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Table of Contents

page no.
Articles

Potable Water Generation from Atmospheric Moisture in Coastal Areas Using the Thermoelectric Effect

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Abstract

Purpose: *Although water covers more than two-thirds of the Earth's surface at nearly 70%, potable water is still scarce and insufficient to the consumption rates stipulated by the standards of the World Health Organization (WHO). Therefore, many countries, where fresh water resources are scarce, have directed their efforts to conducting research and studies to find suitable ways to provide drinking water from non-conventional sources. Researchers have found multiple ways to desalinate seawater; such as reverse osmosis devices, evaporation and re-condensation of sea water, recycling polluted water, or drilling artesian wells to extract groundwater. However, the disadvantage of these methods is that they are financially costly and require the region to be located in a geographical area close to the sea. They may also be disrupted for various technical reasons; such as lack of energy to operate or damage to mechanical parts.*

Design/Methodology/Approach: *This study was conducted using quantitative methodology by collecting information about weather conditions in the geographical area of the northern coast of the city of Alexandria at geographic coordinates (Lat. 31.2 and Long. 29.95). It aims to design a device for generating water from atmospheric air using the thermoelectric effect (Peltier effect), which is characterised by simplicity of design and distance from complex mechanical installations. It is used to solve the problem of drinking water scarcity on the northern coast of Egypt, which is characterised by the relatively high humidity of air (60-70%), especially during the months from January to August.*

Findings: *The results have reached the possibility of using this device to generate 2.86 litres/hour of fresh drinking water at a temperature of 30 degrees Celsius and a relative humidity of 60% with an average electrical energy consumption of 0.02 kW/h/litre. This amount is suitable for the daily consumption of a family consisting of (4-5) adults according to the standards of the World Health Organization (WHO), as it is economically inexpensive in terms of its electrical energy consumption.*

Key-words:
Atmospheric Humidity, Dehumidification, Moisture Harvesting Relative humidity, Water Capture, Water Generation, Peltier effect, Thermoelectric.

1. INTRODUCTION

According to the World Health Organization (WHO), clean water is essential to human health. However,, almost 800 million people in the world do not have access to clean water. The reasons for this are many and varied, yet they include factors such as climate change, poverty, and poor infrastructure. In addition, the demand for water is increasing all the time as the world's population grows. Researchers have resorted to finding various alternative sources to traditional sources of drinking water to overcome the problem of providing potable water from their traditional sources. These include using recycled waste water, using desalination plants, and tapping into underground water supplies. These methods have various drawbacks, such as the need for infrastructure, expensive technology, and the potential for environmental damage.

In the context of the search for a source of potable water characterized by the possibility of providing it anywhere in the world and at the same time having good economic feasibility, this research paper deals with an attempt to generate potable water from the moisture content in the air. By using a process known as humidification, it is possible to extract water from the air. This process is not only technically feasible, but it also has the potential to be cost-effective. When tackling the problem of water generation from the atmosphere, the first step is to analyze various dehumidification methods. This research looks into how to extract potable water from the atmosphere using advanced technology that is as free of problems as possible when compared to other technologies.

During the preliminary investigation, three common psychometric dehumidification strategies stood out for lowering the temperature below the dew point (condensation by refrigeration), pressure consolidating, or a combination of the two. In addition to this technique, the wet desiccation technique can be used for the aforementioned purpose. These strategies are discussed in more depth until the technical problems with these techniques become clear. The most traditional method for converting the moisture content of the air into water is dehumidification. Refrigeration by using of traditional refrigeration cycle relies on passing air over cooling coils to lower the dew point of the air, and this is shown in Figure 1 (Michael Giglio 2015)

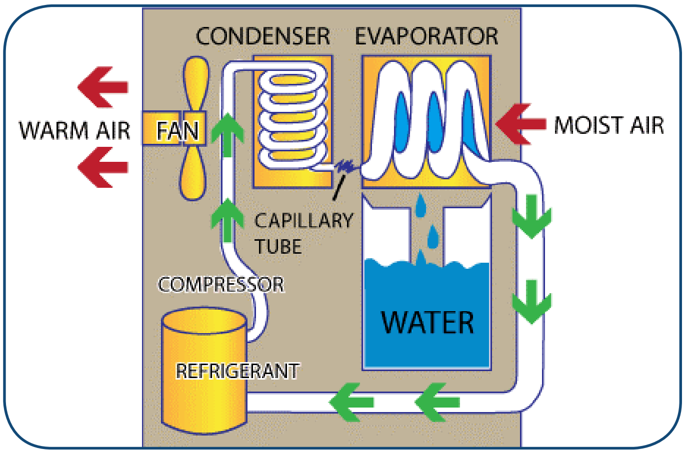

Fig. 1. Dehumidification by refrigeration (Michael Giglio 2015)

For more clarity, the traditional refrigeration circuit is also called the vapour compression cycle, which is shown in Figures 2 and 3. The compressor, condenser, expansion valve, and evaporator are the four main parts of the basic vapour compression cycle, respectively. This four equipment are connected to tubes in which the refrigerant is circulated. When the compressor starts receiving the refrigerant as a saturated vapour, its pressure and temperature are raised at constant entropy until it reaches the highest pressure and temperature values in the cycle before entering the condenser.

Through the condenser, the temperature of the refrigerant is reduced when the pressure is constant and converted to the liquid state before it enters the expansion valve by rejecting the amount of heat that the refrigerant has gained outside the cycle. The refrigerant enters the expansion valve to reduce its pressure to the lowest value, which is the value equal to its pressure before entering the compressor, and that is when the enthalpy is constant. After the refrigerant exits the expansion valve, it enters the evaporator, which converts it back to saturated vapour by absorbing the latent heat from the surrounding medium (Animesh Pal 2018).

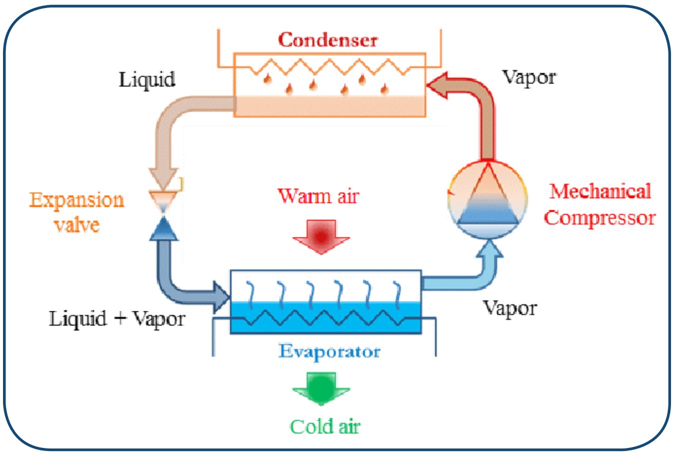

Fig. 2. Vapor compression cycle equipment (Animesh Pal 2018)

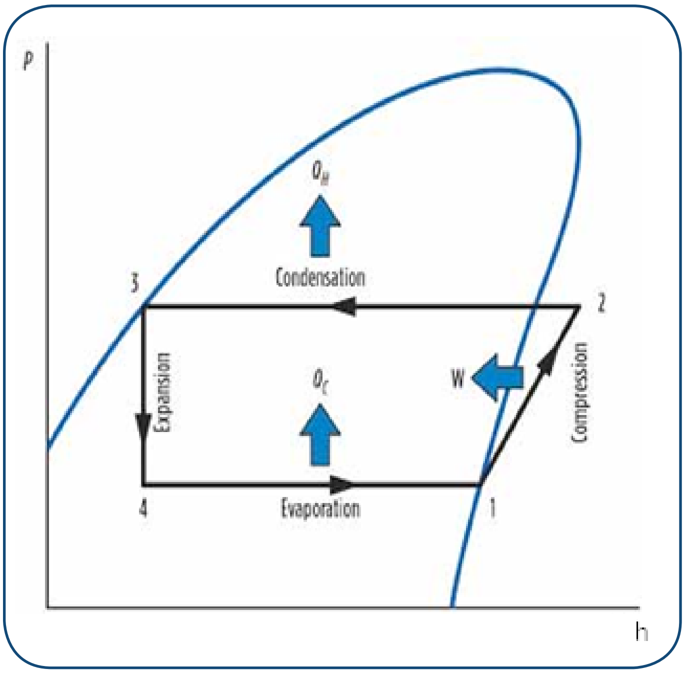

Fig. 3. Vapor compression cycle (p-h) diagram (H. Y. Noh, 2019)

One of the techniques also used to convert atmospheric moisture into water is air compression dehumidification. This technology depends on raising the pressure of the wet air until the dew point rises and the air condenses at the temperature of the surrounding medium. The air pressure can be five times the atmospheric pressure until it reaches the degree of condensation. The degree of condensation ranges from 2 to 3 OC which requires air tanks with strong walls that can withstand pressures up to 5 bar,as shown in Figure 4 (Ionmax, 2022).

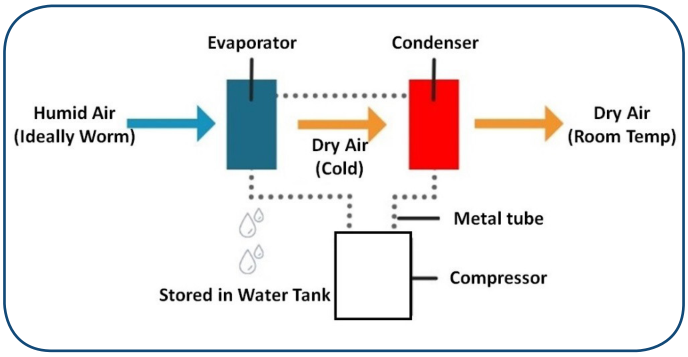

Fig. 4. Air Compression dehumidification (Ionmax, 2022)

Not only that, but there is another way to get water from atmospheric humidity which is called dehumidification by liquid desiccant. It is the technology of removing humidity from the air using liquid desiccants and it depends on the absorption of water vapor from the air by passing it through a special chemical solution such as Bentonite Clay, Silica Gel, Molecular Sieve, and Carbon (CLARIANT, 2022)The ability of the chemical solution to absorb humidity from the air depends on its concentration and temperature. Figure 5 shows the installation of the device used to remove humidity from the air (TROTEC, 2022).

