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MRT Maritime Research and Technology

Maritime Research and Technology (MRT) journal is a biannual international peer-reviewed journal which presents a global forum for dissemination of research articles, case studies and reviews focusing on all aspects of the maritime sector and its role in sustainable development.

MRT publishes original research papers in English analysing the international, national, regional or local maritime industry. MRT includes both theoretical and empirical approaches to topics of current interest in line with the editorial aims and scope of the journal. The objective of MRT is to contribute to the progress, development and diffusion of research in the maritime industry.

The manuscripts presented must be unpublished works, which have not been approved for publication in other journals. They must also fulfil all the requirements indicated in the 'Technical Specifications' section. The quality of the papers is guaranteed by means of a process of blind review by two scientific referees and one linguistic reviewer. Although the journal is published in print format, the processes of submission and reception of manuscripts, as well as revision and correction of proofs, are all done electronically.

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Maritime Research and Technology Journal: Introduction

Dr. Ghalwash, Ph.D. holder in Maritime Transport Technology from the Arab Academy for Science, Technology and Maritime Transport (AASTMT) (2004), Alexandria, Egypt and the Master Degree in General Maritime Administration and Environmental Protection from the World Maritime University (WMU) (1997), Malmo, Sweden. He started his career working on board Merchant Ships for 13 years (1981-1994). He joined the (AASTMT) in 1994 as a Lecturer, Nautical Department, College of Maritime Transport, 1994-2004.

As a member of AASTMT (The most reputable and greatly respectable educational organization in the region) extended family, during the period 2004-2011 he was graded from Head of Maritime Postgraduate Studies Department to Dean of College of Maritime Transport & Technology.

From 2011-2015 he was Vice President for Maritime Affairs, and from 2015-2021 he was Vice president for Training, Community Service and Sustainable Development. He is the leader of the team of the AASTMT, which was involved in the establishment of the International Association of Maritime Universities (IAMU) initiative, The Global Maritime Professional Body of Knowledge (GMP-BoK) from 2017 to 2019.

Meanwhile he is AASTMT President Consultant for International Maritime Relations and the Editor in Chief of the "Maritime Research and Technology" Journal.

Maritime Industry is considered an essential driver for the sustainability of the world economy due to its significant contribution to the global supply chain. In light of the recent rapid and foreseeable developments in the Maritime Industry technology and applications, which became a multidisciplinary field, a lot of concerns regarding the current need for more studies and research are raised in the Maritime Community.

I am delighted to announce the launch of the First Issue of the "Maritime Research and Technology" Journal (MRT). MRT is published by "The Academy Publishing Centre" (APC) of the Arab Academy for Science, Technology and Maritime Transport (AASTMT). AASTMT is a specialized organization that belongs to the League of Arab States focusing on Maritime Education, Training and Research besides a wide range of multidisciplinary fields.

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MRT is an International Academic biannual peer-reviewed Journal, which presents a global forum for the dissemination of research articles, case studies and reviews, focusing on all aspects of the Maritime Industry and its role in Sustainable Development. It publishes original research papers in English analysing the international, national, regional, or local hot topics related to the Maritime Industry. MRT includes both theoretical and empirical approaches to topics of current interest in line with the editorial aims and scope of the Journal. The objective of MRT is to contribute to the progress, development and diffusion of research in the Maritime Industry providing a multidisciplinary forum for studies from the perspective of broad areas of scientific knowledge. It provides easy and free access for readers, and a free publishing system through the website:
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MRT has an outstanding international editorial and advisory board of eminent scientists, researchers and experts who contribute to and enrich the journal with their vast experience in different fields of interest to the journal.

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Automation of Maritime Industry in the Era of Digitalization

His Excellency Prof. Dr. Ismail Abdel Ghafar Ismail Farag assumed the presidency of the Arab Academy for Science, Technology and Maritime Transport on 10-25-2011, based on the decision of the General Assembly of the League of Arab States. His Excellency held several positions throughout his career, where he graduated from the Military Technical College in 1978 with a grade of distinction with honors, obtaining a Bachelor's degree in Electrical Engineering, specializing in Computer Engineering, and then obtained a Master's degree in 1982 from Cairo University.

He started his career as a teaching assistant in the Computer Department at the Military Technical College (MTC). Prof. Farag obtained a doctorate degree in electrical engineering from George Washington University in the United States of America in 1989 and became specialized in computer engineering. He then resumed his career within the Military Technical College as a faculty member in the Computer Department in 1989.

In 2001, he was appointed as Head of the Research Planning Department at the College, then Head of the Electrical Engineering Department in 2003. In January 2005, he was chosen to the position of Assistant Director of the College for Graduate Studies and Research, then Assistant Director of the Military Technical College for Education in January 2006. Due to his skills and scientific and professional competence, he was appointed as Vice-Director of the College in January 2007. He remained in this position for two years, then became Director of the Military Technical College in January 2009 until he was chosen to head the Arab Academy for Science, Technology and Maritime Transport in October 2011.

During his tenure of these positions, his scientific expertise varied in the fields of computer networks, security of computer systems, computer algorithms, and computer architecture.

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1. INTRODUCTION

With the rapid technological advancement of the fourth and fifth industrial revolutions in recent decades, the international maritime industry has been challenged to be aligned with the requirements of the new effective and efficient technological development. Key challenges are to sustainably utilize new technologies and applications of artificial intelligence (AI) and unmanned systems efficiently in the maritime industry while maintaining high levels of safe maritime operations.

Technologies such as AI, big data, 3-D printing, virtual augmented and mixed reality, and omniverse are just examples of results of the Fourth Industrial Revolution (4IR). In addition, the world is witnessing the commencement of the transition to the Fifth Industrial Revolution (5IR), which may be defined as a new era of collaboration between humans and machines, with emerging disruptive technologies demanding the maritime community, academia, and industry to act swiftly on many frontiers. The (5IR) can be described as the collaboration between humans and machines in the workplace with various prospects for automation.

Autonomous technology is poised to reshape the maritime sector with crewless vessels; small crafts and unmanned underwater vehicles (UUVs) are already developed and in service with larger vessels under development. Technical feasibility combined with compelling economic advantages, such as improved efficiency, reduced human error, and operating costs, are driving adoption, especially in the maritime industry. It is time for the maritime industry to collaborate and align its efforts within the various sectors to the fact that autonomy is coming and to address current gaps through understanding how autonomy can shape the future of such a rich industry and how to exploit it for the benefit of the blue economy and the shift towards greener vessels. This article aims to shed light on the concept of Maritime Autonomous Surface Ships (MASS), the challenges it presents, and the role of Maritime Education and Training (MET) institutes in preparing for it.

2. DEVELOPMENT OF MARITIME AUTONOMOUS SYSTEMS

The growth in Maritime Autonomous Systems over the past two decades has exceeded the world's expectations. Major initiatives by organizations such as Rolls Royce, Japanese shipbuilders, and the Norwegian-based company "Kongsberg" have revealed plans to develop all-electric and autonomous ships shortly. Other organizations, Universities, and R&D centres throughout the world are developing complementary, even competing concepts and systems to support unmanned operations, coupled with infrastructure initiatives, including autonomous ports and high bandwidth communication channels/equipment.

Chenguang Liu, et al. analyzed the main universities contributing to the MASS research, the top 10 research centres according to the number of publications were selected, and the VOSviewer software is used to cluster the units with more than five publications and more than 20 citations (Van Eck and Waltman, 2010). The results of this analytical study are shown in Figure 1. Fig. 1 demonstrates that the current MASS research is mainly concentrated at the Norwegian University of Science and Technology, Dalian Maritime University, Wuhan University of Technology and Delft University of Technology, etc. (Liu et al. 2022).

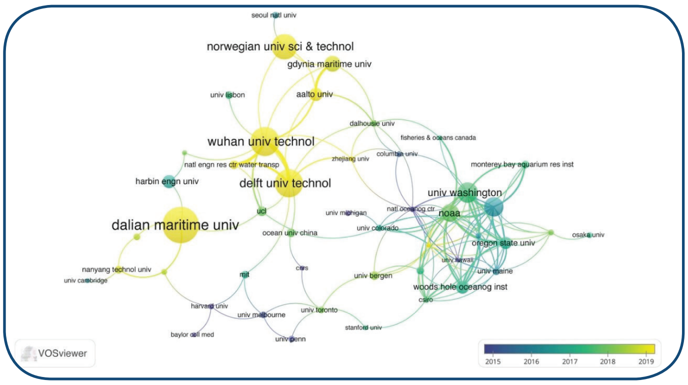

Fig. 1: A summary of research centres and universities contributing to MASS development (the darker colour means the earlier research is carried out, the thicker connecting line means the more mutual cooperation, and the larger circle means the larger number of publications) (Source: Liu et al. 2022).

Many companies and institutions launched their autonomous systems just after the concept of MASS was formally proposed at the MSC 98th session in the IMO in 2017. Later that year, "ABB" Group launched a navigation situation awareness solution designed to make ship operations safer and more efficient under the name of "ABB Ability Marine Pilot Vision", which realized real-time visualization and autonomous perception of the ship environment.

In 2017, Wuhan University of Technology (WUT) developed a ship-borne safe navigating intelligent assistance system, which enabled the monitoring of all ships in different navigation areas in three-dimensional real-time.

In 2018, "Maersk Group" and "Sea Machines" used AI technology to improve the ability of maritime target recognition, tracking and situation awareness. In the same year, "Rolls-Royce" launched its ship navigation situation awareness system, which integrated ship 3D Map and Light Detection and Ranging (LiDAR) to create a 3D environment by linking GPS data and providing the navigation situation information to ship navigators in the form of virtual reality (VR) and augmented reality (AR). The system has been utilized for sailing Merchant Marine Mitsui in Japan. The test was conducted on the 165-meter Sunflower passenger ferry between Kobe and Oita.

In 2019, "Kongsberg" developed a situational awareness solution combining multiple sensors with AI, machine learning, and traditional sensor fusion. This solution introduced real-time detection, tracking, and classification of objects and situations to replace human visual identification. Table I shows a sample of research projects that contributes to MASS development.

Table I: A Sample of Research Projects that Contributes to MASS Development
(Source: Liu et al., 2022)

Year	Project/Name	Introduction	Source
2017	NOVIMAR	• "The NOVIMAR project aims to expand the entire waterborne transport chain up".	NOVIMAR (2017)
2020	IntelliTug	• "Smart navigation assists the Tug Master with passage planning to prevent potential collisions".	Wärtsilä (2020)
2017	Great Intelligence	• A 38,800-ton smart bulk carrier "Great Intelligence" was built, which is the world's first "i-Ship" and "iDolphin" smart ship certified by China Classification Society and Lloyd's Register of Shipping.	CSSC (2017)
2017	Roboat	• "Roboat investigates the potential of self-driving technology to change the waterways with autonomous floating vessels"	Roboat (2017)
2018	Falco	• Demonstrated the world's first unmanned ferry Falco, and completed unmanned and remotely piloted navigation.	FinFerries (2018)
2019	Samsung	• Samsung Heavy Industries have conducted several tests of remote control and autonomous navigation for the model ship and the tug based on 5G and other technologies.	Samsung Heavy Industries (2019)
2020	KASS	• "aimed to successfully develop core technology for MASS in order to promote Korean interest in creating a synergy effect among shipping, shipbuilding and relevant industries".	KASS (2020)
2019	NYK	• NYK has conducted the world's first MASS trial performed in accordance with the IMO's Interim Guidelines for MASS trials.	NYK (2019)
2020	Seafar	• Seafar NV conducted a remote piloting test on a 135-metre-long barge Zonga.	Seafar (2020)

With the development of artificial intelligence, unmanned driving, and advanced communication technology, autonomous ships have attracted many researchers to develop ship capabilities in recent years. Europe, China, South Korea, Japan and other developed countries in the shipbuilding industry have performed intensive research, including numerical simulations and experimental tests in this field, as shown in Table I (for further information see: Liu et al. 2022).

In summary, the research of MASS is in the ascendant, and its application experiments have proved the feasibility of related technologies.

3. MASS AND INTERNATIONAL REQUIREMENTS

MASS in concept presents several challenges within the areas of application, operation, management, and administration, which must be addressed before the concept may be fully integrated within the international shipping regime.

The IMO Maritime Safety Committee (MSC), at its 103rd session in May 2021, has concluded a regulatory scoping exercise, which aimed to determine how the safe, secure, and environmentally sound operation of MASS can be introduced into the IMO instruments. Consequently, the MSC (104) agreed to develop a goal-based instrument for MASS, a possible MASS-Code, with a target completion year of 2025. This goal-based instrument aims to identify functional and operational requirements and corresponding regulations suitable for all four degrees of autonomy, as classified by the IMO, and address the various gaps and themes identified by the regulatory scoping exercise.

Other key issues that emerged are to include the functional and operational requirements of the remote-control station and MASS reception facilities, the possible designation of a remote operator as a seafarer, the role and responsibilities of the shipmaster, in addition to the challenges related to safety and security, including issues like environmental protection, piracy, and cyber security. And consequently, the type of education and training required to ensure the safe and secure operation of MASS both onboard and ashore.

4. HUMAN ROLE IN MASS OPERATION AND DEVELOPMENT

Ship navigation situational awareness is complex and requires the ship operator to understand technical limitations, surrounding severe environment, encountering scenarios, and conducting risk assessment based on perceiving the navigation environment with integrated sensors and systems. To develop a dependable situation awareness system, three levels must be efficiently functioning:

- The first level is to perceive the current environment state accurately.
- The second layer is to allow the machine to understand the current situation.
- The final layer is to reflect and respond with a timely decision.

