (5.14/0.85) + (5.02/0.84)) /6 = 6.002404802

CI= (6.002404802 - 6)/5 = 0.00048096

CR= 0.00048096/1.24 = 0.000387871

It is concluded that CR value is < 0.05. Thus, the values are acceptably consistent.

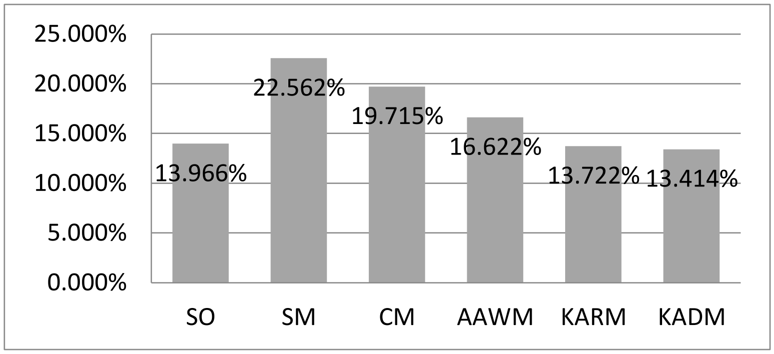
Finally, the ranking is identified, where the ship management has the first ranking with a percentage of 22.562%, followed by cargo management with 19.715%, and the third rank is the ability to apply task and workload management with a percentage of 16.622%. Finally, it is noticed that the other three criteria have close percentages, which are 13.966, 13.722, and 13.414

respectively. These results are concluded after calculating the geometric mean of the criteria, which are shown in Table 4 and Figure 1:

Table 4: Pairwise Comparison Matrix for the Main Criteria

Criteria	GM	W
SO	0.8549	13.966%
SM	1.38109	22.562%
CM	1.206856	19.715%
AAWM	1.017495	16.622%
KARM	0.83997	13.722%
KADM	0.821128	13.414%

Figure 1: Weight of the Main Criteria



Ranking of Ship Operation

A pairwise comparison matrix is done through identifying the decision matrix and the weight of sub- criteria of ship operation. This comparison is shown in Table 5.

Table 5: Values of Ship Operation

Criteria	SO1	SO2	SO3	SO4	SO5
SO1	1.00	0.35	0.50	0.72	1.15
SO2	2.84	1.00	1.09	1.94	2.85
SO3	1.99	0.92	1.00	1.34	2.31
SO4	1.39	0.52	0.75	1.00	1.54
SO5	0.87	0.35	0.43	0.65	1.00
Sum	8.093	3.139	3.768	5.646	8.851

From Table 5 CW and WSV are calculated, where their values are shown in Table 6;

Table 6: Criteria Weight and Weighted Sum Vector of Ship Operation

Criteria	CW	WSV
SO1	0.744634	3.69
SO2	1.944171	9.60
SO3	1.511685	7.70
SO4	1.038491	5.22
SO5	0.660584	3.32

From the above table, the ʎmax, CI, and CR are calculated.

ʎmax= ((3.69/0.74) + (9.60/1.94) + (7.70/1.51) + (5.22/1.04) + (3.32/0.66)) /5 = 5.009181484

CI= (5.009181484 - 5)/4 = 0.002295371

CR= 0.002295371/1.12 = 0.002049438

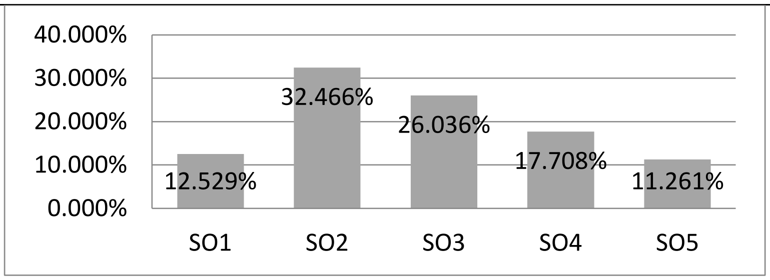
It is concluded that CR value is < 0.05. Thus, the values are acceptably consistent.