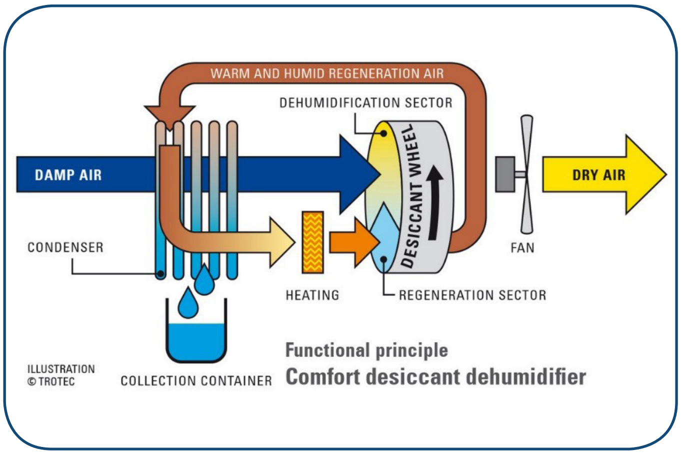

Fig. 5. Dehumidification by desiccation (TROTEC, 2022)

Due to the disadvantages of the previous methods in terms of the presence of complex mechanical parts or the use of materials that may negatively affect human health, such as freons and moisture-absorbing

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chemicals, the idea of using another method to generate water from the moisture content in the atmospheric air, which is the method called (Thermoelectric Refrigeration) arose. This technology is equivalent to vapor compression technology, but it depends on converting the difference in voltage between the ends of the thermocouple into a difference in temperature and vice versa. One of the most famous applications that depend on the thermoelectric effect is the so-called (Peltier) technology, as shown in Figure 6 which illustrates the Peltier effect device (Pravinchandra, 2015).The main reasons for this technology's being superior to that of other technologies used to extract potable water from the atmospheric air humidity are (compact size, few mechanical and rotating parts, need for regular simple maintenance in order not to make much noise) (Solutions, 2022, Nandy et al., 2014, Nitheesh et al., 2019, Suresh P S*1)

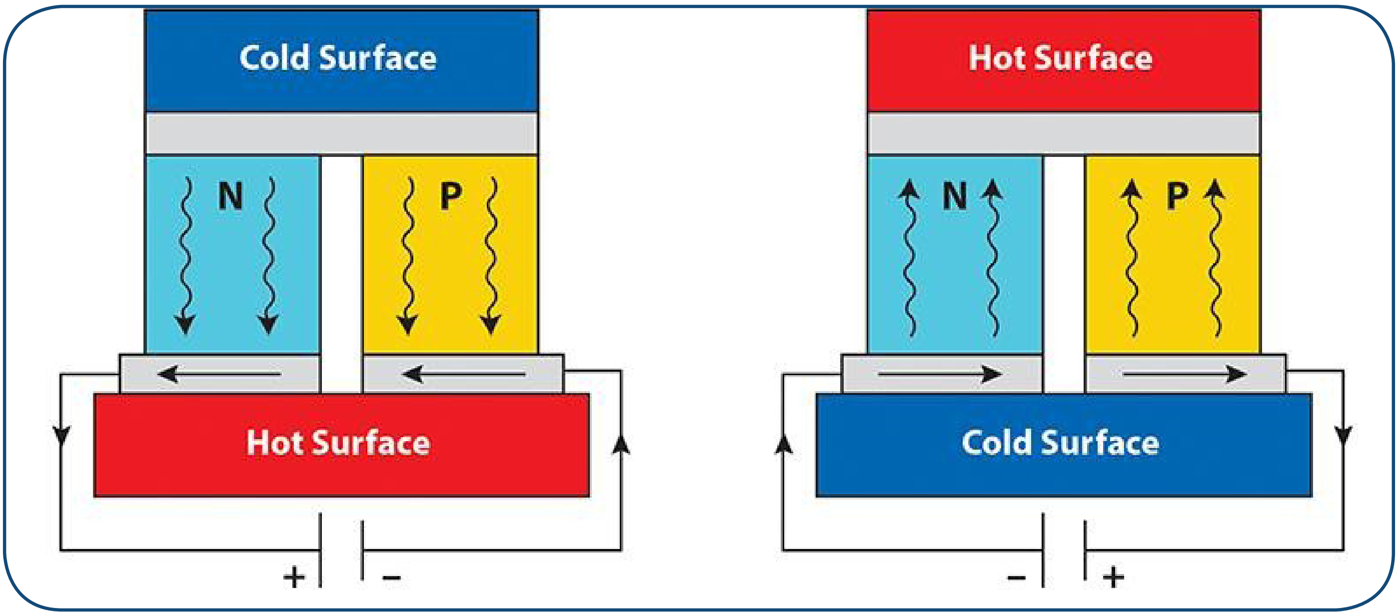

Fig. 6. Peltier refrigeration device
(Icecube, 2022)

In order to obtain accurate scientific results that can be measured and generalized in the future from the use of the thermoelectric effect method in generating water from the moisture content in the atmospheric air, the geographical area located on the northern coast of Egypt, specifically on the northern coast of Alexandria, was chosen at the geographical coordinates (latitude: 31.2 and longitude: 29.95) as a case study.

LITERATURE REVIEW

By reading the scientific researches that are interested in studying and evaluating the vapour compression refrigeration system, including (Anbarasu, 2011), it becomes clear that despite the effectiveness and spread of this system, it is flawed as follows:

- It needs a traditional energy source to supply it with the energy needed for operation;
- It is difficult to provide portable units of the type of vapour compression systems;
- It requires the presence of mechanical equipment in its installation such as the compressor and expansion valve; and
- It can produce noise during its operation.

By reading the scientific researches that focus on studying and evaluating the system of dehumidification using the desiccant, including (Khan et al., 2022), it is possible to notice the small amount of potable water that can be extracted using this technique, which may not exceed the right of one ml / kW.h, in addition to the high cost of material needed For manufacturing. Through the study of scientific research that dealt with the extraction of potable water from atmospheric air using Pelier effect technology (Kabeel et al., 2016), among which it is clear that this technique is the most technology that is free from the problems of previous technologies due to its distinctiveness as follows:

- Small (compact) size.
- It needs maintenance more easily than other methods of obtaining fresh water such as reverse osmosis devices or vapour compression systems.
- Environment friendly.
- It is possible to produce portable units from it.
- It can be operated using renewable energy methods such as photovoltaic and solar energy as the rate of energy consumption required to generate one litre of fresh water is approximately 0.02 kilowatt hours.
- It can be used easily in remote places.
- Produces reasonable quantities of potable water where it can produce about 3 litres of fresh water per hour, which is enough to consume a family consisting of 4-5 adults according to the standards of WHO.

This article aims to solve the problem of potable water scarcity in the northern coast of Egypt, which is characterized by the high relative humidity of air in the atmosphere (60-70%) by designing a portable water generator that meets the following conditions:

- Applying WHO standards for safe potable water ((W.H.O). 2017).
- Small size and the ability to move easily.
- Simplicity in design and avoiding complicated mechanical installations.
- Not relying on traditional energy sources for operation as the generation of one litre of potable water does not need more than 0.02 kW.h.
- The possibility of operation by non-specialists.
- Safe operation.
- Low Cost.

This depends on the (Peltier Effect) and takes the energy necessary to operate it from solar energy. This water generator can generate 3 litre/h of fresh potable water which satisfies the needs of a family of 4-5 adults according to the standards of WHO.

METHODOLOGY

In this research paper, a quantitative research methodology is applied by collecting atmospheric conditions (temperature and relative humidity) at different times throughout the year for the geographical area that has been identified to conduct the study, which is the northern coast of Alexandria. This information will be considered as the starting point conditions for the cooling process necessary to condense the air humidity and turn it into water. After that, the type of fan that will pump the air into the cooling system is chosen, where the conditions for air exit from the fan is considered as the end-point conditions for the cooling process.

After defining the conditions for the start and end points of the cooling process based on the previously collected data, this data are entered into a computer program for psychometric calculations to determine the water rates that can be obtained from condensing moisture content in the atmosphere. After obtaining the results from the psychometric process of condensation, the use of these results are for selecting the appropriate components of a thermoelectric cooling system (Peltier) that will be used in the design of the device needed for water generation.

Wither Data Collection

According to Egypt Climate Charts Index (Climate, 2022), it can be observed that the temperature ranges between 2-40 OC and relative humidity ranges between 60-70% in Alexandria throughout the entire month of the year, as shown in Table. 1 and Figure 7.