Seafarers, at the current stage, cannot be entirely replaced by machines. Although the machine has several pros in conducting massive calculations and analyzing big data with high levels of certainty, machines lack reasoning within a rapidly changing fuzzy environment. On the other hand, humans have the upper hand in understanding such complex situations and have the ability to respond timely. On the downside, humans have higher error probabilities. Therefore, the maritime industry and researchers have put in massive efforts over the past two decades to take human-machine cooperation to the next level of autonomy for safer and more efficient ship navigation; a step forward toward a fully intelligent ship.

With the further development of AI, communication, and brain-like computing technologies, machines will undertake more tasks than humans during the ship's intelligent navigation, resulting in an intelligent, and more importantly safer maritime industry.

5. MASS AND CHALLENGES IN MARITIME EDUCATION AND TRAINING (MET)

The application of autonomous and remote technologies to shipping unquestionably requires a different caliber of maritime professionals possessing a new set of talents and skills. MASS, therefore, presents two main challenges to MET institutes: each challenge involving several sub-challenges.

Firstly, the application of new technologies on MASS requires higher standard maritime talents. With the wide application of automatic control and decision support systems in MASS, a new set of knowledge, skills, and attitudes needs to be introduced in the existing education and training process.

The IMO has, for now, classified MASS into four degrees of autonomy. Ships of the first degree depend on the shipboard crew to manage limited automated processes onboard. The following two degrees of autonomy are ships that are remotely controlled with degree-three ships having no crew on board. A ship of the fourth degree is intended to have complete autonomy over its processes with no onboard crew.

This brings one to the second challenge; MET needs to adapt to and accommodate the various degrees of MASS. As the concept of MASS develops, seafarers and remote operators will require increasing levels of knowledge and skills. To the extent that some seafaring tasks onboard will be completely replaced by either remote operation or complete process autonomy. MET institutions owe it to the seafarers of the future to prepare them to be competent operators whatever the degree of autonomy is. More importantly, Seafarers need to be prepared for a possible shift to shore occupations.

6. AASTMT COPING WITH MARITIME AUTONOMY

The strategy in AASTMT is aligned with the advancement in the maritime industry to meet the market needs. For example, in 2017, AASTMT established the first Artificial intelligence (AI) College in the Middle East and North Africa region (MENA). The AI College is located in the New Alamein City, on the North Coast of Egypt, where students practice a series of closely entwined technologies that the author believes will transform maritime operations and underpin autonomous systems. During their studies, AI students learn about sensors and situational awareness technologies that are fundamental to the process of autonomous systems and their safe operation.

In addition, the College of Computing and Information Technology develops the graduate's capabilities with the required skills in connectivity, communications, and information exchange, which will provide a catalyst for the future by enabling the digitization of the marine environment. On the other hand, it allows AASTMT graduates to consider risks for systems protection in 'cyberspace'.

It is worth mentioning that AASTMT researchers in the College of Engineering and Technology are putting effort into developing energy management and sustainability, which is seen as a limiting factor in the widespread deployment of autonomous systems. The author wants to ensure that AASTMT is well prepared and ready for the upcoming challenges. AASTMT strategy considers that the more the maritime industry depends on advanced technologies, the more the staff need to push their educational borders towards producing highly skilled, well-trained, and qualified people to lead the futuristic, intelligent and robust maritime industry shortly, under the umbrella of the IMO.

7. GMP-BOK ADDRESSING MARITIME AUTONOMY

The International Association of Maritime Universities (IAMU) launched its Global Maritime Professional (GMP) initiative in 2017. AASTMT, then Head of the Academic Affairs Committee of the IAMU, was part of a three-member-university Task Force entrusted by the IAMU to develop the Global Maritime Professional Body of Knowledge (GMP-BoK), which is intended to meet the envisaged needs of industry and a rapidly evolving educational and career context. The GMP-BoK was introduced to the maritime community in July 2019 at the headquarters of the IMO.

The GMP-BoK is applying the modern concepts of maritime higher education and an outcome-based approach. Of the 28 focus areas identified in the GMP-BoK, many of them are of relevance to preparing graduates of maritime institutes for MASS.

AASTMT is currently using its vast resources and expertise to implement the GMP-BoK to its MET system. In doing so, AASTMT hopes to provide its graduates with the necessary set of knowledge, skills, and attitudes they need to successfully cope with the future, a future where MASS is no longer a concept, but a reality.

8. CONCLUSION

The challenge in the Maritime Industry development is always how to manage and safely control the new technologies introduced to the maritime field, keeping them suitable and efficient in the era of digitalization.

Technologies such as artificial intelligence (AI), big data, 3-D printing, and virtual and augmented reality were brought forth by the Fourth Industrial Revolution (4IR), while (5IR) combined humans and machines in the workplace with various prospects for automation such as (MASS). The maritime industry and researchers have put in massive efforts over the past two decades to take human-machine cooperation to the next level of autonomy for safer and more efficient ship navigation, which is considered a step forward toward a fully intelligent ship. the author trusts that within the coming few years, with the further development of AI, communication, and brain-like computing technologies, machines would undertake more tasks than humans during the ship's intelligent navigation, resulting in an intelligent, and more importantly, a safer maritime industry.

Autonomous technology is poised to reshape the Maritime Industry with crewless vessels, which means it is time to understand how autonomy will shape the future industry and how best to exploit it. There are growing numbers of small-scale autonomous vessels being operated across various applications.

Regulatory schemes are being revised and the IMO has concluded a regulatory scoping exercise, which aimed to define the safe, secure, and environmentally sound operation of MASS and its compatibility with the current maritime regulatory regime.

Despite the comprehensive brought forth of such technologies, the shortage of skilled seafarers worldwide and the relatively high operational costs of running such ships are key factors and cornerstones. Capacity building is one of the principal challenges in developing and operating MASS. Thus, MET institutes are eager to continue developing and delivering world-standard educational programs to their graduates. They will need to adapt to and accommodate the various degrees of MASS as the concept of MASS develops.

AASTMT strategy considers that the more the maritime industry depends on advanced technologies, the more its staff need to push their educational borders toward producing highly skilled, well-trained, and qualified people to lead the futuristic, intelligent and robust maritime industry.

As one looks to the future, it appears that Maritime Autonomous Surface Ships are just around the corner; autonomous vessels are already being developed and tested, regulatory schemes are being revised, roles and responsibilities are being reconsidered, and MET regimes are being renewed. In short, MASS is no longer a prospect of the future; it is a reality in the making.

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A QFD As Decision Model For Reevaluating Seaport Criteria

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Abstract

Maritime container and cargo shipping are profitable pursuits for shippers and shipping lines associations to transport various cargo types among different seaports and harbors. Locating and selecting the most appropriate ports and routes from several alternatives are referred to be a complicated Multiple Criteria Decision Making (MCDM) issue since it demands multiple factors.

Since the shipping line is integrated with the global supply chain and controlling the port and route choices. The port selection criteria have changed and have become different from traditional selection factors. Thus, the needs for reevaluating the various ports selection criteria to be compatible with the new selection maritime transportation era are being obvious.

Port selection criteria in the shipping route based on the Quality Function Deployment (QFD) concept research findings had changed as a result of, integration management of maritime shipping lines into global supply chains. The most noteworthy determining criterion when shipping lines select the port of call on a single route is, port Geographical Location as a second most significant selection parameter behind port effectiveness and IT ability. The third issue to take into consideration is the port dues and terminal handling charges.

This paper uses quality function deployment (QFD) as an analysis tool to determine the relative weight of top eight port selection criteria (port location, water draft, size of the hinterland, feeder services and intermodal connections, cargo volume, port charges, port efficiency and IT ability). Raw data are collected via distribution of questionnaires to various shipping lines and stakeholders operating in this field. The QFD model results show that Port efficiency and reliability, IT ability and port location are the most important port selection criteria. Port competition and development should consider these changes in port selection criteria.

Key-words:
Quality Function Deployment (QFD) - Port selection criteria - Multicriteria decision making - Task oriented weighting - intelligent decision support

1. INTRODUCTION

The transportation activities have become crucial for most of the globalized container shipping line and shipping companies due to the development in the existing economic sector. Organizations must choose the proper technique to ship and transport their cargo, containers, and merchandises through the proper supply chain partners as the effectiveness of these activities enhances the competitive advantage of organizations, with their huge market share of global trade, maritime shipping and transportation that have recently become one of the most essential industries.

Evaluating the suitability of seaport for a specific task in marine transportation is challenging and complex. The complexity of the evaluation and selection process is due to: (a) the presence of multiple, often conflicting evaluation criteria and their associated sub-criteria (Balmat, et al, 2008), (b) the multidimensional nature of the problem (Wibowo and Deng, 2009), (c) the existence of subjects and uncertainty in the human decision making process (Wibowo and Deng, 2009; Zimmermann, 2000).

The challenge of the selection process and the evaluation comes from the needs for making transparent and consistent decisions in a timely manner and cost crash based on a comprehensive evaluation of sea ports criteria with respect to shipping line perspective (Ang et al, 2007). Many approaches were developed to solve the seaport evaluation and selection problem from different perspectives, these approaches focus on maximizing the profit in selecting and evaluating sea ports criteria considering the uncertainty on the shipping integration factors and the horizontal integration of shipping lines in the global supply chain in the decision making process.

Multi criteria analysis is a decision making tool for complex decision problems. Different from single criterion analysis, multi criteria analysis is able to deal with complicated situations where more than one criterion exists and even their relative importance is not constant (Guy and Urli, 2006). A multiple-criteria decision analysis MCDM tool as the analytic hierarchy process (AHP) and technique for order of preference similarity to ideal solution (TOPSIS) is introduced in evaluating and assessing the seaports criteria. The risks of using these methods are the candidates' different levels of quality, lower response rate and inconsistency. However, these approaches need as a main requirement computational considerable effort due to using integer programming in the port criteria evaluation and selection process (Gabriel et al, 2005).

Han et al, (2001) presented a decision approach based on quallity function deployment (QFD) methodology in the maritime transportation for container ship selection as mainfacture application. The proposed decision model takes into account ship attributes and customer needs in addition the relations between them. Due to this fact the maritime transportation factor that includes the ship characteristics and relationships between company needs are still imprecise and vague, other factors as port selection criteria may have qualitative or quantitative dimensions need to be re-evaluated using smart techniques to develop the MCDM approach.

Hauser and Clausing (1988) presented the changes in shipping line behaviour and global supply chains that affect port selecting criteria and choosing the proper ports in the different shipping routes. However, on the other hand, how could ports react to shipping lines' change and how ports could be developed to be combustible and more competitive under the new situation remains a confusing problem to the world. None of the studies have examined port choice based on intelligent techniques in a situation where a port is considered as an element of a supply chain (Magal, 2004). This research demonstrates a way to re-assess the properties of port selection criteria and reevaluating the impact of shipping line integration in the global supply chain, based on the QFD support decision tool.

Analyic descriptive methdolgy to review previouse work and determine the knowleadge gab. Then it applies the QFD as a MCDM tool to provide general empirical findings of the targeted ports in QFD model and support the research model and outcomes. In so doing, a questionnaire has been designed, include multiple choice questions to allow respondents to select one or more options from a list of answers that was defined and correlation matrixes to collect primary real data and distributed to (98) participants from target shipping line that choose to expand networks through slot charter agreement, shippers, freight forwarder, Consignees, logistics service providers and port authorities (Ding, 2007). A Likert scale, nine points were employed in the questionnaire design to denote weak, medium and strong relationships between customer needs and port criteria, acquire original data which will be used in a QFD support model is that used as the major method in this research. The results from QFD model will be analyzed through a few basic statistical techniques (average, quartile, etc.). Finally, some analyses based on QFD outcomes will be employed to provide implications, suggestion as well as innovative thoughts for change of selection criteria and port competition.

2. SELECTION AND REFINERY OF CRITERIA

Chang et al (2008) singled out 22 criteria as the most important affective port selection criteria as follows: geographical location, water draft, feeder connection, inland-hinterland connection , scope of hinterland, port reputation, port dues, terminal handling charge (THC), handling speed/efficiency, service reliability, cargo volume, transshipment cargo volume, import and export cargo balance , cargo profitability, berth availability, IT ability, convenience of customs process, relationship between management and workers, acceptance of special requirements ,easiness of communication with staff, calling for competitors, and slot exchange cooperation lines.

The current research finds these criteria in need of reconsideration. The reasons for so doing are as follows. First, some factors are kind of overlapping in terms of meaning, hard to measure and a bit ambiguous. Second, it is not rational to include too many factors in the questionnaire, especially when one considers the time needed to complete it. Finally, the main paper objective is to verify QFD as a decision support model in reevaluating the port selection criteria.

To reduce the number of factors from 22 to 8 , some factors were disregarded (ambiguous) and others were merged together (port dues and terminal handling charge). Thus, the eight criteria to be considered are: geographical location, water's draft, hinterland size, feeder and intermediate connection, cargo volumes, port dues, terminal handling charges (THC), port efficiency, reliability and IT ability.

3. THE (QFD) CONCEPT

QFD is a strategic tool for developing and improving services and products based on consumer needs and requests. It is an organized method of translating customer wants into engineering characteristics of a service or production order to ensure a quality level that fulfils the customer's desires at every stage of manufacturing and service application. QFD is founded on gathering and translating customer requests into specifications and Individual features, process plans, and production and service requirements are then developed.

Figure (1) below shows each of the sections contained in "the House of Quality (HOQ)". Every section holds important data, specific to a part of the QFD analysis. The matrix is usually completed by a specially formed team, who follows the logical sequence suggested by the letters A to F, but the process is flexible and the order in which the HOQ is completed depends on the research team. The house of quality is a qualitative and subjective tool for translating the client's requirements into technical features.