Finally, the ranking is identified, where SO2 has the first ranking with a percentage of 32.466%, followed by SO3 with 26.036%, and the third rank is SO4 with 17.707%. The fourth rank is SO1 with 12.529%. Finally, the fifth rank is SO5 with 11.261%. These results are concluded after calculating the geometric mean of ship operation, which are shown in Table 7 and Figure 2:

Table 7: Pairwise Comparison Matrix for Ship Operation

Criteria	GM	W
SO1	0.680725	12.529%
SO2	1.763965	32.466%
SO3	1.414637	26.036%
SO4	0.962146	17.708%
SO5	0.61186	11.261%

Figure 2: Weight of Ship Operation



Ranking of Ship Management

A pairwise comparison matrix is done through identifying the decision matrix and the weight of sub- criteria of ship management. This comparison is shown in Table 8.

Table 8: Values of Ship Management

Criteria	SM1	SM2	SM3	SM4	SM5
SM1	1.00	0.91	0.82	0.80	1.26
SM2	1.10	1.00	0.77	0.83	1.25
SM3	1.22	1.31	1.00	0.98	1.51
SM4	1.25	1.20	1.02	1.00	1.49
SM5	0.79	0.80	0.66	0.67	1.00
Sum	5.351	5.223	4.271	4.282	6.513

From Table 8 the (CW) and (WSV) are calculated, where their values are shown in Table 9;

Table 9: Criteria Weight and Weighted Sum Vector of Ship Management

Criteria	CW	WSV
SM1	0.959952	4.80
SM2	0.988656	4.93
SM3	1.202081	6.01
SM4	1.192317	5.98
SM5	0.785062	3.93

From the above table, the ʎmax RC, CI, and CR are calculated.

ʎmax= ((4.80/0.96) + (4.93/0.99) + (6.01/1.20) + (5.98/1.19) + (3.93/0.785)) /5 = 5.002471738

CI= (5.002471738 - 5)/4 = 0.000617934

CR= 0.000617934/1.12 = 0.000551727

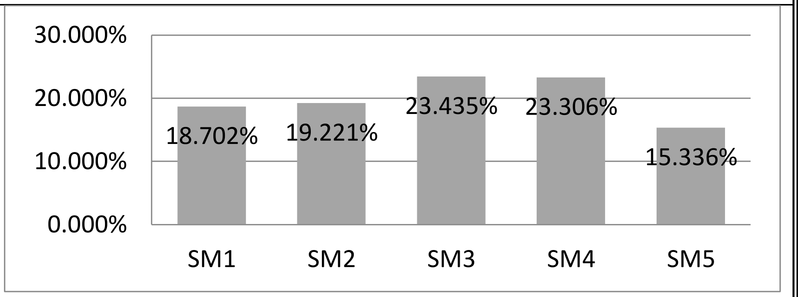
It is concluded that CR value is < 0.05. Thus, the values are acceptably consistent.

Finally, the ranking is identified, where SM3 has the first ranking with a percentage of 23.435%, followed by SM4 with a very close percentage that equals 23.306%, and the third rank is SM2 with a percentage of 19.221%. The fourth rank is SM1 with a percentage of 18.702%. Finally, the fifth rank is SM5 with a percentage of 15.336%. These results are concluded after calculating the geometric mean of ship management, which are shown in Table 10 and Figure 3:

Table 10: Pairwise Comparison Matrix for Ship Management

Criteria	GM	W
SM1	0.946544	18.702%
SM2	0.97285	19.221%
SM3	1.186109	23.435%
SM4	1.179584	23.306%
SM5	0.776173	15.336%

Figure 3: Weight of Ship Management



Ranking of Cargo Management

A pairwise comparison matrix is done through identifying the decision matrix and the weight of sub- criteria of cargo management. This comparison is shown in Table 11.

Table 11: Values of Cargo Management

Criteria	CM1	CM2	CM3
CM1	1.00	1.08	1.92
CM2	0.92	1.00	1.69
CM3	0.52	0.59	1.00
SUM	2.44	2.68	4.61

From Table 11 the (CW) and (WSV) are calculated, where their values are shown in Table 12;

Table 12: Criteria Weight and Weighted Sum Vector of Cargo Management

Criteria	CW	WSV
CM1	1.334162	3.99
CM2	1.203304	3.62
CM3	0.704629	2.11

From the above table, the ʎmax, CI, and CR of cargo management are calculated.