Table. 1: Temperature Distribution Throughout the Year
(Climate, 2022)

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum Temperature in (°C)	27.7	32.7	38.4	43.4	45.1	44.6	39.0	40.0	39.8	37.9	35.2	29
Minimum Temperature in (°C)	2.2	2.8	3.3	6.8	10.1	13.4	17	18.6	15	11.2	10.3	4.4
Average Temperature in (°C)	14.95	17.75	20.85	25.1	27.6	29	28	29.3	27.4	24.55	22.75	16.7

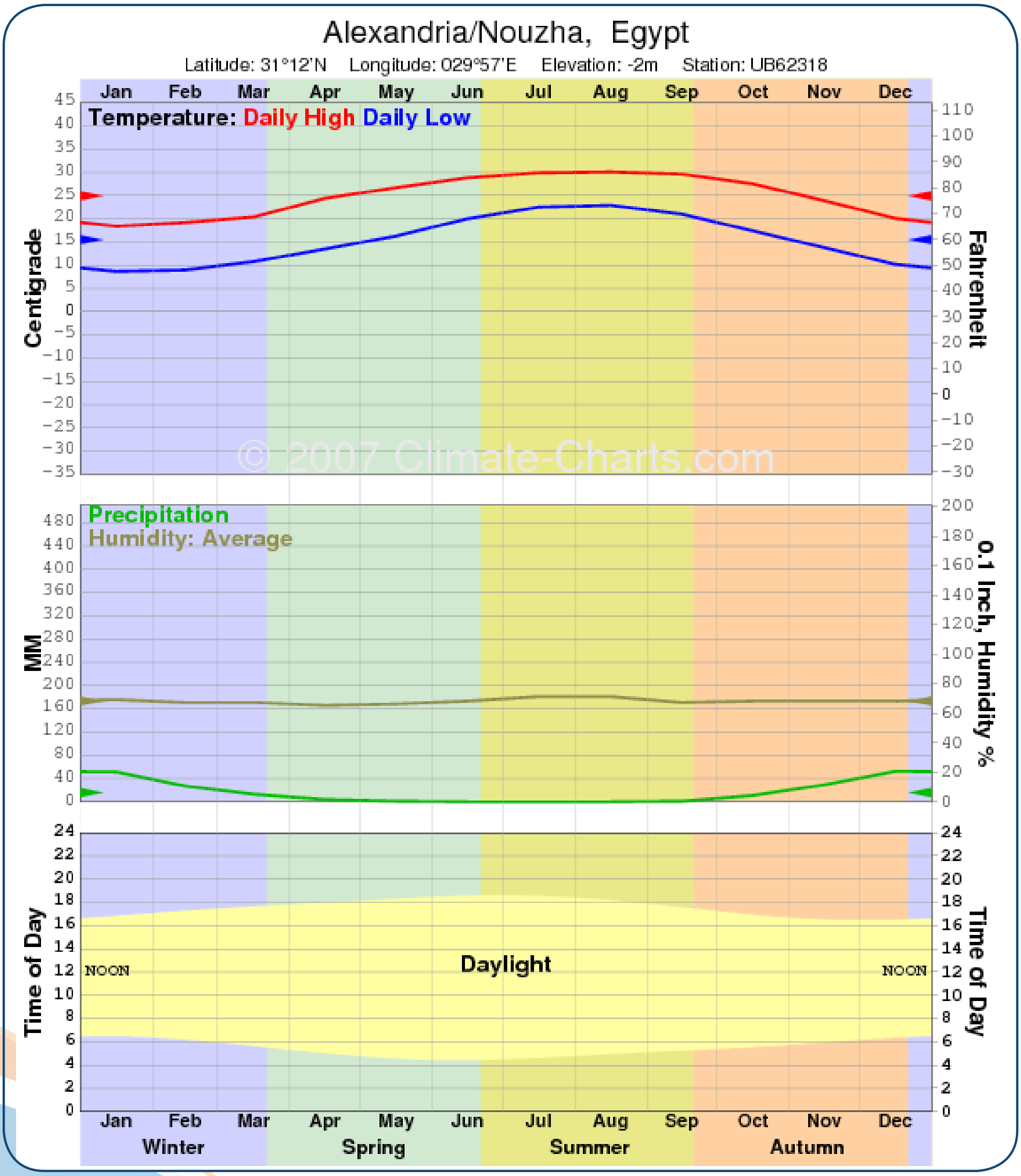

Fig. 7. Alexandria climate average weather data (Climate, 2022)

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Air Supply Fan Selection

Select (Dayton 6KD70 Fan, Axial, 108 CFM, 12 V) (Dayton, 2022) which shown in Figure 8 and has the following specifications as shown in Table. 2

Fig. 8. Dayton 6KD70 fan (Dayton, 2022)

Table. 2: Dayton 6KD70 Fan Specifications (Dayton, 2022)

Body Material	PBT
Brand Name	Dayton
Color	Black
Item Weight	0.010 ounces
Model Number	8541603174
Noise Level	42.0 decibels
Number of Items	1
Part Number	6KD70
Specific Uses For Product	Personal
UNSPSC Code	43201619

Using Psychometric Chart Software

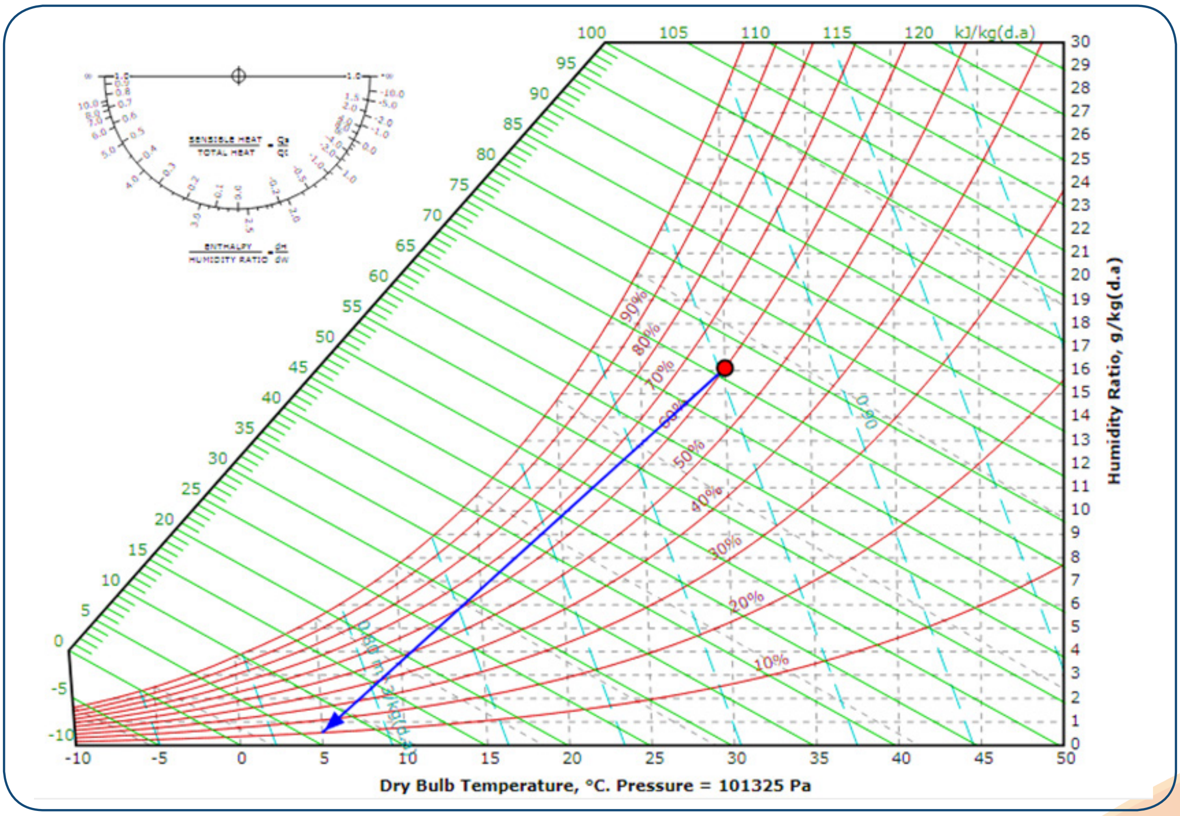

Fig. 9. Dehumidification process in psychometric chart (FlyCarpet, 2022)

By using Psychometric Chart software V4.4 as shown in Figure 9, the inlet and outlet humid air condensation process properties will be as shown in Tables. 3 and 4.

Table. 3: Humid Air Inlet Properties

Property	Value	Units
Rate of Air Mass Flow (m)	0.05	kg / s
Pressure	101.325	kPa
Dry Bulb Temperature (T_{db})	30	^{O}C
Wet Bulb Temperature (T_{wb})	23.8	^{O}C
Enthalpy (h)	71.4	kJ / kg
Absolute Humidity (H)	16.12	g / kg
Relative Humidity (R.H)	60	%
Dew Point Temperature (T_{dp})	21.4	^{O}C

Table. 4: Humid Air Outlet Propertie

Property	Value	Units
Rate of Air Mass Flow (m)	0.05	kg /s
Pressure	101.325	kPa
Dry Bulb Temperature (T_{db})	5	^{O}C
Wet Bulb Temperature (T_{wb})	-2.4	^{O}C
Enthalpy (h)	6.4	kJ / kg
Absolute Humidity (H)	0.538	g / kg
Relative Humidity (R.H)	10	%
Dew Point Temperature (T_{dp})	-24.1	^{O}C

According to the results obtained by the program and recorded in both Tables 4 and 5 ,the following results can be reached:

- The Rate of Generated water amount = 2.86 L/h.
- The energy required to produce ptable water per litre = (inlet enthalpy – outlet enthalpy) / amount of generated water. = (71.4- 6.4)/ 2.86 = 0.02 kW.h/litre.

Peltier Module Selection

By using Peltier – Thermoelectric Cooler Module Calculator (TE Technology, 2022) software according to the previously obtained results, the selected peltier module will be (CH-41-1.0-0.8) and its specifications are as shown in Figure 10 and Table 5.