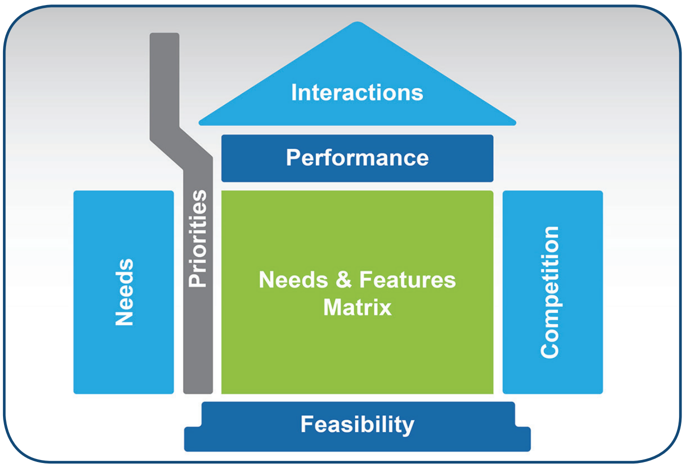

Figure (1): House of quality by Qualica QFD
Source: https://hygger.io/blog/quality-function-deployment-qfd

Each cell and part of the body of HQA in Fig 1 displays the relationship between client needs, and both technical requirements and characteristics (Han, et al, 2001).

4. QFD METHODOLOGY

The QFD approach entails creating matrixes or quality tables. The first integrated matrixes are known as "the House of Quality (HOQ)". Each part contains crucial data pertaining to a certain aspect of the QFD assessment. There are four phases to a comprehensive QFD:

a. Service Planning: Translate client requirements and establishing the house of quality
b. Service Design: Convert service requirements into essential system service criteria
c. Process Planning: Determine the important process procedures required including and process parameters (or target values) are recorded.
d. Process Control: Include control activities, create control strategies, performance indicator and training programs

5. INTRODUCTION OF QFD AS A SMART APPROACH FOR CRITERIA SELECTION

The approach method for solving the port selection criteria decision making based on QFD is presented in this section. MCDM procedures can be utilized to make an appropriate decision for a port evaluation and selection challenge defined by the existence of many and conflicting decision criteria and the availability of various alternatives.

The goal of companies as shippers, shipping lines, or stockholders in a port selection dilemma is to discover suitable ports to convey their cargo safely, within a reasonable time limit, and at a reasonable cost via a reputable shipping firm.

Customer requirements must be evaluated by the QFD team in accordance with the level of priority of the company's strategic objectives. Then, so as to calculate the weights of each port selection criteria, which is one of the main outputs of the house of quality (Bevilacqua et al, 2006), the correlation relationship between client requirements and port criteria must be determined. The weighted summation of the relationship scores with the prioritized customer requirements determines the importance weight of each port selection criteria.

6. QFD-BASED DECISION MODEL FOR CRITERIA SELECTION

A criteria selection problem is applied to demonstrate the implementation of the suggested QFD-based decision-making approach in this section. The port selection problem in this paper depend on fictitious data for port alternatives. The case in question is to choose among the Mediterranean appropriate ports, which are situated in the heart of a network of trade lanes.

6.1 Importance Weights of Customer Needs

In a port and ship selection problem, the objective of the companies is to find a ship to transport their merchandise safely, within a predetermined time limit, at a lower cost via a reputable shipping company. Thus, user needs which can be used in the QFD process are delivery of cargo in undamaged condition (CN1), timely delivery of cargo (CN2), total cost (CN3), the reputation of the shipping company (CN4) (Gaonkar, 2011).

The firm needs are used to plan the quality home. The QFD team used an integer scale to prioritize the company's needs. The weightings are based on the direct experience of team members with the transportation procedure (Hauser, 1988).

6.2 Interrelation Matrix

The interrelation matrix indicates the link between the customer's needs and the port criterion measures that intended to improve service. The first step in creating an interactive matrix is to get feedback from customers on what they want and need from a particular service. These perspectives are taken from the planning matrix and placed on the interrelationship matrix's left side. The port managements can start formulating a strategy to enhance their service with this customer overview.

Both strengths and weaknesses are then weighed against the company's priorities to determine which aspects require modifying to outperform the competition, which elements require changing to cope with the competition, and which aspects will remain intact. It is important to choose the best combination possible. Recognizing what needs to be improved enables the generation and display of a list of performance measurements across the top of the interrelationship matrix (Han et al, 2001).

6.3 Properties Matrix

The port's criterion weights, that weighted the total relationship scores with the prioritized company needs are one of the most important outputs of the house of quality (Wibowo and Deng, 2012), specific entries are often used in the properties, matrix for recording

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the priorities assigned to requirements. It also shows the competing products' performance as well as the difficulty of developing each criterion.

On the high priority quality characteristics, an organization's existing product can be compared to competitors' service. QFD aids businesses in identifying areas where they may achieve the highest levels of customer satisfaction at the lowest expense. Properties Matrix calculated in Table I by applying the following equation:

- attention of port criteria equals: Σ PC n = VOCx importance * PCx weight
- attention of customer requirements equals: Σ VOCx = Total PC weight * VOCx importance

For example:

PC1 (Geographical Location) = (5×5) 25 + (5×9)45 + (4×7)28 + (5×4)15 = 113

Relative importance CN1 (Delivery of cargo in undamaged) = (5×5 ×6)150 + (5×7×2)70 = 220

6.4 Competitive Matrix:

The competitive assessment matrix makes up a block of rows corresponding to each technical descriptor in the house of quality. After respective factors have been established, the service is evaluated for each factor that addresses VOC. Similar to the customer competitive assessment, the data that are useful in uncovering gaps in judgment are recorded.

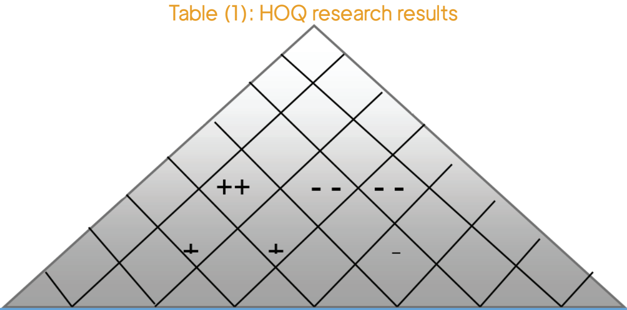
6.5 Port Criteria Correlation (synchronization) Matrix

Existing performance measures are frequently in conflict with one another. The roof, or correlation matrix, is used to aid in the construction of links between customers' requirements and port criteria, and it identifies where these units must function together or they would be in a design conflict. The symbols or numerical value are used to demonstrate the impact of each condition on the others to attract attention to any demands that may be in conflict. Any cell with a high correlation sends a strong signal, that any alterations will require modification.

6.6 Building House of Quality (HOQ) for Port Selection Criteria

The House of Quality is a tool for analyzing customer feedback and is an important part of the QFD process. It all begins with the customer's voice (company needs). It is a tool for converting what consumers demand of services that fit their design principles by establishing a relationship matrix. Table II shows the main structure of HOQ.

Table (1): HOQ research results



		PORT CRITERIA												
Company Needs	Importance (priority)	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	Total	Total %	Customer survey	Competitor 1	Competitor 2
VOC 1	5	5	5	5	5	5	5	7	7	220	27%	This part for any future new ports design and as an assessment for existing port W.R.T other ports		
VOC2	5	9	5	5	7	5	5	7	7	250	30%			
VOC3	4	7	3	5	7	7	9	7	7	208	26%			
VOC4	3	5	3	5	5	5	7	7	7	132	16.3%			
WEIGHTS OF PORT CRITERIA		113	71	85	103	93	107	119	119	810				
		0.140	0.88	0.104	0.127	0.115	0.132	0.15	0.15					
RELATIVE WEIGHTS		14%	8.8%	10.4%	12.7%	11.5%	13.2%	15%	15%	100%				

*VOC 1 Delivery of cargo in undamaged
VOC 2 Timely delivery of cargo
VOC 3 Total cost
VOC 4 Reputation of the shipping company

PC 1 Geographical location
PC 2 Water draft
PC 3 Hinterland size
PC 4 Feeder and intermodal connection

PC 5 Cargo volumes
PC 6 Port dues and terminal handling charges
PC 7 Port efficiency and reliability
PC 8 IT ability

7. THE EMPIRICAL FINDING OF PORT CRITERIA BASED ON APPLYING QFD

The empirical finding of applying QFD on each Port Criteria importance relative to each customer needs are shown in table I which illustrates that both criteria Port Efficiency and Reliability criteria (PC7) and IT ability criteria (PC8) are ranking as the highest relative to (VOC1), which means that both requirements have the highest importance to the shipping lines reflecting a deep desire to deliver the shipments and cargo in undamaged condition. Also, the table illustrates that Geographical Location (PC1) ranks as the highest relative to the company need, Timely Cargo Delivery (VOC2) which means maritime ports geographical location still has an important role in creating long-term economic growth. Furthermore, QFD results show that Cargo Volumes that include Port dues and terminal handling charges (PC6) rank as the highest relative to (VOC3), which means that this criterion has the highest importance for shipping cost crashing. The empirical finding of applying QFD reflects that Cargo Volumes (PC6), Port Efficiency and Reliability (PC7) and IT ability (PC8) rank the highest relative to (VOC4), which means that port efficiency, reliability and IT ability beside Port dues and terminal handling charges are the most important criteria to improve the ports and shipping lines reputations.

7.1 The Significance of Port's Location

It will be essential to emphasize and spot the importance of port location even in the Mediterranean logistics area. A good port geographic location must be able to provide convenient access to the hinterland for cargo and ships that are connected to the ground transportation network. Sea ports compete for various hinterlands, and a reasonable port geographic location accelerates this access and assists port gain competence from the start. For any ports, geographical expansion will be the solution for the sake of better location Ports.

7.2 A New Perspective on Port Efficiency and Reliability

An old, obsolete knowledge will never lead to develop the marine service and improve the ports competency. Development requires up-to-date knowledge and perspectives. As the first sharing with IT Ability most important criteria for port selection, port efficiency is the factor needed to be re-considered for the sake of continuous development. Traditional opinion on port efficiency, including the loading and unloading speed of containers is defined as cargo handling efficiency. However, as port becomes an essential element of global or regional supply chains network or even a distribution center of a region, port efficiency must be reconsidered as port logistics efficiency to be compatible with the new trends in the maritime industry. Port logistics efficiency is a set of various efficiency indicators measuring and monitoring the supply chain performance.

8. CONCLUSION

The research findings on port selection criteria in the shipping route are based on the QFD concept considering the integration of the shipping lines into global supply chains. The most noteworthy discovering when shipping lines, select ports of call on a single route, port Geographical Location is the second most significant selection parameter, behind only port effectiveness and IT Ability. The third issue to take in consideration is the port dues and terminal handling charges. This conclusion has significant implications for port development and competition such as a focus on intermediate links and new port development concepts like port-centric logistics. Those responses draw a more detailed conclusion of what this research paper is about. First of all, the liner shipping market factor changing as a consequence of its deeper integration into the global supply chain, this changes force the shipping lines to respond to this new challenge by striving themselves to integrate into global supply chains and value chains as to provide end-to-end logistical services (end-to-end, added value, etc.).

Second, it is obvious from the empirical finding of applying QFD that the aforementioned modifications have an impact on port selection criteria for the shipping lines, the four most essential port selection criteria presently, according to the report findings, are port efficiency and reliability, IT abilities, port geographic location, and Port dues and terminal handling charges (THC). It is gaining more interest as a feeder and intermediate connection.
Last, the port location still is an important concern in port selection, and freight distribution patterns are linked to

port location. For all parties associated with supply chain activities, the strength and breadth of intermediate links are critical. It is also essential that the port transforms itself to become more logistics integrated rather than being led by the logistical requirements of shipping lines. However, present port expansion and competition plans fall short of this strategic goal.

9. RECOMMENDATIONS

The current research supports the claim that port selection criteria will change as shipping lines become more involved in and integrated into global supply chains, networks, and it gives a rough notion of what the key and influencing changes are. Nevertheless, the following are the research's significant flaws and further recommendations:

1. If the businesses are unfamiliar with the ports, they will most likely choose the port with the best reputation to mitigate the potential risks. In order many "soft" criteria also need to be overlooked such as port management level, stevedore-management interaction, and reaction to shipping lines' various demands. To acquire a better understanding of the relative weights of port selection factors, the research advises that all influential criteria should be explored closely next time.
2. To improve port logistics activities and value-added procedure more research is required to focus on port logistics effectiveness.
3. QFD's adaptability has been made to be more convenient to integrate with other advanced quality methodologies.
4. Further, researchers should be able use QFD recent software such as Qualica 2000 software.

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A Passive Flow Separation Approach for Reducing Slamming Loads on Large Catamarans – Experimental Investigation

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Abstract

High-speed catamarans have, over the past three decades, extended their service areas from protected waters to the open ocean where impacts with waves can result in structural damage. This work is aimed at addressing the lack of high-quality three-dimensional (3d) experimental data suitable for benchmarking catamaran vessels impacting with water in a 3d regime, as well as establishing an understanding of the key elements influencing the severity of wetdeck slamming loads. A series of experimental tests were conducted on a high-speed catamaran's bow section during water entry using a constant speed drop testing facility.

The water impact facility allows the water/model interaction to occur at relatively high-velocities up to 10m/s and with two angles of trim, e.g. 0° and 5°. The tested model was constructed with two interchangeable centrebows to study the influence of flow separation prior to slam events. It was found that limited pressure transducers that are localised in space and time could be important for validating numerical techniques but should not be used as a basis for structural design. The findings of this study would also provide designers and classification societies with an approach to predict pressure distributions along the archway of non-uniform structures.