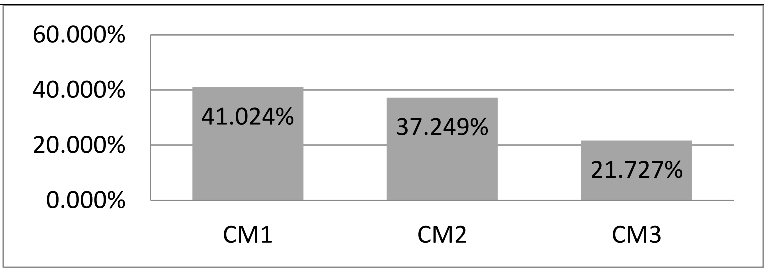
ʎmax= ((3.99/1.33) + (3.63/1.20) + (2.11/0.70)) /3 = 3.000291016
CI= (3.000291016 - 3)/2 = 0.000145508
CR= 0.000145508 /0.58 = 0.000250876
It is concluded that CR value is < 0.05. Thus, the values are acceptably consistent.

Finally, the ranking is identified, where CM1 has the first ranking with 41.024%, followed by CM2 in the second rank with 37.249%, and the third rank is CM3 with 21.727%. These results are concluded after calculating the geometric mean of cargo management, which are shown in Table 13 and Figure 4:

Table 13: Pairwise Comparison Matrix for Cargo Management

Criteria	GM	W
CM1	1.276425	41.024%
CM2	1.158953	37.249%
CM3	0.675998	21.727%

Figure 4: Weight of Cargo Management



Ranking of Ability to Apply Task and Workload Management

A pairwise comparison matrix is done through identifying the decision matrix and the weight of sub- criteria of ability to apply task and workload management.

This comparison is shown in Table 14.

Table 14: Values of Ability to Apply Task and Workload Management

Criteria	AAWM 1	AAWM 2	AAWM 3	AAWM 4
AAWM 1	1.00	0.38	0.48	0.60
AAWM 2	2.60	1.00	1.08	1.73
AAWM 3	2.08	0.93	1.00	1.06
AAWM 4	1.67	0.58	0.94	1.00
Sum	7.35	2.89	3.50	4.39

From the above table, the criteria weight (CW) and weighted sum vector (WSV) are calculated, where their values are shown in Table 15;

Table 15: Criteria Weight and Weighted Sum Vector of Ability to Apply Task and Workload Management

Criteria	CW	WSV
AAWM 1	0.617367	2.48
AAWM 2	1.601356	6.38
AAWM 3	1.267991	5.15
AAWM 4	1.047545	4.20

From the above table, the ʎmax Random Consistency value (RC), CI, and CR are calculated.

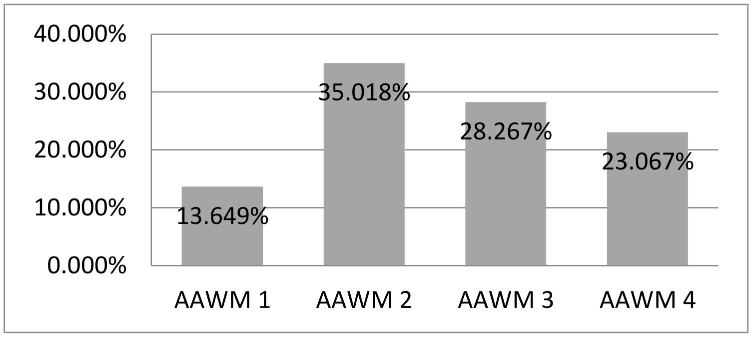
ʎmax= ((2.48/0.62) + (6.37/1.60) + (5.15/1.27) + (4.20/1.05)) /4 = 4.01689892
CI= (4.01689892- 4)/3 = 0.005632973
CR= 0.005632973/0.9 = 0.006258859
It is concluded that CR value is < 0.05. Thus, the values are acceptably consistent.