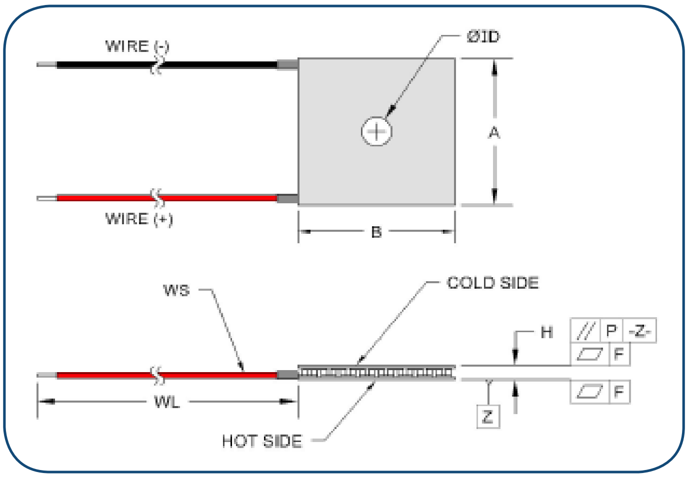

Fig. 10. Peltier module (CH-41-1.0-0.8) (Technology, 2022)

Table. 5: (CH-41-1.0-0.8) Peltier Module Specifications

Specifications	(27 °C)	(50 °C)
(Volt) V_{max} (V)	5.3	5.9
(Current)I_{max} (A)	5.7	5.7
(Power) Q_{max} (W)	18.6	20.4
Max T_{db} (°C)	68	77
Storage/ Operation Temperature	(- 40 °C) to (+80 °C)	

(Technology, 2022)

Potable Water Capture Device Layout

After completing the calculations of the potable water generation rate, the selected device design is Shown in Figure 11 (Nurhilalb, 2016).

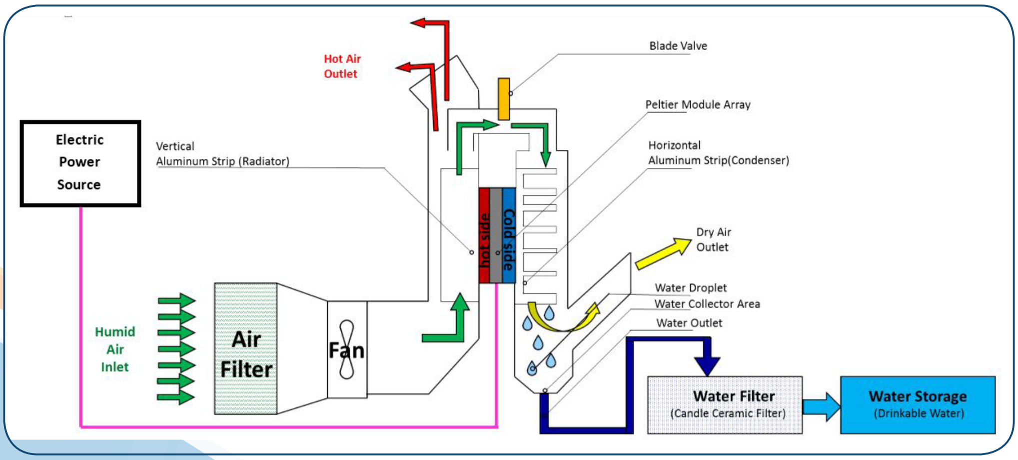

Fig. 11. Potable water capture device layout (Nurhilalb, 2016)

Drawing the curve of the relationship between relative humidity and the rate of water generation while holding the other variables, such as temperature and air flow rate, is constant, as shown in Figure 11. This reveals that there is a linear relationship between the two, indicating that as relative humidity rises, the rate of water generation rises as well.

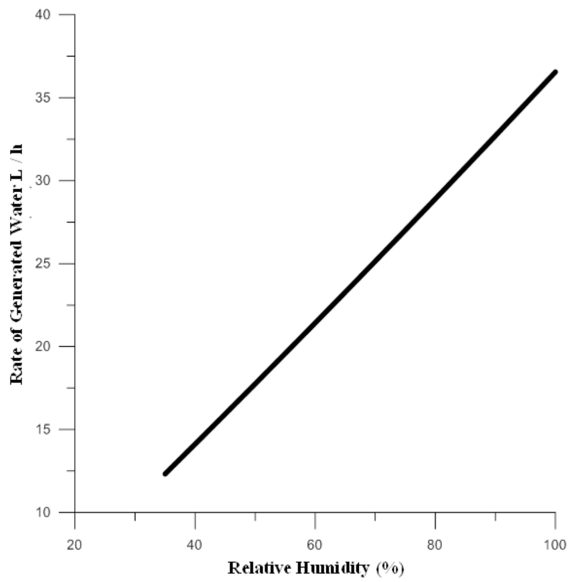

Fig. 12. Relationship between relative humidity and water generation rate

RESULTS AND DISCUSSION

At the end of this article and its findings, discussion can be as follows:

a) The device that was designed allows for the generation of up to 2.86 L/h of potable water from the atmosphere of the northern Egyptian coast at a temperature of 30 OC and relative humidity of 60 %, which is enough to supply a household of five adults with enough to drink. This is in accordance with the standards of WHO, which set the rates of consumption of water by an adult with a quantity of 3 to 4 litres per day. In comparison, the goal of designing the device for the purpose of providing the quantity of safe water per day has been achieved by 100%.

b) The goals for which the device was designed were achieved in terms of small size, simplicity of design, safety in operation and the ability to transport easily by one hundred percent.

c) As for the goals that are concerned with avoiding the use of complex mechanical installations such as rotating and reciprocating parts, they have been achieved at a large percentage that may reach ninety percent, due to the inability to dispense with the fan that continuously supplies the device with air, as this fan represents one of the rotating parts.

d) As regards the objectives that are concerned with dispensing with traditional energy sources, they have been achieved with a large percentage that may reach ninety percent until the implementation of another research concerned with the possibility of operating the device by relying on renewable energy sources.

e) Finally, for the goal that is concerned with studying the financial cost of manufacturing this device as a quantitative production, an independent research need to be conducted to compare it with other traditional methods used to obtain potable water.

CONCLUSION

The results obtained through the article can be summarized as follows:

1. The best way to provide potable water in places where traditional water and energy sources are scarce is to generate water from the moisture content of the atmosphere.
2. The most suitable refrigeration system that can be used to design a portable potable water from atmospheric air is the thermoelectric refrigeration system using pettier module.
3. A quantity of potable water can be generated from the atmosphere of the northern Egyptian coast at a rate of up to 2.86 L / h at a temperature Tdb = 30 OC, and relative humidity R.H = 60%.

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Investigating Proactive Measures Towards MET Development With Respect To 4IR

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Abstract

Purpose: *The increasing technological advancement in the maritime industry imposed by the Fourth Industrial Revolution (4IR) contributes significantly to changing the nature of jobs, which according to the World Economic Forum, might lead to massive job losses owing to either redundancy or skills mismatch. Nevertheless, the maritime workforce can endure the adverse effects of this transformation by adopting proactively responsive measures for boosting the potential role of seafarers through sustaining an appropriate level of Maritime Education and Training (MET) that comprehends the dynamic evolution of the industry and addresses its future needs. Despite the fact that the IMO has taken several global initiatives in support of the 4IR, it appears that further measures are still urgently required. This implies obligations upon both the national maritime authorities and the maritime educational organizations to tackle this challenge. It is well acknowledged that the primary responsibility of MET Institutions is to equip graduates with future competencies and skills needed for employment. Such duty involves a set of challenges that the MET system needs to address effectively in order to continue delivering a relevant education to the current technological revolution.*

Design/Methodology/Approach: *This research aims to demonstrate indicative examples of global proactive measures adopted at international, national and institutional levels in addition to future skills requirements concerning 4IR.*

Findings: *The research concludes with a key approach to the transformation strategy for enabling MET Institutions to maintain the sustainable development of MET.*

Key-words:
MET, Maritime Industry, 4IR, Seafarers, Competences, Measures.

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1. INTRODUCTION

Nearly all modes of transportation have recently been influenced to varying degrees by the current technological revolution (Outay et al, 2020). This includes various maritime domains that have significantly advanced and still growing to rely heavily on cutting-edge technologies brought by the Fourth Industrial Revolution (4IR) (Ichimura, et al, 2022). Since the human element's involvement in maritime operations has been continually transformed and redefined by technological advancements (Steven C. M. et al, 2020), the impending transformation of the maritime industry necessitates a need for a comprehensive proactive approach to address the future seafarers' role in the industry including their relevant education and training.

The 4IR is globally recognized as the current developing living and working environment in which a set of technological innovations and trends such as the Internet of Things/Services (IoT) & (IoS), Artificial Intelligence (AI), Autonomous Vehicles, Blockchain, Robotic systems, Drones, Augmented/ Virtual reality (AR) & (VR) are evolving the way people live and work (Hermann et al., 2016). Furthermore, according to Schwab, (2016), and Oztemel & Gursev, (2020), there are other important 4IR-related topics including real-time big data transfer, human-machine interface, cyber-physical systems, digital twin, 3D-printing, cloud technology, smart sensors, and cyber-security. From a historical background, the world has gone through four industrial revolutions; the first started when mechanical manufacturing driven by steam-powered engines was introduced; the second, when mass production was made possible by the discovery of electricity, then the third, when production become automated thanks to the renaissance of information technology (IT) and electronics. Eventually, the fourth is primarily centred on digitalization and innovative cyber-physical systems offering novel lifestyles for humans and highly advanced capabilities for machines (Liao et al., 2018). Currently, the 4IR contributes to the maritime industry development as well as the previous three revolutions did. Figure (1) shows the impact and time frame during which the four revolutions commenced taking place in shipping.