Key-words:
Water impact; Wetdeck slam; Experimental tests; Fluid Structure Interaction (FSI)

1. INTRODUCTION

This paper aims at addressing wetdeck slamming, one of the principal mechanisms for wave induced loads on catamaran ships. A catamaran experiences this type of slamming when operating in large waves as the wetdeck, the exposed deck area between the two demi hulls of the catamaran, impacts the water surface with a high relative vertical velocity (see Fig. 1). Wetdeck slamming is a significant design issue for catamarans since it can cause major structural damage and avoiding its occurrence is one of the main reasons a vessel's master reduces speed or changes course in heavy weather, adversely affecting the vessel's operation and schedule.

The main area of interest in the design of large wave-piercing catamarans is the impact loading in the vicinity of the centrebow during immersion (Davidson et al., 2006, Faltinsen, 2006). Several large high-speed catamarans have suffered damage due to wetdeck slamming, although these vessels were designed to classification society rules (Rothe et al., 2001, Steinmann et al., 1999, Thomas et al., 2002).

Some prominent examples of damage due to wetdeck slam events are as follows:

- Cracks in MS Sollifjell (Wang and Guedes Soares, 2013);
- localised buckling of plates, stiffeners and distortion of centrebow stiffeners of Incat Hull 050 (Thomas et al., 2002); and
- extensive structural damage to the bow of HSS Stena Discovery (Thomas, 2003).

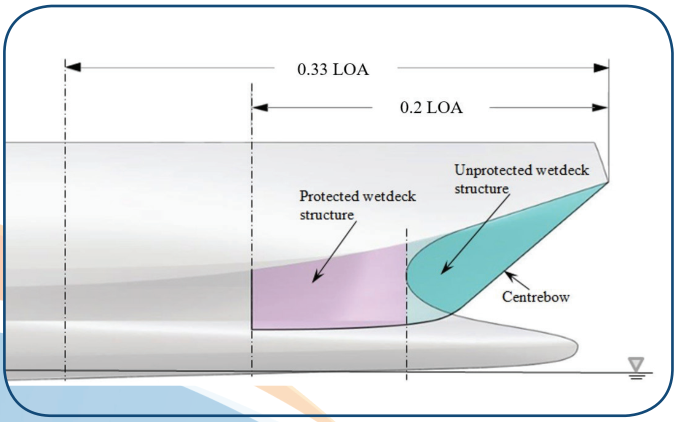

Fig. 1. Schematic diagram of bow section for a catamaran.

To eliminate the prospect of structural damage and to secure insurance cover in case of damage, high-speed craft are designed to rule-based design loads. Currently, classification societies (Cummings and Roden, 1998, LR, 2019, DNV-GL, 2018, ABS, 2016), provide designers with a range of empirical formulae that are based on quasi-static pressure predictions due to the impact on high-speed catamaran's wetdeck, which may over- or underestimate the actual impact pressure distributions.

The wetdeck slamming problem is significantly more complex than that for monohull slamming as it involves rapid changes of local loads in time and space, air inclusions, and the compressibility of mixing fluids (water and air) over a non-uniform surface in three dimensions.

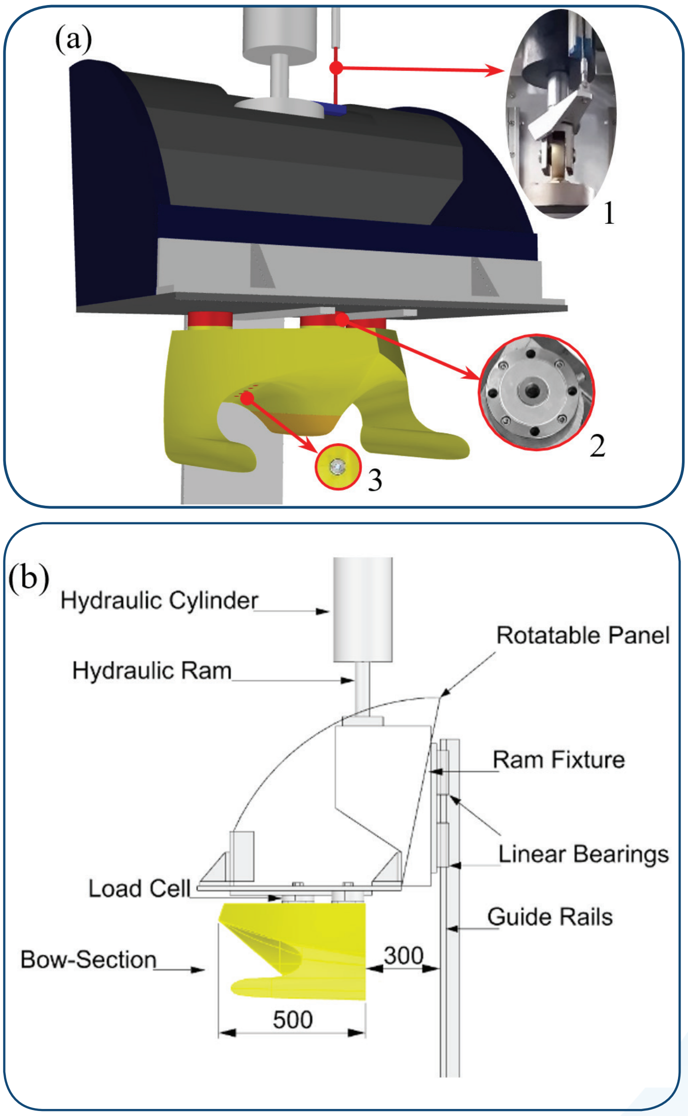

Fig. 2. The experimental test setup instrumentation; Subplot (a) showing 1 = longitudinal vertical displacement transducer (LVDT) and hydraulic ram cylinder, 2 = Load cell and 3 = Pressure transducer and fitting surface. Subplot (b) illustrates a set of linear bearings, dimensions are in mm.

With increasing capabilities in Computational Fluid Dynamics (CFD) and High-Performance Computing (HPC), CFD 3-d tests are becoming more affordable and well suited to supplement empirical formulae, experimental studies, and full-scale trials although validation of computed results would still require data.

The drop test technique is used extensively to characterise slam loads in a more controlled environment. However, there are limited data available in the public domain, which is just limited to 2-d multihull vessels (Davis and Whelan, 2007, Swidan et al., 2014, Swidan et al., 2013). An exception is the study conducted by Swidan et al.(2016) and Swidan et al. (2017), where two series of 3-d drop tests were performed to evaluate the behaviour of a catamaran bow section during the water-impact phase at a range of constant speeds from 2.5m/s up to 5m/s in 0.5m/s increments. The aim of this study is to characterise the wetdeck slamming phenomenon and to provide designers and classification societies with an approach to predict impact loads magnitudes and pressure distributions, based on reliable experimental work and test bench data that would allow researchers to validate the numerical results.

The present work extends upon the experimental works conducted by Swidan et al.(2016) and Swidan et al. (2017) through providing non-dimensionalised pressure coefficients of the maximum pressure peaks of a catamaran during water-entry at two relative impact angles and range of impact velocities. It is very useful to represent pressure in terms of a dimensionless quantity, like that of lift and drag, as a step forward to eliminate the uncertainty related to experiments with scaled models, which is an issue currently being discussed by the international scientific community (Rizzo et al., 2018).

2. EXPERIMENTAL SETUP

To provide high-quality experimental data suitable for validation purposes a series of drop-test experiments were conducted using the Servo-hydraulic Slam Testing System (SSTS), at Industrial Research Limited, Auckland, New Zealand (Swidan et al., 2016).

Fig. 2 illustrates the main mechanical components of the SSTS. The hydraulic system can achieve a range of controlled water-entry velocities up to 10 m/s, with the required hydraulic power for each target velocity that is controlled by a servo-proportional control valve.

For the purpose of the present study, the impacts were conducted with the model at two fixed trim angles (⊠) of 0° and 5°. The water depth and temperature during tests were 1.15 m and 11°, respectively. All tests were performed in a controlled environment and with an initially calm water-surface.

The main particulars of the test model shown in Fig. 2 are: length (L) 500 mm, beam (B) 638 mm, height (H) 327.6 mm and total mass 14.8 kg, while the expected flow behaviour during water penetration of both parent centrebow and the amended centrebow is shown in Fig. 3. It was sized to ensure that there would be a gap between the model and the tank wall of double the model's overall beam. This was to minimise boundary condition effects and the possibility of wave reflections.

A three-dimensional Computer Numerically Controlled (CNC) router was used to cut the model out of 15 layers of glass reinforced plastic giving a total shell thickness of 10 mm with minimal surface roughness. Details of the used instrumentation on the test rig are given in Table I. However, further details about the device and uncertainty analysis can be found in Swidan et al. (2016).

Table I. Instrumentation Details

Gauge	No. of Channels	Manufacturer	Model	Maximum Range
High-speed video camera	0	Photron	Fastcam SA5	7500 fps
Position sensor	1	Vishay	REC 139L	3 m
Load cell	3	Precision transducers	LPC 5t	5000 kg
Pressure transducers	5	PCB piezotronics	113B- 26.68950	kNm^{-2}

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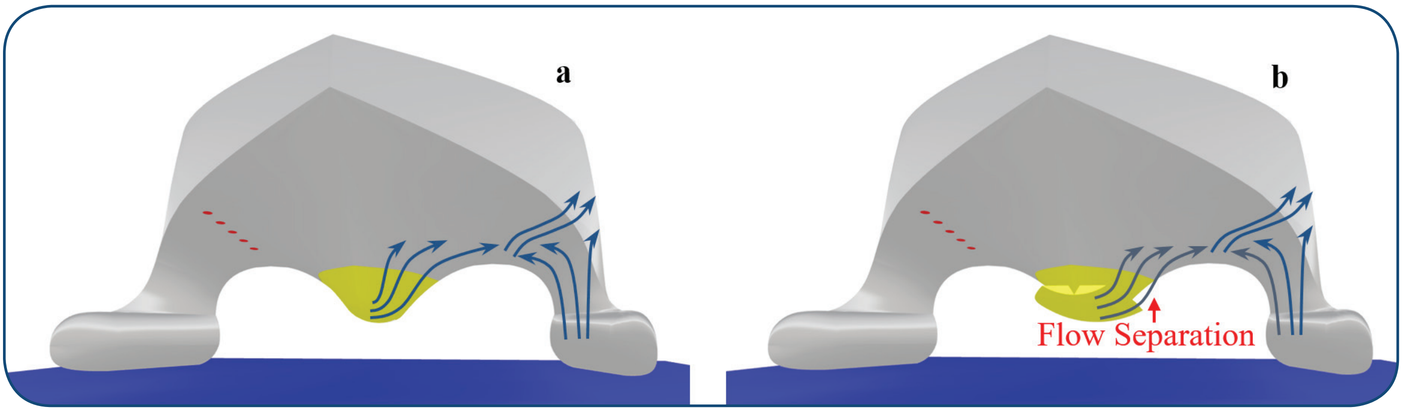

Fig. 3. Schematic drawing showing the expected low behaviour on one side during water penetration of; (a) parent centrebow and (b) amended centrebow (Swidan et al. (2016b).

Fig. 4. The new centrebow design of Saint John Paul II, Incat catamaran, length overall = 110m. (Swidan et al., 2019). Note: that all Incat manufactured vessels had previously a smooth centrebow without any appendigies for water separation during water-entry and to enhance her vessels' seakeeping performance.

3. RESULTS AND DISCUSSION

This section discusses experimental results to characterise the wetdeck slamming phenomenon and to gain knowledge with regard to the flow behaviour beneath an arched wetdeck, the work exerted, the slam load magnitudes, and pressure distributions when using two interchangeable centrebow configurations. The parent hull form is a generic wave-piercer catamaran (presented in Fig. 3.a), similar in style to those designed by Revolution Design Pty Ltd and manufactured by Incat Tasmania.

Swidan et al. (2017) proposed the second winged-centrebow (named in this study amended hull) as a new design for the centrebow and aimed to induce water separation at the tip of wings during water entry, as presented in Fig. 3.b and was implemented by Incat Tasmania in her new vessels starting from year 2019, as shown in Fig. 4. The objective of this early water separation is to generate an air cavity that can work as damper during wetdeck slamming. Another feature is the larger exposed area with a reduced deadrise angle to try and provide greater resistance during water-entry and reduce the impact velocity. Additionally, the winged shape of the amended centrebow is designed to increase the drag force during water-exit after slamming events, reducing the pitch motions.

3.1 Experimental Results

All the data presented starts at 0 immersion, e.g. the model touches the initially calm free-surface.

Fig. 5a illustrates the velocity traces of the tested model at an angle of trim of 0° on the left hand side and an angle of trim at 5° on the right hand side of the figure. The area under the curve (Fig. 5b) presents the energy exerted on both hull models due to hydrodynamic loads. Saving this energy reduces the probability of structural failure and the ability to design lighter weight ships without hull deformations (Payne, 1988). Although Fig. 5.b demonstrates that the measured force traces of the amend hull are with a slight reduction of 6% in slam force peaks when compared with parent hull at the same condition.

It is also interesting to see a great influence of the trim angle, which is the relative angle between the model and the initially calm water surface, on the severity of slam loads and pressure peaks. In contrast, Fig. 4c, illustrates that the peak slam pressures increase by 15% when utilising the amend centrebow over the parent hull.

Though the pressure peak distributions close to the impact region depend on the distribution of the normal component of relative velocity over that region (Cooker and Peregrine, 1995), this observation confirms the finding of Faltinsen et al. (1997) that large pressure peak magnitudes do not necessarily mean large stresses on the structure. Thus, integrating a limited number of pressures can lead to in-accurate force predictions, except where complete pressure mapping is provided.