Finally, the ranking is identified, where AAWM2 has the first ranking with 35.018%, followed by AAWM3 in the second rank with a percentage of 28.267%, and the third rank is AAWM4 with a 23.067%. Meanwhile, the fourth rank is AAWM 1 with 13.649%. These results are concluded after calculating the geometric mean of the ability to apply task and workload management, which are shown in Table 16 and Figure 5:

Table 16: Pairwise Comparison Matrix for Ability to Apply Task and Workload Management

Criteria	GM	W
AAWM 1	0.578023	13.649%
AAWM 2	1.483018	35.018%
AAWM 3	1.197094	28.267%
AAWM 4	0.976886	23.067%

Figure 5: Weight of Ability to Apply Task and Workload Management



Ranking of Knowledge and Ability to Apply Effective Resource Management

A pairwise comparison matrix is done through identifying the decision matrix and the weight of sub- criteria. This comparison is shown in Table 17.

Table 17: Values of Knowledge and Ability to Apply Effective Resource Management

Criteria	KARM1	KARM2	KARM3	KARM4	KARM5
KARM1	1.00	1.28	1.04	1.29	1.26
KARM2	0.78	1.00	0.79	1.03	0.92
KARM3	0.96	1.26	1.00	1.22	1.15
KARM4	0.78	0.97	0.82	1.00	0.91
KARM5	0.79	1.09	0.87	1.10	1.00
Sum	4.309	5.594	4.525	5.638	5.244

From Table 17 the (CW) and (WSV) are calculated, where their values are shown in Table 18;

Table 18: Criteria Weight and Weighted Sum Vector of Knowledge and Ability to Apply Effective Resource Management

Criteria	CW	WSV
KARM1	1.174359	5.87
KARM2	0.905657	4.53
KARM3	1.118079	5.59
KARM4	0.894994	4.48
KARM5	0.969197	4.84

From the above table, the ʎmax Random Consistency value (RC), CI, and CR are calculated.

ʎmax= ((5.87/1.17) + (4.53/0.91) + (5.59/1.12) + (4.48/0.89) + (4.87/0.97)) /5 = 5.000816767

CI= (5.000816767- 5)/4 = 0.000204192

CR= 0.000204192/1.12 = 0.000182314

It is concluded that CR value is < 0.05. Thus, the values are acceptably consistent.

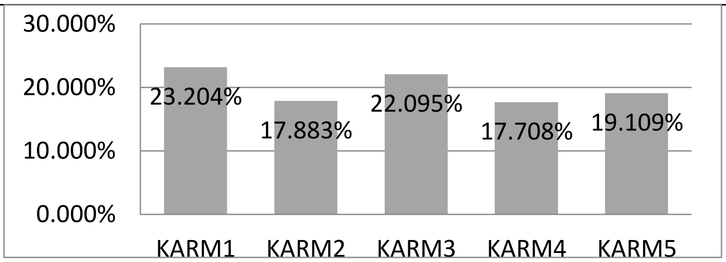
Finally, the ranking is identified, where KARM1 has the first ranking with a percentage of 23.204%, followed by KARM3 in the second rank with 22.095%, and the third rank is KARM5 with 19.109%. Meanwhile, the fourth rank is KARM2 with 17.883%, ending with the fifth rank, which is KARM4 with 17.708%.

These results are concluded after calculating the geometric mean of knowledge and ability to apply effective resource management, which is shown in Table 19 and Figure 6:

Table 19: Pairwise Comparison Matrix for Knowledge and Ability to Apply Effective Resource Management

Criteria	GM	W
KARM1	1.167419	23.204%
KARM2	0.899708	17.883%
KARM3	1.111582	22.095%
KARM4	0.890907	17.708%
KARM5	0.961386	19.109%

Figure 6: Weight of Knowledge and Ability to Apply Effective Resource Management



Ranking of Knowledge and Ability to Apply Decision-Making Techniques

A pairwise comparison matrix is done through identifying the decision matrix and the weight of sub- criteria of knowledge and ability to apply decision-making techniques. This comparison is shown in Table 20.