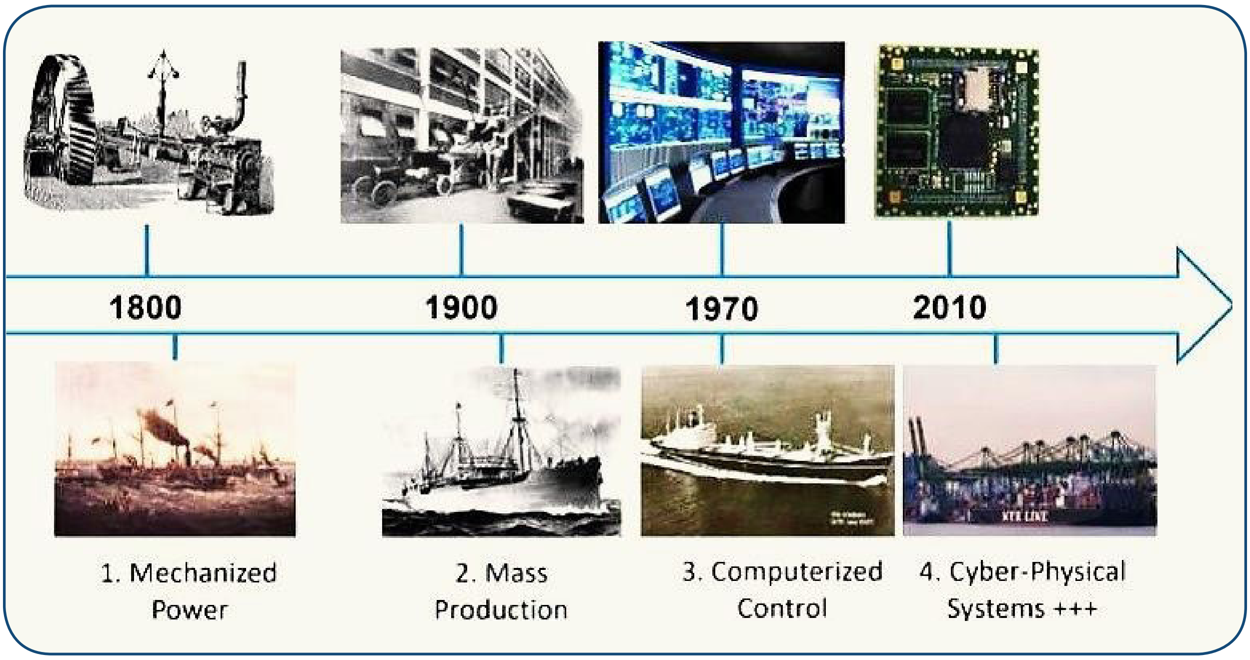

Fig. 1. Impact of the four IRs on the maritime industry
Source: Stanic Venesa et al. 2018

As technology, infrastructure, processes, competitiveness, and interactions with multiple modes of transportation evolve, new emphasis is placed on the future demands of the maritime industry. These evolutions have the potential to transform the nature of present professions and introduce new skills and competencies that could be entirely generic to the existing paradigm of the industry. Evolving maritime education and training (MET) with adequate knowledge and skills for current and future innovation development is a key component in preparing the maritime workforce to cope with the upcoming shifts (Bogusławski et al, 2022).

In this research, with the aim to demonstrate multiple indicative examples of global measures adopted at international, national and institutional levels, the author intended to highlight the implications of the 4IR on the maritime workforce with a particular focus on investigating future skills that should be addressed by the MET outcomes.

2. THE CONSEQUENT IMPACT OF THE 4IR ON THE MARITIME WORKFORCE

The maritime workforce cannot stay aloof from the impact of 4IR since the rapidly changing nature of the industry due to automation and technological innovation is permanently changing everything with consequent implications on demands for seafarers. The maritime industry, which contributes to the transportation of 80% of global trade (UNCTAD, 2020), is currently backed by a substantial front-line workforce of 1.89 million seafarers serving the world fleet and running more than 74,000 merchant ships across the world (BIMCO & ICS, 2021).

There are multiple examples of innovative technologies that have been deployed already in the industry with encouraging results and promising futures such as the use of IoT by the Maersk Group to track containers and monitor reefers on shore and at sea (Cross et al., 2017). Currently, by utilizing artificial AI, several maritime corporations are widely investing in the creation and development of autonomous ships that are controlled by innovative systems capable of making decisions (Steven et al, 2020). Rolls-Royce Plc, (2016) revealed that the maritime industry should widely invest in autonomous ships for improving ships' safety and efficiency by eliminating human error, as well as increasing profits by allocating additional space for cargo, and lowering operation costs by cutting down crew expenses including wages and provisions, besides conserving fuel needed for accommodation and ultimately minimizing emissions. According to Poornikoo et al, (2022), the current progress of Maritime Autonomous Surface Ships (MASS) would introduce a new age in the maritime industry leading to a paradigm shift in terms of effectiveness, safety, security, and environmental protection.

On the shoreside, an increasing number of ports started to adopt a strategy for creating smart ports which according to Min, H., (2022) constitute more viable and rational replacements for conventional ports, particularly with the advent of digital technology prompted by the 4IR. However, from a distinctive viewpoint, the World Economic Forum (WEF) has drawn attention to the disruptive effects of 4IR which could directly impact the global workforce employment by highlighting serious concerns regarding the potential future loss of jobs, either because of mismatch with the needed skills or due to significant changes in the nature of jobs induced by technology advances and innovative manufacturing techniques (WEF, 2018).

In parallel, when seafarers consider shifting careers to shore-based jobs they confront considerably reduced employment opportunities since they are not adequately equipped with the relevant competencies. This is agreed with the findings of the research project titled "Mapping of Career Paths in the Maritime Industries" which was carried out by Southampton Solent University and funded by the European Commission (EU, 2020). The study revealed that shore-based jobs cannot currently be fulfilled by seafarers as the present MET systems heavily emphasize operational and technical competencies at the expense of soft, managerial, and administrative skills, including commercial and business management.

There is an urgent need for developing dynamically responsive strategies to address the threats and possibilities associated with this transition according to the conclusion of the joint report "Transport 2040: Automation Technology Employment and Future of Work" produced by the World Maritime University (WMU) and the International Transport Workers Federation (ITF). The study reveals that automation and technologies can result in a higher risk of redundant low-skilled and medium-skilled jobs. Nevertheless, high-skilled professions like Masters and officers, as well as Pilots are not included in the linearly positive relationship between present and future automation (WMU, 2019).

Figure (2) demonstrates that tasks carried out by low and middle-skilled individuals have higher levels of automation, whereas those performed by high-skilled groups are least vulnerable to automation. Automation and technology are frequently used to assist high-task professions, provided that they acquire the appropriate education and training so that they can attain the optimum performance outcomes in their fundamental jobs. Therefore, the idea is to prepare them on how to make use of technology in their core tasks.

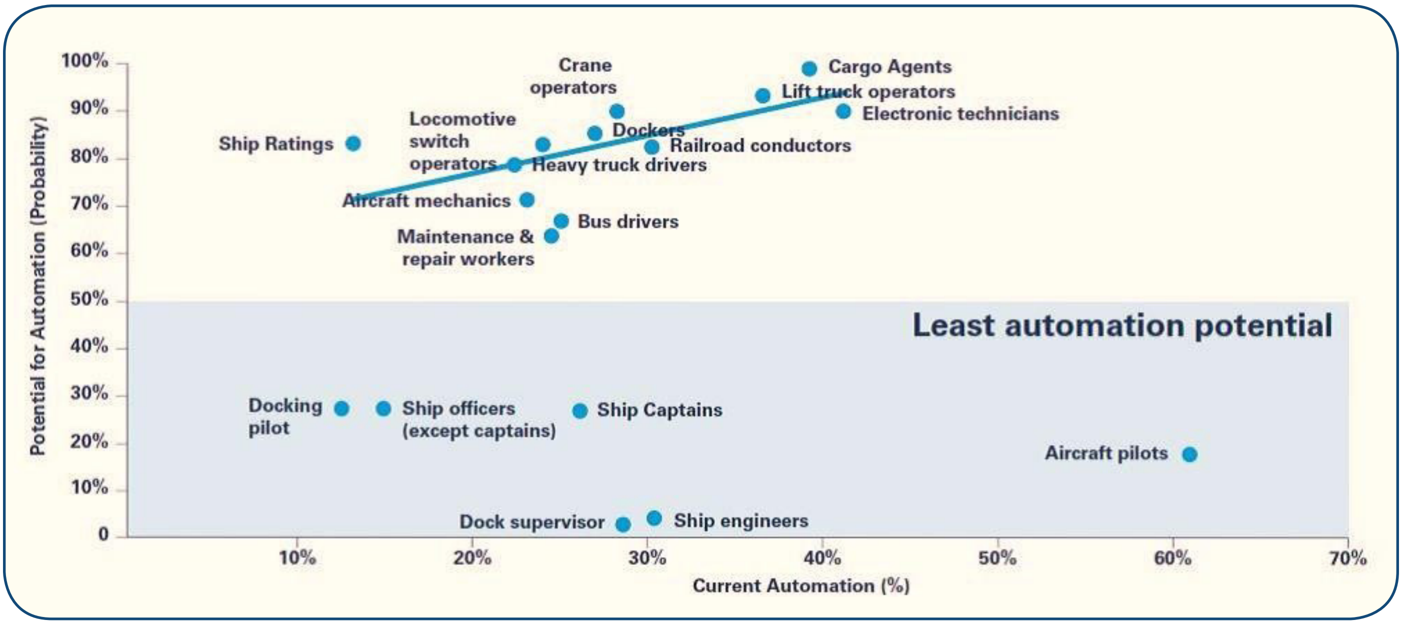

Fig. 2. Potential for automation in maritime professions

Source: WMU (2019)

In order to address multiple aspects of the challenges associated with the changing nature of work resulting from the fast technological advances and innovation in the industry, several leading nations implemented policies and initiatives to promote the integration of innovative technologies of information, communication, and cybersecurity in the educational systems. This is in addition to adopting the necessary legislation for ensuring adequate preparation of the maritime workforce to satisfy future labour market demands (UNCTAD, 2020), which according to Ziarati et al, (2010) is ultimately the most important and essential goal of MET institutions.