Fig. 6. demonstrates the mean velocity of pressure pulses in the longitudinal direction that was evaluated on the basis of pressure transducer longitudinal locations as a gradient of corresponding slam pressure spiking times. This 3-d plot demonstrates that the wetdeck water impacts create a rapid change in water velocities. The related slam pressure peaks increase with the increasing rate of change of hydrodynamic momentum, which is strongly dependent on relative water impact velocity as well as transducer longitudinal location, with the maximum pulse velocity (vy) is at P1 being more than double the P5, as shown in Fig. 6.

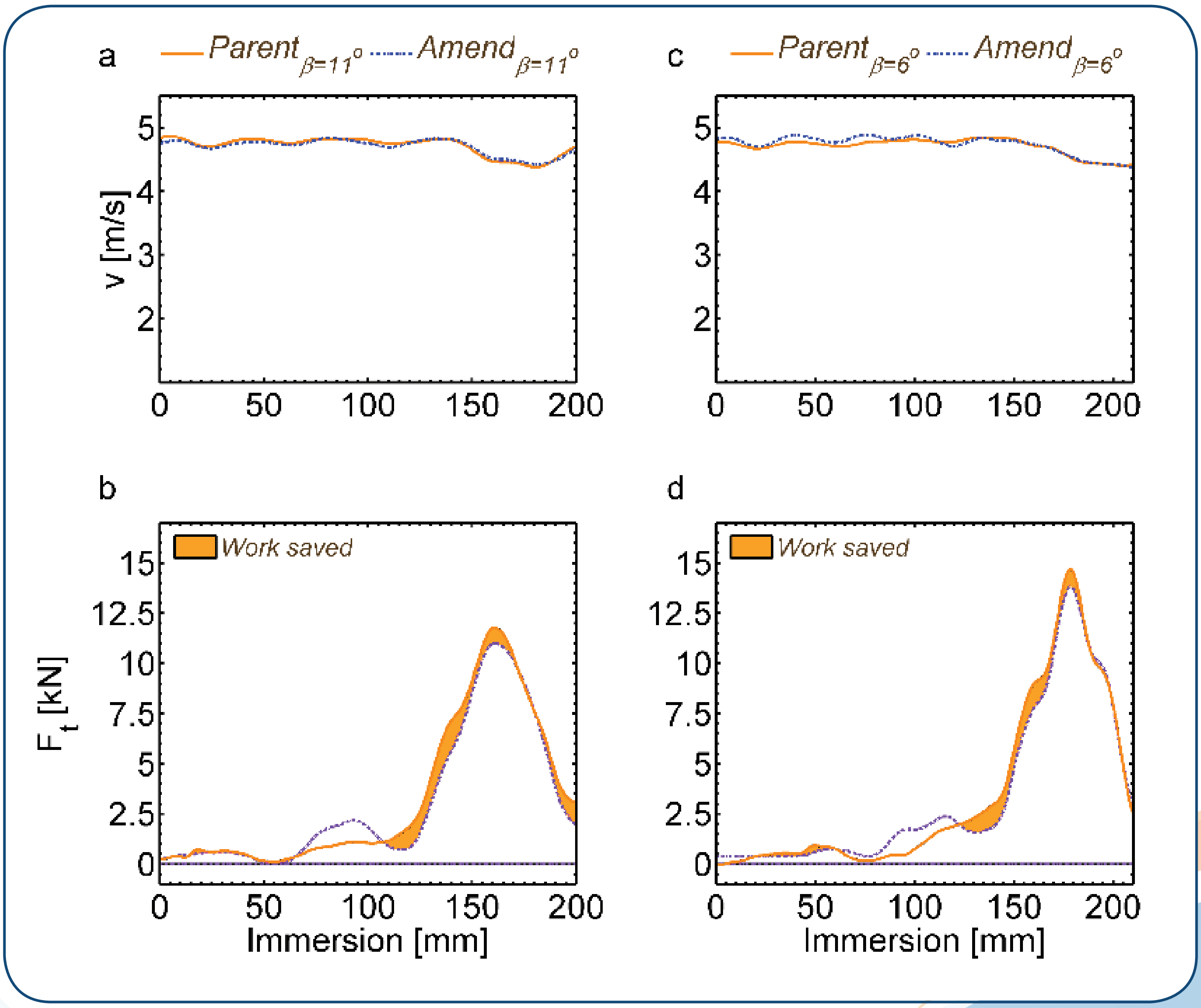

Fig. 5. Showing the experimental measurements of a catamaran bow hull model during water impact tests at approximately 4.5 m/s. Subfigures (a) show the measured velocity profile, (b) the measured forces and the work saved, (c) the mean pressure traces with respect to model immersion.

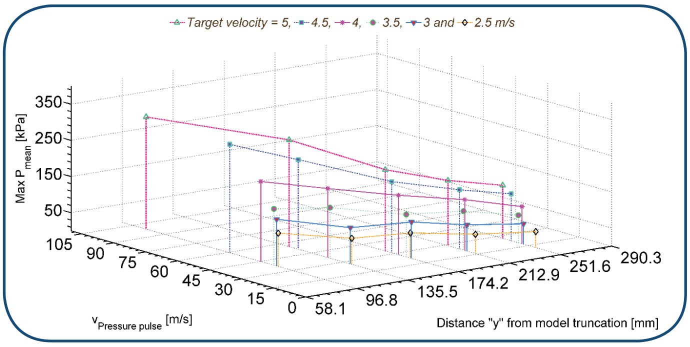

Fig. 6. 3-d plot showing the effect of the transducer location on both the peak slam pressures and the corresponding pressure pulse velocities (vy) in the "y" direction in relation to six water impact velocities. The x-scale presents the longitudinal locations of the five pressure transducers against the y-scale that presents the range of the calculated mean vy and the z-scale that presents the mean slam peak pressures of 26 tests.

The pressure pulse velocity, which could be extracted from Fig. 6, correspond to the development of water jet along the archbow during water entry at relatively high-speeds. The measured pressure as function of time was analysed and the pressure pulse was presented in Fig. 6. This would provide researchers with the water jet velocity along the archway, which would help them in solving boundary layer regimes and selecting adequate turbulence model for validating further numerical simulations based on calculated longitudinal velocity. These 3-d effects would not have been captured in the model experiments if the model had been simplified to 2-d sections.

Although, the pressure distributions demonstrate the possibility of finding a relation between the maximum peak pressure magnitude that occurs at a certain location, e.g. Pressure transducer number 1 (P1, see Fig. 7), and the rest of the five pressure transducers, the localised nature of such a transient slam pressure peaks makes the repeatability of those data uncertain, especially at less controlled environments, e.g. seakeeping tests or full-scale trials. Thus, it could be of an importance to find the maximum pressure coefficient of each hull model. This study is limited to finding the pressure coefficients of the parent hull for a minimum of three repeated water impact tests for the at relative impact angles of ***β*** = 11° and 6°, that are equivalent to angles of trim of 0 and 5 degrees respectively, and for all relative velocities, e.g. from 3 to 5m/s in 0.5 m/s increments.

The mean traces of maximum pressures at P1 are aligned using the cross-correlation function in Matlab that can detect and align the peaks of a number of signals and has allowed accurate calculation of the average of maximum pressure time histories.

From this, designers could be able to calculate the pressure coefficient at the two relative impact angles using the traditional Wagner formula, as presented in Eq. 1 and 2 (The terms mentioned in Eq. 1 and 2 are defined in Fig. 7`

(1) $$\xi_{\beta^\circ} = \frac{z_{Pmax(\beta^\circ)} - z_{\beta^\circ}}{z_{\beta^\circ}}$$

(2) $$C_{P(\beta^\circ)} = \frac{2P_{max(\beta^\circ)}}{\rho v^2}$$

The repeatability of the experiments is acceptable since ***CP***(***β°***) traces are in very good agreement. The maximum pressure coefficients of parent hull model ***CP(0°)max*** = 26 ±2 and ***CP(5°)max*** = 34.5 ± 1.5 are found approximately constant and uniform and it does not depend on impact velocity. It is interested to know that this was also noticed previously by a number of researchers, e.g. (Dobrovol'Skaya, 1969), (Zhao and Faltinsen, 1993), (Zhao.R, 1996), (Yettou et al., 2006) and (Lewis et al., 2010) but for other hull model shapes.

Fig. 8 demonstrates that the smaller the relative impact angle ***(β)***, the sharper the pressure coefficient trace, the more significant the pressure coefficient is ***CP(β°)*** (***max***) and the shorter the peak, this correlates well with slam force traces for ***β*** = ***6°***. Further numerical simulations are necessary to understand the disconnect between the slam force peaks and the pressure distributions using both hull model shapes. As, utilising a high-speed camera to capture the flow behaviour deemed to be limited for 3-d catamarans with protected hull structure.

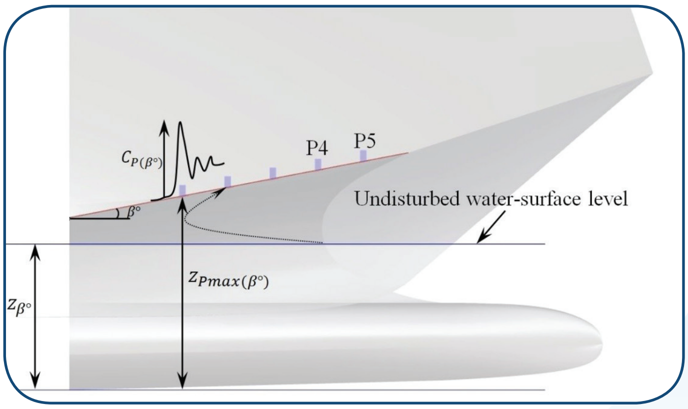

Fig. 7. Side profile view of model defining the variables used to non-dimensionalized the maximum slam pressure peaks at P1. Also shown on the archway are the locations of the five pressure transducers

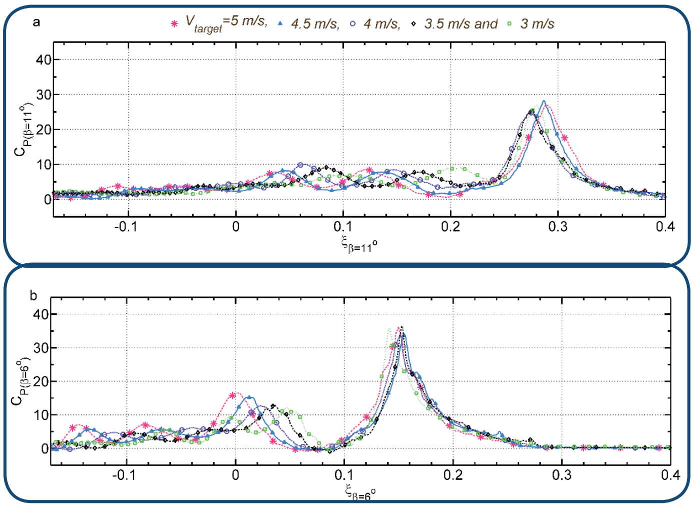

Fig. 8: Catamaran pressure coefficients at two relative impact angles with non-dimensionalisied catamaran entry-depth.

4. CONCLUSIONS

The presented work reports on a series of experimental tests that were conducted on a 3-d bow section of a catamaran model impacting with water in a 3-d regime. The catamaran model is constructed with two interchangeable centrebows. The experimental data and CFD results including flow behaviour, pressure distributions, vertical force, applied work and corresponding immersions gave new insights into the wetdeck slamming phenomenon.

It is important for classification society rules to consider the influence of pitch angle on wetdeck impact load severity, as it was found through utilising computational and experimental tests that an increase of 5 degrees in trim angle can increase the vertical slamming force on the entire model by up to 30%.

As a result of using the amended centrebow, flow on the tips of the wings separation was reported during centrebow-water entry. Thus, the larger air-cushioning effect between the wetdeck and water surface showed a decrease in the resultant force by 6% in comparison to the parent centrebow. This inventory idea has been implemented by Incat in her new built vessels.

It was observed that limited pressure distributions should not be used to assess slam loads due to the finding that localised pressure measurements are more dependent on flow behaviour than on the entire slam load magnitudes. Thus, larger peak pressure magnitudes (at selected locations) do not necessarily lead to a larger total force. The 3-d water-impact experiments can be extended by implementing scaled-velocity traces recorded from full-scale sea trials rather than conducting constant-speed water impact tests. This will enable further investigation on the issue of scaling of slam loads.

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A Proposed Protocol for GMP-BoK Implementation Gap Analysis – Case Study at AASTMT

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Abstract

Purpose: *Maritime Education and Training (MET) plays a crucial role in maintaining the safety and sustainability of the maritime industry. However, it remains behind the industry expectations to fulfill the gap regarding the required level of maritime capacities to safely control efficient new technology and keep them sustainable and effective during the industrial revolution era.*

The International Association of Maritime Universities (IAMU) developed the Global Maritime Professional Body of Knowledge (GMP-BoK) to address the current gap between the maritime industry expectations and the delivered Maritime Education and Training (MET) programs.

Design/methodology/approach: *This paper briefly introduces the GMP-BoK and proposes a protocol for a new analogous instrument to efficiently implement the GMP-BoK via a user-friendly method developed at the Arab Academy for Science, Technology and Maritime Transport (AASTMT). The developed analogous instrument helps maritime universities and institutes to digitalize and develop an integrated curriculum framework that is based on robust evaluation and data analysis to develop strategic plans to improve seafarer capabilities. Moreover, the paper suggests a protocol for mapping and analysis of maritime programs and courses, enabling educators to reliably perform gap analysis and identify repetitions within delivered courses and programs based on the GMP-BoK recommended practices. As a case study, the proposed protocol was validated utilizing the Maritime Engineering Technology Program (METP).*

Findings: *The findings of this study revealed that the examined METP includes 30% repetition and focuses on the cognitive and psychomotor methods of education, with little focus on the affective technique.*

Key-words:
GMP-BoK, Higher education, Maritime Education and Training (MET). STCW.