Table 20: Values of Knowledge and Ability to Apply Decision-Making Techniques

Criteria	KADM1	KADM2	KADM3	KADM4
KADM1	1.00	0.63	0.96	1.32
KADM2	1.59	1.00	1.21	1.92
KADM3	1.04	0.83	1.00	1.22
KADM4	0.76	0.52	0.82	1.00
Sum	4.39	2.98	3.99	5.46

From Table 20 the (CW) and (WSV) are calculated, where their values are shown in Table 21;

Table 21: Criteria Weight and Weighted Sum Vector of Values of Knowledge and Ability to Apply Decision-Making Techniques

Criteria	CW	WSV
KADM1	0.978715	3.89
KADM2	1.428627	5.70
KADM3	1.022041	4.17
KADM4	0.775777	3.10

From the above table, the ʎmax Random Consistency value (RC), Consistency Index (CI), and Consistency Ratio (CR) are calculated.

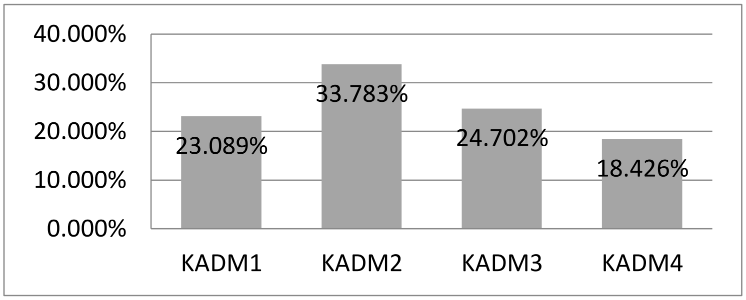
ʎmax= ((3.89/0.98) + (5.70/1.43) + (4.17/1.02) + (3.10/0.776)) /4 = 4.011801312
CI= (4.011801312- 4)/3 = 0.003933771
CR= 0.003933771/0.9 = 0.004370856
It is concluded that CR value is < 0.05. Thus, the values are acceptably consistent.

Finally, the ranking is identified, where KADM2 has the first ranking with 33.783%, followed by KADM3 in the second rank with 24.702%, the third rank is KADM1 with 23.089%, and the fourth rank is KADM4 with 18.426%. These results are concluded after calculating the geometric mean of knowledge and ability to apply decision-making techniques, which are shown in Table 22 and Figure 7:

Table 22: Pairwise Comparison Matrix for Values of Knowledge and Ability to Apply Decision-Making Techniques

Criteria	GM	W
KADM1	0.946431	23.089%
KADM2	1.384751	33.783%
KADM3	1.012526	24.702%
KADM4	0.75527	18.426%

Figure 7: Weight of Values of Knowledge and Ability to Apply Decision-Making Techniques



8. Research Discussion

After applying the AHP analysis, this section discusses the most important concluded results from the analysis. Firstly, ship management has proved to be the most important factor among the other five factors, this pointed out the importance of ship management and how it represents the initial factor that affects the unmanned and autonomous ships. Another important matter is that three of the six factors; ship operation, knowledge, and ability to apply effective resource management and knowledge and ability to apply decision-making techniques, have a very close ranking, which means they have the same importance according to the experts or the variation between them is very small.

In the absence within STCW, prioritizing ship management is vital to uphold regulatory compliance, safety measures, environmental responsibility, and international cooperation. It necessitates effective training of seafarers, compensating for the lack of STCW guidance and ensuring lawful and responsible operations of unmanned and autonomous ships.

Looking for the analysis of each criterion, in ship operation it is noticed that caution and dangerous voyage have the highest rank, which means that it is the most important factor, while the least important factor is search and rescue, where it has the least rank.

In ship management criteria, the significance varies based on the degree / level of autonomy. The management of shipping supplies and medicines represents the most important factor with the highest ranking, followed by life-saving equipment and life-saving fire extinguishing management with a very small difference in the percentage compared to the first factor, which means that they have a very close importance. This underscores the criticality of these factors, particularly in autonomy degrees one and two, where seafarers are present on board, readily available to assume control over shipboard systems (MSC.1/Circ.1638). In contrast, compliance with international conventions ranks lowest among the other sub-criteria.

Ship management gains importance. Emphasizing shipping supplies and life-saving equipment underscores the critical role ship management plays in safety. However, the low rank of compliance with international conventions highlights the challenge of maintaining standardized practices without STCW. Seafarers bear the responsibility of ensuring safety and adherence to best practices within this ambiguous legal and regulatory environment.