3. THE MARITIME INTERNATIONAL LEGAL FRAMEWORK TOWARDS 4IR

There has been a remarkable improvement in the global MET approach since the International Maritime Organization (IMO) presented the concept of Electronic Navigation in 2006 as "the harmonized collecting, integrating, exchanging, presenting, and analyzing of maritime information on ships and ashore throughout digital means". Recently, the development of Information and Communication (IC) infrastructure is giving a solid foundation for the evolution of autonomous and unmanned vessels. As a responsive measure, a framework for the administrative scope was agreed upon during the 99th meeting of the Maritime Safety Committee (MSC) in May 2018 to determine the safety, security, and environmental aspects of autonomous ships and how they can be addressed in the requirements of IMO (IMO, 2018).

The Standards of Training, Certification, and Watchkeeping (STCW) convention, being the IMO's key instrument addressing the seafarers' competencies, adopted major amendments in 1995 to assure the emphasis on competencies comprising "knowledge", "skills" and "attitudes". The present STCW, as amended by Manila 2010, is incorporating newer soft skills in addition to the fundamental technical competencies, such as "teamwork", "leadership", "decision-making", "problem-solving", and "effective resources management" (IMO, 2017).

Despite all IMO's efforts, there are growing doubts about whether the currently produced skills are now adequate for a seafarer to be considered highly qualified under the 4IR era.

In this regard, Kitada et al. (2018) claim that IMO legislative frameworks related to MET and established by STCW for seafarers to cope with the 4IR needs are still in the initial stages of development and cannot be regarded as sufficient in their current state.

Similarly to that though, the IMO Sub-Committee on Human element, Training and Watchkeeping (HTW) received a report from the International Chamber of Shipping (ICS) outlining maritime employers' concerns regarding the current STCW regime and requesting a comprehensive review to reformate the STCW Convention (ICS, 2019). This is attributable to ICS's belief that the current IMO STCW regime might not remain adequate for purpose in the third decade of the twenty-first century, while only a completely revised convention could enable a further flexible platform for competency accumulation and certification than is currently feasible, and would provide a framework with a certain flexibility in a way that satisfies the future needs of maritime industry stakeholders (ICS, 2020).

These given facts highlight the necessity for more efficient initiatives by both National Maritime Authorities and MET Institutions to proactively respond to 4IR's needs and to share the responsibility with the IMO in achieving this goal.

4. EXAMPLES OF STRATEGIES AND PROACTIVE MEASURES AT THE NATIONAL LEVEL

Looking at several leading maritime countries within the European Union such as Denmark, Norway, the UK and the Netherlands; it can be noted that there is early recognition of the rapidly changing nature of the maritime industry.

For example, the Danish government established a maritime strategy in 2018 to create a "Blue Denmark" development plan with the aim of transforming Denmark into a major maritime power hub in 2025. Through an appealing framework, the plan outlines the necessary steps that authorities should undertake in collaboration with all interested parties to turn Denmark into a knowledge and digitalization hub. Furthermore, by outlining the necessary MET components to keep up with future technological advancement, the plan contributes to the evolution of the MET system and facilitates the ability of MET institutions to adapt and tackle the 4IR challenges while offering state funds for undergraduate maritime professionals to attain a Bachelor's degree (DMA, 2018).

As another illustration, the Norwegian Maritime Authority in collaboration with the Coastal Administration and the Norwegian Industries Federation launched the "National Forum for Autonomous Ships (NFAS)", with the goal to examine every element of autonomous ships' operations, as well as anticipating the changes related to the required skills and knowledge owing to changing nature of jobs that is a major concern for MET. The forum's outcomes demonstrated a vital need for industry-wide collaboration in overcoming the challenge and supporting maritime authorities in obtaining a good comprehension of how future administration can be improved. The technical director of the Norwegian Maritime Authority, Mr Lasse Karlsen, declared during the autonomous shipping test-bed debuted in 2017 by Kongsberg; "We ought to recognize what these new technologies offer, as we also must ensure following this evolution firmly" (Kongsberg, 2018).

The Dutch maritime administration addressed the progressive shipping's digitalization and the expanding technological possibilities by motivating the development of maritime simulation to provide adequate students' preparation for the most innovative technology advancements while tackling also the industry's reduced opportunities for onboard training on advanced ships, which is an effective strategy to accomplish multiple goals simultaneously (Maung, 2019).

On the other hand, governmental funds are provided to almost all public maritime institutions in Europe depending on each country's legislative requirements, and although there are several funding models, the performance-based funding system is increasingly growing popular according to the Norwegian Higher Education Authority, (2017). For instance, the University of South-Eastern Norway (USN) is entitled to receive certain amounts of state funds for each participant in a Bachelor's, Master's, or Doctorate. This gives organizations the ability to develop educational simulations and encourages scholarly exchange, information sharing, and research collaborations amongst maritime institutions, industry, and governmental entities through projects and forums.

In summary, it can be noted that these strategies have been developed at the national scale as cited and had been implanted only in a few EU countries, which might be viewed as limited proactive measures for assisting MET Institutes to effectively cope with the rapid evolution of the industry. Improving the technical-competency training to maintain it in line with technological advancements needs to be acknowledged by national executive bodies responsible for supervising maritime matters such as maritime administrations or authorities. Their functions should no longer be confined solely to administrative duties but instead should entail active work to support their countries' growth in the maritime field by promoting MET and fostering interrelations with the academic, industrial, and governmental sectors for achieving this ultimate objective.

5. THE PROACTIVE MET PRACTICE AT THE INSTITUTIONAL LEVEL

As per the seafarers' supply and demand report 2021 produced by the Baltic & International Maritime Council (BIMCO) and ICS, there would be an estimated serious shortage of 89,510 seafaring officers by the year 2026. Therefore, in order to cope with this future demand for seafarers, the maritime industry must actively promote training and employment levels by enhancing the current MET globally, with a special emphasis on providing the innovative knowledge and skills that will be strongly needed to maintain a sustainable and better digitally advanced industry (BIMCO & ICS, 2021).

This implies obligations upon MET Institutions to investigate the range of skills that will be needed during the upcoming years. In March 2018, The International Association of Maritime Universities (IAMU) performed a survey titled "A future Global Maritime Professional" that involved participants from all world regions who represent a diversity of maritime sector professions (IAMU, 2018). The survey results indicated 15 competencies that are deemed to be particularly crucial in the future of the maritime industry as shown in Table (1). The survey referred to a scale of changes in the importance of each competency by numbers from 1 to 15 within time frames of a short period of up to five years, a medium period of five to ten years, in addition to a long period of twenty years.

Table 1: Change Scale for Vital 15 Maritime Competencies.

Competency	Short	Med.	Long
Technical competencies	1	2	2
Technological awareness	3	1	1
Adaptability and flexibility	7	4	4
Computing & informatics skills	9	3	3
Teamwork	2	7	8
Communication skills	4	6	8
Leadership	6	5	7
Discipline	3	9	10
Environmental/sustainability awareness/concern	12	5	5
Learning and self-development skills	9	9	6
Complexity and critical thinking	8	7	11
Language ability	5	8	14
Professionalism and ethical behavior	9	9	9
Responsibility	5	11	13
Inter-personal and social skills	14	9	10

Source: IAMU, 2018.

When analyzing Table (1), it can be observed that "Technical Competencies" are still recognized as the primary needed skills within the short period and the secondary ones during both the medium and long-term periods. Although this implies the continued essential role of technical skills throughout the industry's future, technological awareness shall be promoted in priority from the third needed skill within the short period to the foremost vital skill of the future. Other skills that are highly addressed within the short period such as teamwork, communication, discipline, complexity, critical thinking, language ability, and responsibility appear to be decreasing in importance through the medium and long term period.

Regarding emerging skills, further attention is given to adaptability, flexibility, and self-development, as their importance is increasing and will eventually become crucial throughout a long-term period. Following the IAMU report, none of these skills is presently underlined in the current skills addressed by the STCW convention.

Given these findings, the 4IR is creating a necessity for additional knowledge and skills needed by seafarers that aren't yet adequately addressed by STCW. It seems that it is time for MET Institutions to consider modifying their MET system beyond the current STCW requirements and address the needed skills to prepare their delegates for the 4IR impact.

As a proactive response driven by the need for a reskilling revolution to close the gap between what is needed and what is currently produced by MET, the IAMU established the Global Maritime Professional-Body of Knowledge (GMP-BoK) initiative to entail a wide range of educational outcomes well above the requirements of the STCW Convention. This initiative has been made in partnership with the Nippon Foundation to provide comprehensive academic programs that cover the STCW requirements while also incorporating a set of knowledge and skills that suits the demands of the industry and other stakeholders (IAMU, 2019).

The BoK's defined learning outcomes are based on learning outcome taxonomies for three domains of learning: the cognitive domain (knowledge), the affective domain (attitudes), and the psychomotor domain (skills), as demonstrated in Figure (3) which have been presented in the workshop for the implementation of GMP-BoK by the AASTMT GMP team during the period from 6th to 8th April 2021.

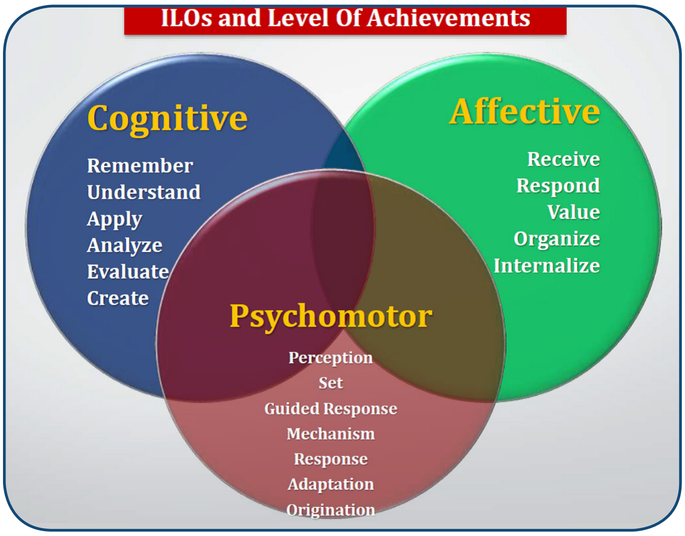

Fig. 3. Learning domains of GMP-BoK

Source: Ghalwash et al, (2021)

The IAMU initiative represents a significant proactive step taken by MET Institutions to address the effective preparation of maritime officers to cope with the current demands and future needs of the industry while also increasing their employment opportunities ashore.