1. INTRODUCTION

The success and sustainability of any service industry such as the maritime industry are entirely subject to securing and preserving highly qualified human resources through effective Maritime Education and Training (MET). Effective education and training in the maritime sector are derived from scientific and academic rigour and the development of a clear link between practical skills, management techniques, and a focus on quality. Indeed, several industry-influencing factors determine the future of the international maritime industry and formulate the character of the next generation seafarer and the optimum MET curriculum.

The International Convention on Standards of Training, Certification and Watch keeping for Seafarers (STCW) was the first international standards for seafarer training, certification, and watch keeping. However, the convention's first version had many flaws, and later significant changes in 1995 and 2010 attempted to align the standards with the changing nature of the industry, legislation, and socio-cultural dynamics. Seafarer education and training nowadays are centred on the technical and affective competencies proposed by the STCW 1978, as amended (IMO, 2017).

The 2016 International Association of Maritime Universities (IAMU) Haiphong Statement recommends that in the context of IAMU,

> *"Degrees for seafaring officers should include educational outcomes well above and beyond the minimum requirements of the STCW to prepare future seafarers for a rapidly changing industry."*

IAMU embarked on a bold initiative to formulate a comprehensive guideline for the next generation of leaders under a new title "The Global Maritime Professional (GMP)" and formulated a task force to set up the action plan for the GMP initiative and establish the required roadmap.

In the same year, a new working group (WG) was established by experts from three universities; The World Maritime University (WMU), The Arab Academy for Science, Technology and Maritime Transport (AASTMT), and Satakunta University of Applied Sciences (SAMK), in addition to the executive director of the IAMU, to align the curricula of the IAMU member universities with the agreed Intended Learning Outcomes (ILOs) concept at national and regional levels taking into consideration their academic freedom and requirements of their jurisdictions.

In 2017, the WG gave its final report to the IAMU International Executive Board (IEB) in Varna, Bulgaria. The report recommended preparing a Body of Knowledge in detail, including its content and the action plan for accomplishing the task.

Subsequently, the working group set up two Fundamental Principles for establishing the GMP. The first was to identify the learning outcomes deemed common for optimizing human resource competency for the maritime industry across all national boundaries by focusing on student ability and constructive alignment learning outcomes-based education as opposed to objectives-based education. Based on the internationalization principle of respecting the IAMU member universities' academic freedom and jurisdictional sovereignty, the second principle was to leave the determination of specific curricula, syllabi, and learning activities to individual Higher Education systems in sovereign states.

The project passed through several stages, starting with the initial phase of establishing the GMP-BoK down to the final stage of developing a self-evaluation system for confirming whether a member university of the IAMU embodies the philosophy of the GMP-BoK.

The GMP-BoK initiative provides the underpinning philosophy of higher education by envisioning significant curricular improvements in academic preparation and adds a new element, leadership, and ethics; both are increasingly necessary as technology and globalization continue to disrupt the IAMU profession. Preparing maritime students for this new environment is crucial for the near-coming digitalization era of the international maritime industry.

In 2019, IAMU established a new WG for "GMP implementation" to support the proper adoption of this new concept by IAMU member universities. AASTMT was selected as an advisor to the "GMP implementation" WG team members. Subsequently, AASTMT decided to adopt the GMP concept and therefore established an internal GMP. Steering Committee (GMP-SC) to establish and supervise the implementation process.

This paper aims to highlight the importance of the GMP-BoK, the AASTMT vision for implementation. In particular, the research focuses on the gap analysis process that was conducted as a part of the GMP-BoK implementation process in parallel with the MET development policy of AASTMT.

2. GMP-BOK CONCEPT AND METHODOLOGY

The GMP-BoK concept came to take the MET system from the traditional objective-based education to the modern outcome-based educational concept. The outcomes-based educational approach is an "Active" approach that focuses on the student who is learning, which focuses on student ability, Constructive alignment, and Learning outcomes and not learning objectives (Biggs & Tang, 2011).

To do so, the educator must first identify which educational domain this newly added focus area represents, therefore, the GMP-BoK presents a set of tables clarifying each educational domain in the selected focus area.

2.1. Educational Domains

Every learning process can be generally categorized into three educational domains, Cognitive –Affective – Psychomotor, where every subject matter may contain one or two or even all three domains. The educator must identify the educational domain in the subject matter that best suits the learner in a specific educational phase or level (Bloom et.al., 1956).

The first of these domains, the cognitive domain, contains learning skills predominantly related to mental (thinking) processes and the improvement of intellectual skills of the learner through a simple learning process focused mainly on mental abilities to remember, understand, memorize, and, later on, recall and apply the information into different applications.

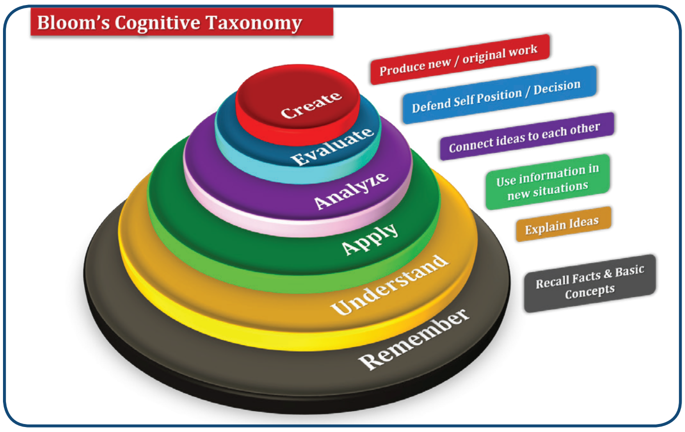
The affective domain describes how certain issues are dealt with emotionally, such as feelings, values, appreciation, enthusiasms, motivations, and attitudes. Affective is the stimulus for the action; it is a monitor and a controller of the cognitive processing activities. Without the affective domain, learners will find learning difficulties, knowledge will not be processed well, and cognitive activities will not run efficiently.

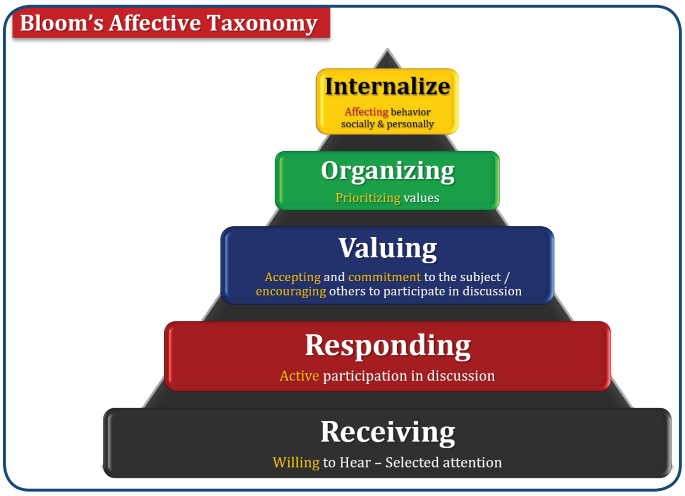
The psychomotor domain merges physical movement, coordination, and use of the motor-skill areas. Development of these skills requires practice and is measured in terms of speed, precision, procedures, or techniques in execution. Thus, psychomotor skills range from manual tasks, such as digging a ditch or washing a car, to more complex tasks, such as operating a complex piece of machinery. This domain is much accounted for in MET, but if not well integrated with previous domains, the psychomotor domain will be fragile and poorly performed.

2.2. Taxonomies adopted by the GMP-BoK

To have a sensible progressive and accumulative procurement of information or data in a single educational domain, the domain was dissected into gradual "Levels of Achievements" (LoA), best explained by the Taxonomy of Learning or educational domains formulated by a group of researchers led by Benjamin Bloom. Bloom's taxonomy was first developed and described between 1956-1972 (Bloom et. Al., 1956) and revised in 2001 by Anderson and Krathwohl.

The GMP-BoK adopts Bloom's taxonomy in both the cognitive and affective domains. However, due to the vocational nature of the MET, Simpson's taxonomy was adopted for the psychomotor domain. The following three figures illustrate the LoAs for each learning domain, showing the gradual nature of these levels. All levels are cumulative and cannot be dependable, as skipping one level could lead to improper assimilation of the domain (Anderson & Krathwohl, 2001) (Simpson, 1972).





Figures 1 & 2: Bloom's Taxonomy – Levels of Cognitive Domain – Levels of Affective Domain.

Source (modified): Anderson & Krathwohl, 2001

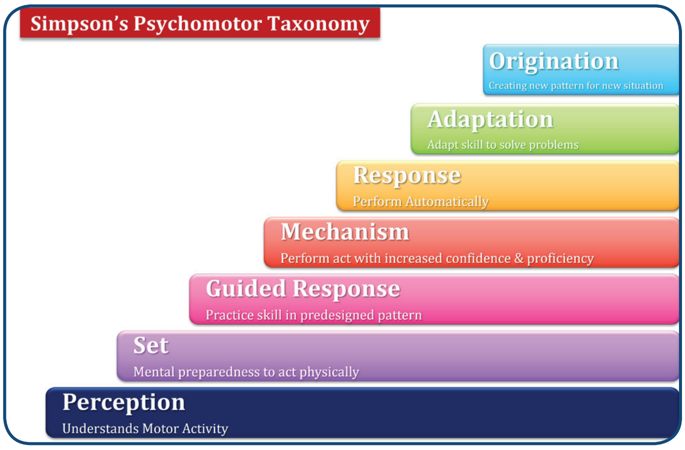


Figure 3: Simpson's Taxonomy – Levels of Psychomotor Domain.

Source (modified): Simpson, 1972

2.3. ILOs in Each Level of Achievement

As a final step of the methodology, the GMP-BoK created a table for each of the three domains containing the newly added focus areas that the GMP-BoK adopted. Each table contains the domain's LoAs as described in the taxonomy.

Table 1 illustrates an example of a "Ship Stability" focus area. The table shows the LoAs for a single domain, in this case, the cognitive domain. Each LoA has several ILOs spelled out as a brief sentence describing what the students should be able to do by the end of the respective part of the program. This ILO is intended as a guiding line for the educator to properly design an educational program covering all three domains in this focus area.

Table 1: Levels of achievement and ILOs (Cognitive Domain - Bloom's Taxonomy)

Subject	Ship Stability					
Cognitive Domain	**Remembering**	**Understanding**	**Applying**	**Analysing**	**Evaluating**	**Creating**
	To remember the list of solving equations.	**To understand** the terms, symbols & the construction of the equations.	**To apply** different scenarios to test ships' stability, e.g. by shifting weights.	**To analyze** key factors affecting ships' stability.	**To evaluate** the weight of relevant factors influencing ships' stability.	**To create** new techniques for analyzing ships' Stability.

Although, there are no hard rules to the number of learning outcomes, normally 1 to 12 PLOs are about right per program and from 4 to 6 CLOs per course. There are many available open-source websites for writing a learning outcome, such as the learning outcome generator and easy generator. All tools share the concept that every learning outcome should be composed of action verbs, content, context, and demonstrable outcome (see Table 2).

Table 2: Showing examples of writing a constructive learning outcome (UNSW, 2022).

Action Verb	Content/ Topic	Context	Demonstrable Outcome
Construct	a reference list	using an appropriate disciplinary style	Construct a reference list using an appropriate disciplinary style
Demonstrate	effective negotiation	with health care providers	Justify solutions to case studies set in hospitals with an identified health care provider
Apply	principles of good learning & teaching	in higher education	Detail your approach to teaching, drawing on your own students' learning experiences
synthesize	elements of a claim of defence	according to law	Prepare court documents in accordance with relevant court rules within the required timeframes

2.4. GMP-BoK Tiers

The GMP-BoK categorizes the learning outcome requirements at four levels or tiers: A, B, C, & D.

- **Tier A:** Operational level certificate of competency (STCW) and a Bachelor of Science Degree.
- **Tier B:** Management level certificate of competency (STCW) and a Bachelor of Science Degree.
- **Tier C:** Management level certificate of competency (STCW) and a Master of Science Degree.
- **Tier D:** Management level certificate of competency (STCW) and a Doctoral Degree.

Each tier acts as a prerequisite to that which follows.

The GMP-BoK sets out tables that show the different GMP tiers as they relate to the relevant taxonomies levels and the specific knowledge, skills, and attitudes (KSAs), as shown in Table (3).

Table 3: Distribution of the GMP tiers on the levels of achievements for the specific KSAs

Principles and Practices Related to;	Levels of Achievement in the Cognitive Domain					
	1 Remembering	2 Understanding	3 Applying	4 Analysing	5 Evaluating	6 Creating
Foundational Elements						
1. Mathematics	A	A	A			
2. Natural (physical) sciences	A	A	A			
3. General humanities and social sciences	A	A	A			
4. English language and maritime communication	A	A	A			
5. Computing and informatics	A	A	A			
6. Physical and mental fitness	A	A	A			
Academic Elements						
1. Problem recognition/ solving	B	B	B	B	C	D
2. Critical thinking	A	A	B	B	C	D
3. Academic research	A	A	A	B	C	D
4. Contemporary global issues	A	A	B	B	C	D
Professional – Technical Elements						
1. Technical competencies as per international requirements (STCW)	A	A	A	B	C	D

Source: GMP-BoK (IAMU, 2019)

3. IMPLEMENTATION OF THE GMP-BOK AT AASTMT

AASTMT has a long history in developing international standard MET programs. Since its inception, AASTMT's purpose has been "to strengthen and develop the maritime sector in each of the participating countries [of the League of Arab States]" through high quality MET (Moukhtar, 1974). Fifty years later, AASTMT continues to serve its purpose not only in the Arab world but as part of a growing global network of maritime universities, the IAMU, seeking to propel the maritime industry into the future by providing the maritime industry with the highest quality maritime professionals as described within the GMP-BoK.