In cargo management criteria, cargo handling has the first rank, followed by care cargoes, and finally the cargo area hull inspection has the least rank with the least importance. In the ability to apply task and workload management criteria, personnel assignment has the highest rank among all sub-criteria, while planning and coordination have the least ranking.

Allocation, assignment, and prioritization of resources are found to be the most crucial sub-criteria in terms of KARM criteria, while assertiveness and leadership, including motivation, and effective communication on board and ashore are the lowest two with very little variation in their percentages.

In KADM, identify and generate options represents the most important dimension, while evaluation of outcome effectiveness has the least importance with the least ranking.

From the above concluded points, the importance of each criterion has been identified, which can help experts in making decisions, which can enhance the operation of unmanned and autonomous ships navigation.

Moreover, it is important to refer that although the current study had depended on previous literature to rank its criteria and way of measuring them, as this is adopted from (Kim and Mallam, 2020 and Lim and Shin, 2022), the current study makes its analysis for different perspective as well as the current study had gathered different factors that are not gathered from before.

9. Conclusion

STCW outlines the duties and capabilities for the seafarers. However, the convention was not initially created with unmanned ships in consideration, resulting in a lack of specific provisions addressing the competencies standing of unmanned ships. Despite this, there is an ongoing debate regarding whether unmanned ships should be acknowledged as "ships" and be exempt from the rights and obligations typically attributed to flag and coastal nations. With a distinction between remotely controlled unmanned ships and autonomous ships without human supervision, compliance with the current IMO regulatory framework is essential. While modest amendments or clarifications may be needed for remote-controlled ships, important amendments are needed for unsupervised autonomous unmanned ships. With a distinction between remotely controlled unmanned ships and autonomous ships without human supervision, compliance with the current IMO regulatory framework is essential.

IMO and MASS guidelines outline liability levels for navigational and operational errors at different levels. Levels 0, 1, and 2 fall to the shipmaster, while Level 3 involves remote operation and monitoring of navigation. Level 4 transfers liability to the shipmaster and SCC, while Level 5 involves fully automated vessels acting independently. Specific procedures may be used in times of system faults, such as terminal operators guiding ships in coastal zones or response teams boarding unmanned vessels. However, these precautions might not be helpful for unmanned seagoing vessels. Unmanned merchant ships are viable up to Level 3 of automation despite implementation difficulties. However, as human elements will still be used to partially manage or monitor oceangoing vessels, man-to-machine contact will still be relevant.

The analysis presented in this study emphasizes ship management as the most critical factor influencing the duties and capabilities of seafarers concerning unmanned and autonomous ships in view of STCW. This underscores the need for prioritizing ship management, enhancing its development, and aligning practices with STCW standards to ensure its effective operation while upholding seafarers' duties. Given the pivotal role of ship management, connecting this discussion to ongoing debates regarding the classification of unmanned ships as "ships" and their implications for seafarers' duties and capabilities among seafarers are deemed imperative. Accordingly, more attention must be directed towards this factor, its development, and alignment with STCW standards to guarantee its proper operation.

10. Research Recommendations

As the current study aims to identify the duties and capabilities of seafarers towards the unmanned and autonomous ships from the prospective of STCW, the current study collected data from experts to identify the most important factors that can affect the navigation of unmanned and autonomous ships. From the concluded results, this paper offered some recommendations for decision-makers.

First recommendation is that experts and decision-makers should examine the accountability and moral challenges related to the creation of unmanned and autonomous operating systems to propose moral and legal norms and regulations that suit the technological development.

Decision makers should also work on developing the necessary skills and awareness of seafarers through retraining and reskilling them for the aim of guaranteeing safety and dependability in ship operations. Moreover, provides suitable training to seafarers to stay updated with the changing risk profile associated with new technology.

The inclusion of larger samples in future research to obtain more reliable results is suggested by the researcher. Limitations related to a lack of time, which hindered the adoption of a small research sample size, were encountered in this paper.

Considering that ship operations and team composition would be modified by autonomous and unmanned ships, it is naive to believe that they will still be safe solely based on the knowledge gained from investigating prior systems. In light of this, it is recommended that future research should focus on management and leadership issues affecting all organizational levels and effective leadership models for managing autonomous ship operations should be examined.

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