6. THE FUTURE PROSPECTS OF MET IN THE 4IR ERA

Since technological innovations could lead to creative educational techniques, the teaching process must adapt quickly to incorporate digital advancements and trends. MET must refine its strategic plans to address the challenges of delivering the desired skills as cited previously. In addition, the following approaches could be adopted in parallel.

6.1. Implementing Effective Human Resources Development (HRD) Plans

The maritime industry, where students will eventually seek jobs, will likely perform differently from how it used to do. In this manner, the current global shortfall of adequately qualified Teachers is one of the biggest obstacles to producing seafarers with essential extensive knowledge and practical skills (BIMCO, 2015). For example, although maritime simulation is widely utilized by several MET institutions, the lack of professional instructors with the necessary qualifications to conduct training efficiently is limiting its potential benefits. As a response to this concern, "HR Development" is becoming crucial and must be viewed as a critical component of success. As per this viewpoint, MET Universities must address HRD comprehensively.

One of the examples that exemplifies this approach is the case of the UK Maritime College of Blackpool and the Flyde College (B&FC) in which HRD is established in line with the employee's needs and the organizational goals. Annually, each staff member is required to consult his direct senior management to develop a distinguished Sustained Professionalism Development (CPD) plan that takes into account both the strategic goals of the College and the individual desires (STC Group, 2016). It's crucial to note that while CPD programs at B&FC College have unique key performance indicators, however, they are reasonably adaptable and can be customized for each staff member. The primary goal of CPD would be to improve an individual or group's capabilities concerning the job they are performing. If the goal is not fulfilled, the reasons would be looked into and properly addressed. While obtaining competent teachers is tough, retaining them is even getting more difficult. Through the use of such an approach among lecturers and instructors, a systematic future career path can be ensured which isn't solely motivating them but also leads to extending their engagement with the organization.

6.2. Revising the MET Curricula to Fit for Purpose

The curriculum in schools and colleges has to be continuously modified to produce highly educated and skilled individuals with new abilities (UN, 2017). According to Obilo et al. (2012), the curriculum is the tool that controls any educational system's activities and is regarded as the medium via which knowledge and other learning processes are disseminated.

There are examples of some practices for modifying the MET curriculum as in Norway where one of the MET Institutions incorporated commercial studies into the MET curriculum, believing that ships' staff members need to be empowered with a certain level of academic competencies in commerce to begin taking over certain commercial functions from management staff ashore (Kitada et al., 2018).

Similarly, the innovative curriculum can incorporate the needed knowledge, skills, and attitudes concerning 4IR, such as computer and information skills with an advanced degree of technological awareness. The maritime educational processes can transmit the additional new skills listed in the IAMU report, such as adaptation, complexity, and critical thinking. For this purpose, MET's curriculum developers need to maintain the curriculum sustainment in line with the 4IR skills transformation.

6.3. Strengthening Cooperation with the Maritime Industry

The fast modification of technologies, being used already or expected to be utilized soon, is making it harder for MET providers to keep the education and training system fit for purpose unless kept acquainted with the new technology applications resulting from the industry's vision towards the future. Ensuring an adequate level of collaboration with industry, especially in research fields of innovation, applications and knowledge transfer can be a vital approach for MET institutions to target the learning outcomes that align with the desired skills.

A noteworthy example is a collaboration between "Kongsberg" and the University of Southeast Norway (USN) on a project titled "Innovating Maritime Training Simulators Using Virtual and Augmented Reality", in addition to further research study concerning autonomous ships. Through similar initiatives, MET institutions can have the opportunity to maintain updated with technological advancements, improve technology awareness among their staff members, and incorporate pertinent knowledge into their curriculum. Furthermore, through joint projects, MET Institutions can receive industry investments for research like the case of the USN when obtained an advanced training simulator for a Titan-class ship, which is a very specific class vessel for seismic operation, through its collaboration with the Norway Petroleum Geo-Services (PGS) and Kongsberg (Kongsberg, 2017).

For the MET system to be modernized adequately in the 4IR era, it is now more important than ever to foster collaboration with the industry that would empower MET institutions to enhance current training facilities and staff resources sustainably while also allowing institutions to keep updating the curricula.

6.4. Creating the Appropriate Infrastructure and Facility

The condition of the educational facility and the level of faculty members have a great influence on how students learn and get educated. In this context, new technologies that have recently received attention linked to 4IR, such as Virtual and Augmented Reality (VR/AR) along with conventional MET resources like training vessels, laboratories, simulators, workshops, and classes, might also view a bright potential for simulation combined with E-learning applications and services.

6.4.1. Incorporating VR/AR technologies in Simulation

In addition to existing simulators for a wide range of missions involving limited, multi, and full mission tasks that have been integrated into MET and require high financial ability, maritime simulation can be significantly improved by incorporating a 3D simulated environment that can closely imitate real-world tasks with multiple senses as being offered nowadays by the advanced VR and AR technologies. VR is a term that refers to a "near reality" wherein a virtual environment is employed. Technically speaking, it applies to 3D computer-generated surroundings that a person can explore and interact with. Different from VR technology, AR is based on integrating both real and virtual elements in a real-world setting while operating interactively in real-time in addition to connecting and aligning both the real and virtual objects together (VR Society, 2022).

By incorporating VR into MET and creating a platform for virtually simulated ship equipment and its associated operational process, maritime students can get engaged with an array of cutting-edge technologies and genuine ship equipment that they might not be given the chance to explore throughout their onboard training. According to Yanliang, & Zhiqiang, (2020) embedding VR-based simulation into MET may broaden the horizon of the practical training outcomes since it can boost the operation skills of maritime personnel. Furthermore, it might be seen as a viable approach to overcome limited funding resources for conventional simulators that need considerably expensive hardware and facilities.

6.4.2. Establishing a digital learning platform

E-learning platforms are regarded as one of the 4IR's accomplishments and can serve as an effective tool for integrating the 4IR needed skills as part of the MET system. The fact that e-learning promotes innovative interactions between educators and learners which contributes to improving the effectiveness and the adaptability of the learning environment in an appealing manner, will make it gain a larger popularity scale amongst students in colleges and universities (Alrawashdeh et al, 2021).

In reality, conventional classrooms that involve face-to-face interaction between teachers and learners would still be crucial in the future education domain. However, it should be reinforced with enhanced digital innovative techniques to effectively prepare seafarers for future paradigms of knowledge and skills. For example, to enhance soft skills like critical thinking, communication skills, teamwork skills, and self-development abilities, a flipping classroom has been implemented as one of the utilized techniques in higher education where digital contents are available to students at any time through videos, online worksheets and quizzes which suits the way they use today to acquire knowledge through their phones, laptops and electronics (Tores C. et al, 2022). Multimedia with highly interactive methods, among several types of e-learning, can replace traditional knowledge transfer or at least change the way education is delivered. If students have the opportunity to spend more time on a guided self-study program through E-Learning at home, then they can make better use of time during classroom hours and dedicate it to questions and discussions with lecturers.

Furthermore, the current advancement in E-learning offers a wide range of effective instructional methods involving online practice with associated feedback from teachers, combining collaboration activities with self-paced studies, while identifying and personalizing learning tracks based on the delegates' desired skills. In addition, it can facilitate using simulation remotely for learners who have difficulty attending conventional classroom training (NETP, 2017).

Given these characteristics, a platform for web-based learning should be developed to enable effective interaction between students and lecturers, as well as to better coordinate and actively manage the necessary knowledge and skills. The digital format offers the possibility to produce automated, adaptable education in which the student has the capacity to extend, replicate, and take control of their education beyond classrooms.

CONCLUSION

The introduction of highly advanced and emerging technologies imposed by the 4IR affects the maritime industry workforce by changing the nature of future jobs. This necessitates a need for a global proactive response to avoid skills mismatches and job-redundancy risks that can end in massive job losses in future. The responsibility is now shifted towards national maritime authorities and MET Institutions to contribute to the contamination of the 4IR consequent impacts in line with the IMO efforts. Creating a framework for industry-government-institution partnership is the most efficient way to preserve knowledge exchange and future vision sharing.

The effectiveness of preparing the maritime workforce for the longer-term transformation relies on the innovative development of MET which can be attained by implementing efficient plans for the development of human resources, revising the currently delivered curriculum in light of anticipated future skills, and strengthening industry collaboration. Integrating technology with these key elements can create a holistic approach to the transformational strategy for enabling MET Institutions to maintain the sustainable development of MET.

The inclusion of digital tools and immersive technology in MET provides a wide variety of teaching and learning possibilities. If the 4IR-related technologies are well employed and used under appropriate intellectual guidance and technical support, they may facilitate and complement various educational techniques for achieving the needed 4IR skills. When it comes to strengthening and systemically building up an effective delivery of the digitalized MET contents, a comprehensive professional preparation plan for maritime educators and instructors regarding innovative digital educational skills is vital.