The successful implementation of the GMP-BoK, therefore, requires a whole institute approach that considers the needs and connectivity of the various administrative and educational levels. The AASTMT Implementation GMP-SC set up a roadmap for the initial implementation of the GMP-BoK (Phase 1) as a model bearing in mind the core GMP concept; the connection among the three parties of the Triple Helix concept.

3.1. GMP-BoK Phase 1 Implementation Roadmap

Phase 1 plan passed through three stages. The first stage commenced with several seminars and workshops to introduce the GMP concept to the AASTMT maritime sector and the relevant national and regional stakeholders. The second stage aimed to set the targets and provide a roadmap for an implementation model (Figure 4). This implementation model was applied to a chosen program within the maritime sector, and the same model was later proposed to the IAMU GMP Implementation WG. Finally, the first phase ended by presenting a GMP Implementation model to the IAMU Presidents Forum during the IAMU Annual General Assembly (AGA21) events in October 2021 in Alexandria, Egypt. Currently, the AASTMT GMP-WG is working with the AASTMT maritime sector entities to implement the GMP approach completely within the next phase.

3.2. Implementation Hierarchy and Concepts

A simple Plan-Do-Check-Act (PDCA) cycle for implantation is used as four discrete processes are envisioned: planning, implementation, monitoring and reporting, and reviewing. The implementation process requires both a top-down approach and a bottom-up approach. Figure 5 shows both approaches as they are being applied to implementing the GMP-BoK in AASTMT.

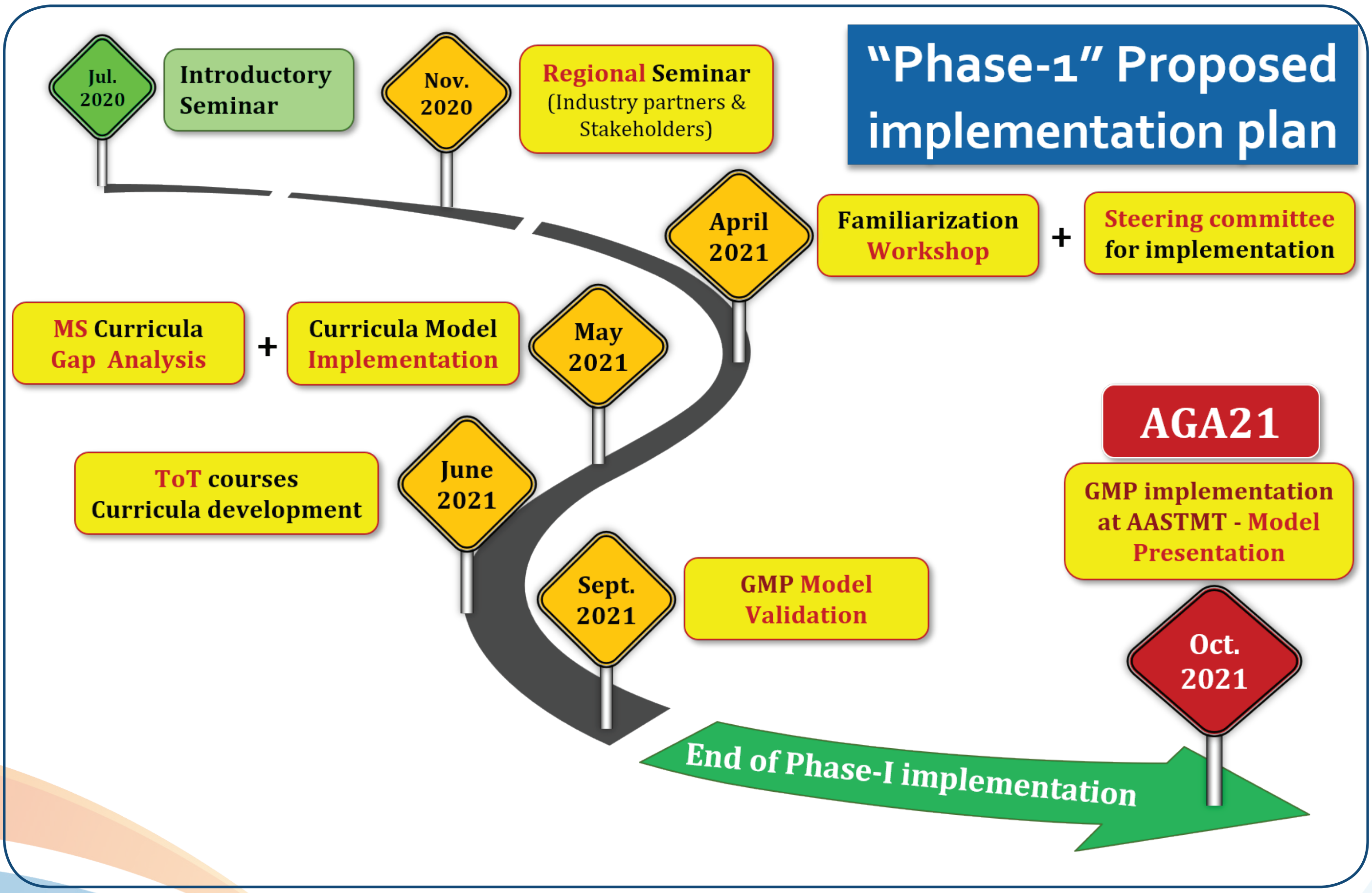


Figure 4: AASTMT Implementation Plan – GMP (Phase I)

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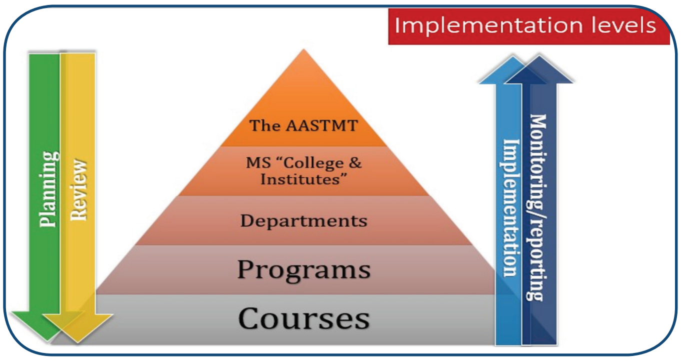

Figure 5: The AASTMT GMP-BoK Implementation Hierarchy

The initial planning process naturally follows a top-down approach where the strategic directions of AASTMT's Maritime Sector (MS) are spelled out. Each entity within MS then incorporates these strategic directions into its own strategic plan which is consequently reflected in the aims and learning outcomes of its programs (PLOs) and subsequently the courses (CLOs) fulfilling these programs. In this regard, AASTMT has created a GMP-SC responsible for overviewing the GMP planning process.

The implementation process follows the reverse direction, a bottom-up approach, starting with applying the GMP-BoK at the course level to realize each Course Learning Outcomes (CLOs) and working the way up to fulfilling AASTMT's strategic targets. Concurrently, monitoring of the implementation process and reporting follow the same direction. Subsequently, the GMP-SC reviews the previous procedures and makes necessary recommendations. AASTMT also realizes the importance of maintaining a solid link with the government represented by the Egyptian Maritime Safety Authority (EMSA) and industry represented by AASTMT's many partners in the maritime field. First introduced by Etzkowitz and Leydesdorff (1995), this triple-helix approach to MET is especially critical in this era of continuous technological disruptions as presented by the ongoing fourth industrial revolution (4IR). AASTMT understands that the envisioned GMP should be at the heart of the triple-helix model (Figure 6).

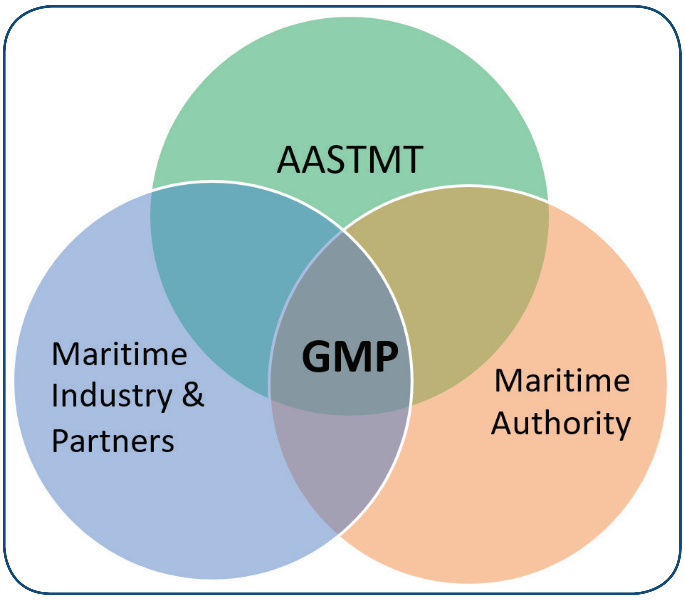

Figure 6: AASTMT Triple-Helix approach to the GMP

3.3. GMP-BoK Implementation Mechanism at AASTMT

As previously mentioned, AASTMT moved towards the GMP concept implementation in the curriculum and programs of the AASTMT maritime education and training institutes.

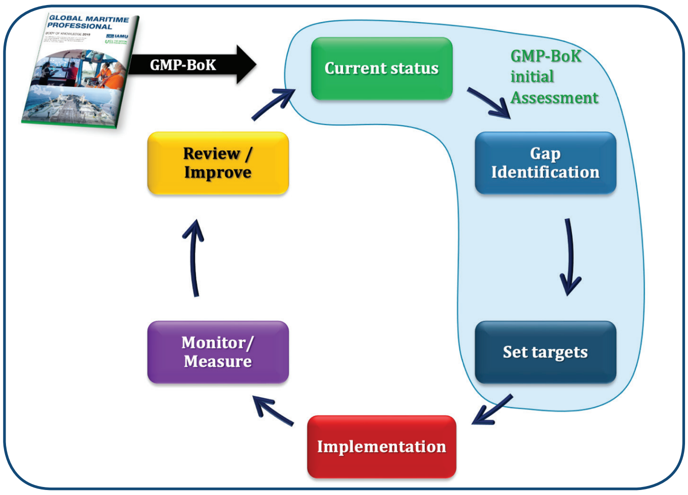

Figure 7: AASTMT GMP Implementation – Self-Assessment Loop

Following the successful validation of the initial implementation model, the AASTMT GMP-SC set up a five-year action plan for the GMP-BoK full implementation. The procedure commenced by evaluating the current status to identify the gap between the present and the targeted level of achievement. The implementation process is presented as a continuous self-assessment loop, as shown in Figure 7.

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4. GAP ANALYSIS AND MAPPING

Based on the proposed self-assessment loop, the gap analysis is one of the main processes for validating and revalidating the implementation procedures. In accordance with the five-year action plan for the GMP-BoK full implementation, AASTMT has developed a protocol for gap analysis and mapping for maritime programs and courses. The protocol allows educators, course coordinators, and program coordinators to reliably perform gap analysis and identify repetitions within delivered courses and programs based on GMP-BoK recommended practices.

The developed analogous instrument (mapping tool) helps maritime universities and institutes to digitalize and develop an integrated curriculum framework based on robust evaluation and data analysis to develop strategic plans to improve seafarer capabilities. The instrument balances the three key learning domains of cognitive, affective, and psychomotor practices while focusing on different levels of achievement in four enabling focus areas, e.g., fundamentals, academics, profession and soft skills required for a competent seafarer, as shown in Figure 8.

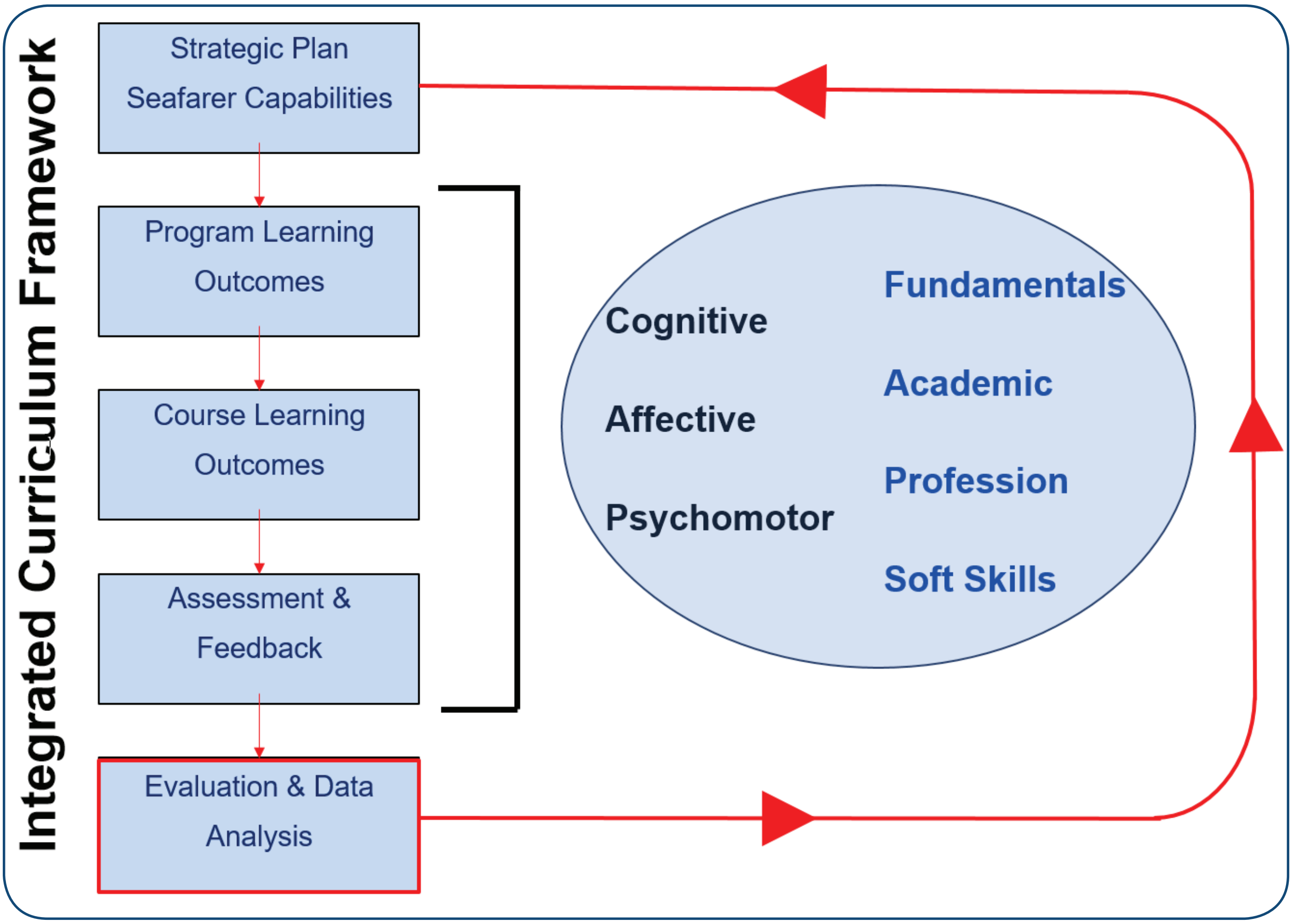

Figure 8: Showing a line diagram of a proposed integrated/digitized curriculum development framework

The mapping tool takes into consideration that the recommended procedure, data structure, and coding strategy can be easy to implement on paper or electronically and convenient for analysis and data post-processing for faculty.

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All maritime programs and courses, e.g., of the four defined tiers in section 2.4 of this manuscript, should align and contribute to one/or a number of the targeted focus areas as defined in the GMP-BoK, and presented in Figure 9.

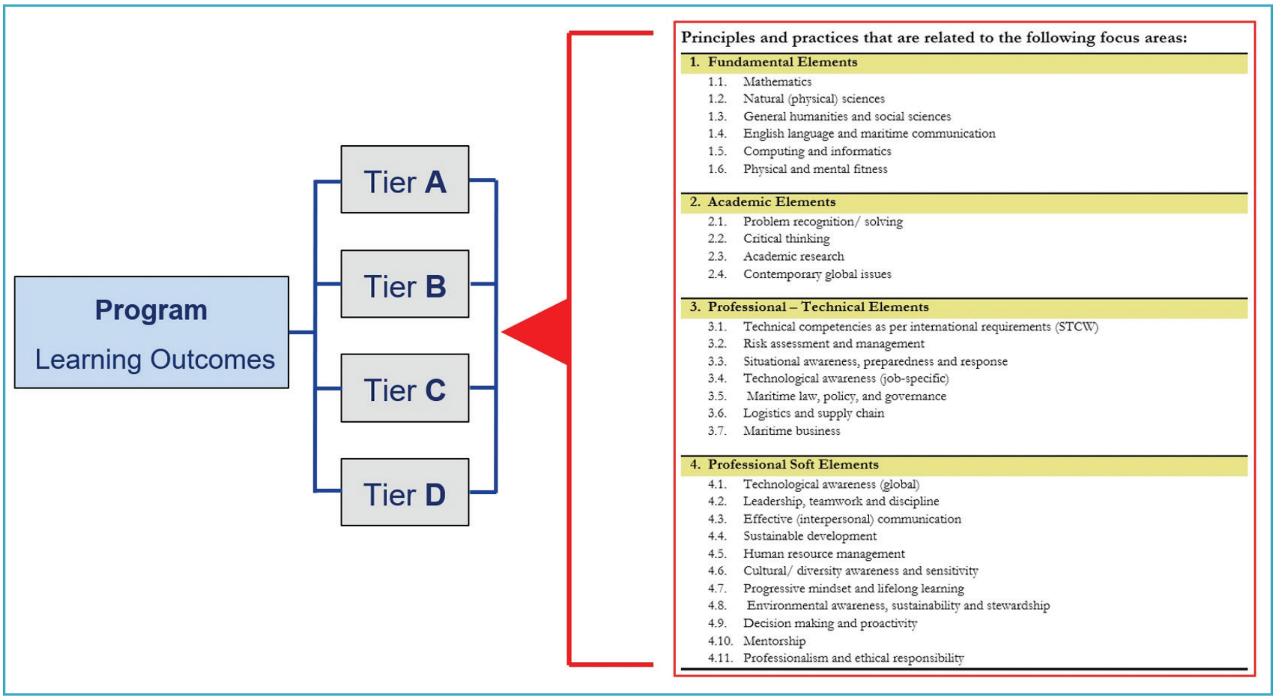

Figure 9: Showing the focus areas as defined in the GMP-BoK.

For this study, the Maritime Engineering Technology Program (METP) in AASTMT was selected to perform both mapping and gap analysis studies utilizing the developed mapping tool. To accomplish this, the PLOs of the METP program were inserted into the mapping tool and the output data were analyzed robustly.

To achieve this, each METP's PLO was mapped with the recommended focus areas shown in Figure 10, and just a symbol/s were selected in the corresponding box, as shown in Figure 10, where CO refers to cognitive, AF = affective, and PS = Psychomotor.

This Analogous Instrument is Developed in the Arab Academy for Science, Technology and Maritime Transport (AASTMT), by (A.Swidan, 2021), to Assist IAMU Members and Maritime Universities Worldwide in Mapping Maritime Programs, Courses and Units with Corresponding GMP-BOK' Teir Level.
All IP rights are protected by law and goverened by AASTMT IP policy.

Date:	26th Oct 21	Program Name:	Mapping GMP-BOK	Coordinator:	Professor Gamal Ghalwash	No. students:	Large	Developed by:	Dr Ahmed A. Swidan
Type of Instituition:	College of Maritime Transport	GMP Tier:	GMP Tier A			Degree:	Bachelor of Technology (BT)		
Service:	Education	Classroom Arrangement:	On-campus						

	1. Foundational						2. Academic				3. Professional - Technical							4. Professional - Soft											Comments
Sub Elem.	1.1	1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3	2.4	3.1	3.2	3.3	3.4	3.5	3.6	3.7	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	4.10	4.11	
PLOs																													
a	CO	CO			CO		CO		CO		CO		CO					CO										CO	
b							CO	CO AF PS																					
c	CO PS	CO PS			CO PS		CO PS												CO PS	CO PS						CO PS	CO		
d			CO AF							CO PS	CO PS	CO PS	CO	CO AF				CO PS			CO AF	CO AF	CO AF		CO PS			CO	
e	CO PS	CO PS		CO	CO	CO	CO PS	CO PS		CO PS	CO PS	CO PS		CO PS				CO PS											
f							PS	PS			PS	PS	PS	PS				PS											
g															CO	CO	CO		CO	CO						CO			
h			CO			CO															CO			CO			CO		
i			CO	CO PS		CO				CO			CO		CO				CO PS	CO PS		CO PS	CO PS			CO PS			
j																			CO	CO		CO	CO				CO	CO AF	
k												CO PS	CO PS						CO PS	CO PS						CO PS	CO PS	CO PS	

Figure 10: Mapping of the METP

5. GAP ANALYSIS RESULTS AND DISCUSSION

5.1. Results

The results of this study are presented in Figure 11, showing that the cognitive method of education is dominant with over 61%, while the affective technique is the lowest percentage at 6%, and the Psychomotor reaches 33%. The data display was also capable of identifying levels of repetition within the PLOs as shown in the summary report in Figure 11, where light blue refers to a gap, medium blue refers to covered once, and dark blue refers to that PLO covered for a couple of times, and the red highlights a repetition for more than two times.

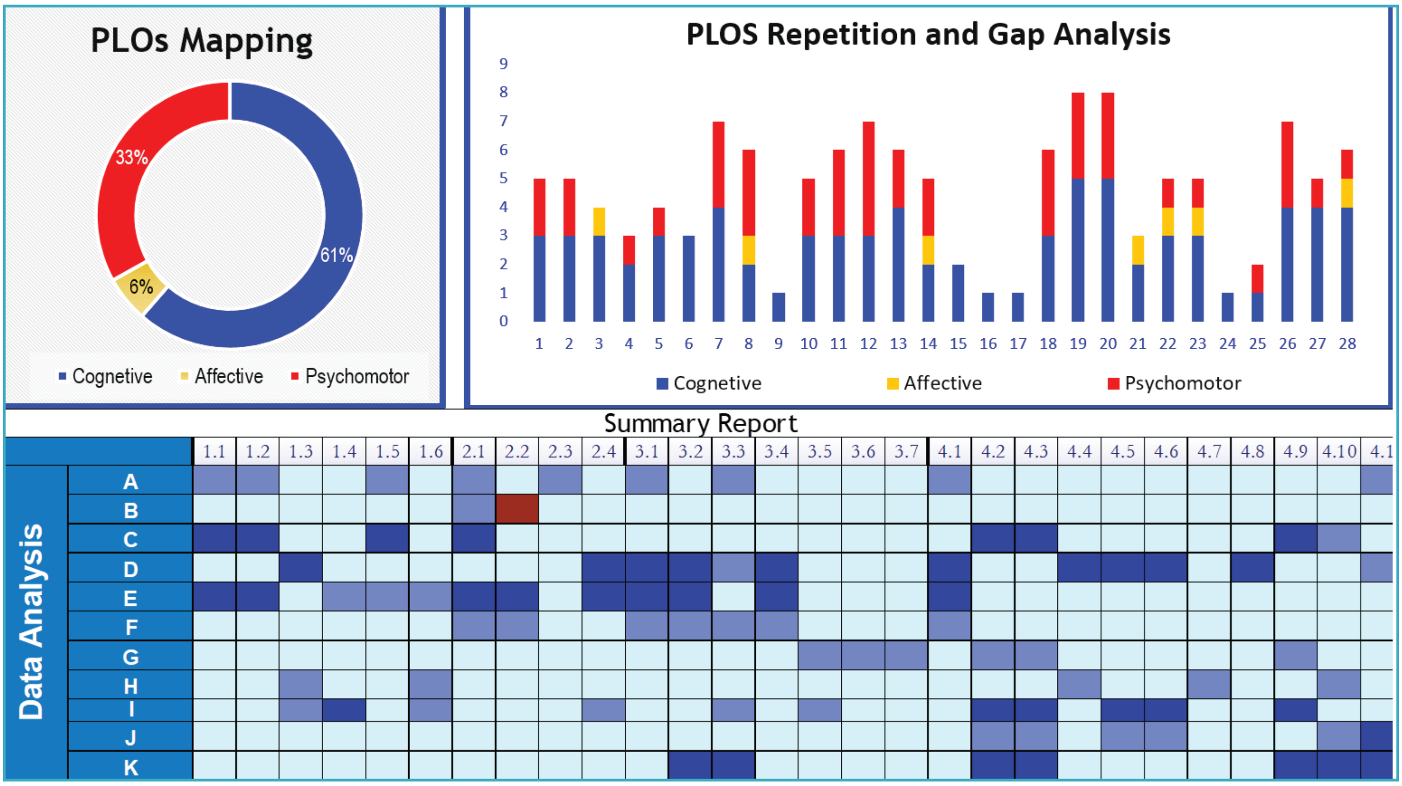

Figure 11: GMP-BoK mapping tool – Summary Report for level of competencies of the METP

5.2. Discussion

Based on the above outcomes, the cognitive domain in the METP program shows the highest level of presence especially compared to the affective domain, an expected outcome due to the current international MET system, which does not explicitly consider the required affective attitudes. On the other hand, the psychomotor domain displayed an expected rate suitable and in consistence with the vocational skills requirement for a dynamic industry such as the maritime industry.

6. CONCLUSION

Maritime industry-influencing factors determine the future of the field and formulate the character of the next generation of seafarers and, therefore, the required MET curricula.

The GMP-BoK was mainly established to enhance curriculum design in IAMU member universities by adding new focus areas to the MET process. It is based on two principles: firstly, to identify the learning outcomes focusing on student ability and learning outcomes-based education. Secondly, to leave the determination of specific curricula, syllabi, and learning activities to individual higher education systems in sovereign states.

The implementation of the GMP-BoK by AASTMT is applied through a simple cycle for as four discrete processes are envisioned: planning, implementation, monitoring and reporting, and reviewing.For the purpose of this study, the METP program in AASTMT was selected to perform both mapping and gap analysis studies utilizing the developed GMP-BoK mapping tool.

The mapping process results show that the METP program focuses mainly on the development of cognitive skills followed by psychomotor skills. While results indicate the need for future enhancements regarding affective attitudes. The mapping process was also capable of identifying levels of repetition in the chosen program.

As a result, the METP Curriculum design was enhanced by adding newly selected focus areas from the GMP-BoK. Finally, the user-friendly GMP mapping tool developed by AASTMT may help other member universities inside the IAMU community to effectively implement the GMP-BoK.

Future work will include a thorough assessment of the taught programs at AASTMT from tier A to tier D to align with AASTMT's strategic plan.

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