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Challenges and Smart Opportunities in Maritime Fields on Effects of 4IR and COVID-19 Pandemic

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Abstract

Purpose: *The COVID-19 pandemic affected world trade, and the economy in addition to public health i.e. adding additional challenges and perhaps opportunities for the maritime industry and the importance of novel technologies. Novel technologies and high levels of automation in maritime transport imposed by the Fourth Industrial Revolution (4IR) are expected to contribute significantly to the changing of maritime operations sooner than expected. Ports are already facing enormous challenges in coping with recent trends including autonomous and mega-ships, and smart concepts such as cyber risks.*

Design/Methodology/Approach: *This paper focuses on a key aspect, i.e. how the maritime industry should adapt to accommodate and interface with 4IR i.e. accelerated after the pandemic. By an inductive and deductive approach, the research demonstrates the challenges facing shipping and ports in preparing for different 4IR challenges. The Suez Canal Economic Zone (SCZone) ports are taken as a case study, which should cope with these 4IR developments and overcome any future pandemic effects.*

For rationality, analyses are done for SCzone, as an example of how to remain competitive in international transport.

Findings: *Findings of the research found that developing countries should be eager to invest in capacity building and legislative adaptation before investing in infrastructure to cope with the latest technologies. Technical cooperation programs under international bodies e.g. IMO, inter alia, can play an important role in these required adaptation developments.*

Key-words:
Pandemic, Autonomous Ships - Ports, 4IR, Challenges, Opportunities.

1. INTRODUCTION TO THE PANDEMIC EFFECT ON MARITIME ACTIVITIES

The COVID-19 epidemic has dramatically impacted global trade. Many countries totally or partly shut down in successive waves; in effect, many trade transactions are slowed down, and maritime activities are significantly affected. Demand for ships for trade in a particular period resulted in a drop in fuel consumption, i.e. led to a significant prompt and instant drop in oil price. Many ships, as a result, found the longer path around the Cape of Good Hope cheaper than using the Suez Canal (SC) route. On the other hand, many oil tankers have been converted to storage tankers for the shortage of land-based storage in a stockpile market. Seafarers as well are dramatically affected, crew changes were banned in many countries, putting more additional burdens on seafarers, which may affect the safe operations of ships one way or another and triggered the need to accelerate autonomous ships applications. Technology advancements definitely induce challenges but can also create multiple opportunities.

The challenges of the Fourth Industrial Revolution (4IR) were considered burdens for developing countries. The 4IR is characterized by the adoption of artificial intelligence (AI) and increased levels of automation throughout industries. Automation and novel technologies are changing the economy, politics, community, and commerce. Consequently, jobs will become more demanding or shift to different economic sectors. In this regard, research can provide opportunities for making digital technology an effective instrument for positive transformation. Regional changes in transportation patterns are anticipated and the pace of incorporating AI into maritime transport sectors both onboard and onshore will have a significant influence (Schröder-Hinrichs, et al., 2019).

Developing countries, e.g. Egypt, should benefit the most from the introduction of 4IR technologies to overcome the market withdrawal of some mega-companies and encourage new foreign investments in its ports. For example, Piraeus port in Greece has attracted Chinese Shipping Line investments after becoming the most interconnected port within the Mediterranean Sea in 2019 (Heleinic Shipping News, 2019). In this regard, the authors of this study believe that Egypt is an example of good investment returns for its promised maritime trade markets thanks to the establishment of the Suez Canal Economic Zone (SCZone).

This study discusses the possible effects of the 4IR on different aspects of maritime transport, particularly, port challenges to survive the effects of the COVID-19 pandemic by using the recent high-tech era as a cure. Autonomous and mega-ships, sustainability, and cyber security are some of the challenges. The research illustrates two fronts of these challenges. First, the move towards digitalization and second, the introduction of mage and autonomous ships; the research exhibited a plan to deal with autonomous ships.

Egyptian ports, among other developing countries, are advised to cope with the research recommendation for developments in international shipping technology. Ports will need to adapt to interface with autonomous ships from one side, and on the other hand, to deal electronically with shippers, consignees and carriers.

A fast development of automation in ports is witnessed especially when compared to the introduction of autonomous ships on a commercial basis. This could be reasoned by the freedom of non-applying international law in port operation sectors versus shipping (Schröder-Hinrichs, et al., 2019). Ports are normally applying national laws, on the other hand, shipping is mostly governed by international requirements, which makes the applicability of innovative technology less flexible.

For example, the "East Container Delta Terminal" located in Maasvlakte in Rotterdam has become the world's first automated container terminal in 1993 (Schröder-Hinrichs, et al., 2019). On the other side, the agenda of Maritime Autonomous Surface Ships (MASS) was expected to be in place before 2035 as per the IMO (DNV-GL, 2018) i.e. accelerated due to the pandemic. Ships should be developed in parallel, not to ignore or resist the escalated development in ports.

2. 4IR AND PORT OPERATIONS

With highly increased automation levels, the 4th IR is driving dynamic changes to industries i.e. will continue to impact all transport systems. Containerization, for example, brought us in the 1950s-1960s major changes in all means of transport profiles, e.g. cargo gear, ship design, port structures, and shortened turnover durations in ports. This section of the study provides illustrations of current and upcoming technological trends.

Maintenance activities could be carried out remotely from the shore side, for example, software updates by specialized crews may be dispatched on-demand when maintenance service is required on-site, (Schröder-Hinrichs, et al., 2019). Maintenance robots would help the crew in carrying out several repair tasks, especially in areas where it's difficult to reach the equipment; in these cases "drones" can undertake multiple potential hazardous inspection activities (Schröder-Hinrichs, et al., 2019). Furthermore, drones are used as an aid to future shore-based pilotage and optimizing port of calls, inter alia (Danish Maritime Authority & IALA, 2019).

Beyond screens, operators should also shift to utilize innovative methods of training and education. In this regard, Simulation, Augmented Reality, Virtual Reality and Mixed Reality are the upcoming future trends in maritime education and training institutions (Schröder-Hinrichs, et al., 2019).

Autonomous systems in vehicles and infrastructure operations would become a basic desire to catch the ride. Before the pandemic, the application of autonomous ships that are supervised by humans was anticipated to achieve an adoption rate of 11-17 % by the year 2040, it was also expected that the operations will be limited to domestic and specialized trades only (Schröder-Hinrichs, et al., 2019) but this scenario is accelerated after the pandemic. In the 100th meeting session held in 2018, the IMO's Maritime Safety Committee (MSC) approved the regulatory scoping exercise's framework for the use of autonomous ships as described below, and as illustrated in figure (1):

- **Degree one – Manned Ship:**
  The traditional way of working: A Ship with decision-support and automated processes but seafarers are present on board to run and manage shipboard systems and operations. Although seafarers on board are ready to take charge, some activities might be automated and occasionally run unattended.
- **Degree two – Remote Ship:**
  Increased sensors and decision-support: A Ship that can be remotely operated but has crew members on board. The ship is managed and operated from a remote location. on board, seafarers are ready to take command and control ship systems and operations when needed.
- **Degree three – Automated Ship:**
  Human-assisted autonomy: A Ship that is remotely operated and has no crew on board. There are no seafarers aboard as the ship is fully managed and operated from a remote location.
- **Degree four – Autonomous Ship:**
  Full autonomy: A Ship with Full autonomy where the ship's operating system is capable of decision-making and can determine required actions by itself. (MSC 100, 2018; UNCTAD, 2019).

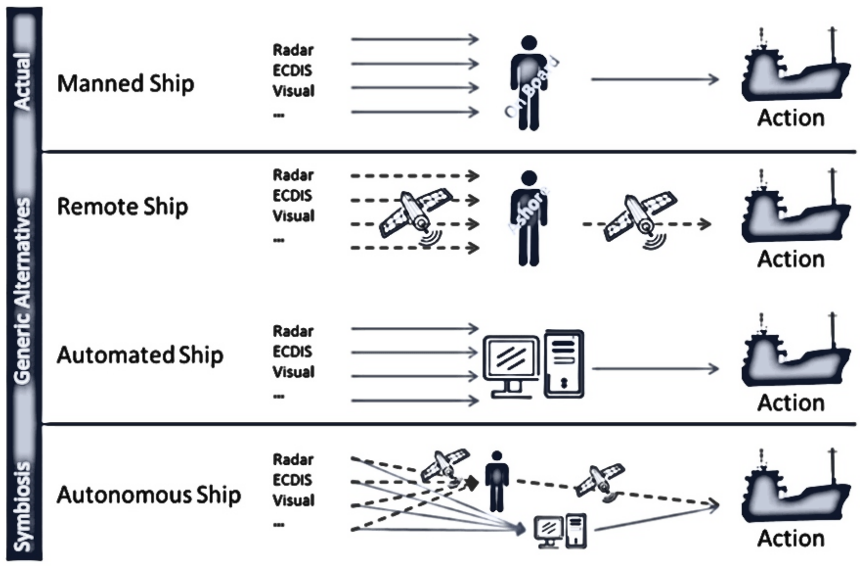

Fig. 1. Illustration of the 4 degrees of the autonomous ships.
Source: (MUNIN, 2016).

On the other hand, technological port infrastructure in developing countries should be examined with care for AI compatibility. New players would appear in the market to develop innovative types of services and platforms that can satisfy customers' demands and port service providers' assessments (MaaS, 2020). For less human interaction and port dues, new port technologies have been created, as in the case of the port of Rotterdam container terminal, to account for a sizable proportion of increased trade flows during the 4IR (Bernhofen, et al., 2016). As an ultimate benefit, Ducruet, et al., 2019, found a positive correlation between the effects of advanced port technologies and the attraction of investment and less use of land i.e. offering a new solution for land scarcity in some ports e.g. Port-Said west.

In the 4IR era, data will be the new role player since many services will have to emerge and cope with data management (EU Horizon 2000 Program, 2018). However, the inflexible flow of data may be witnessed for national security reasons. Horizon 2000 program – EU, 2018, depicts that knowledge sharing and feasible technology investments provide opportunities for the removal of existing operational problems and capacity constraints.

For example, Holm, (2019) presented Sea Machines' current projects. The project retrofitted a vessel with the equipment to merge sensors; through this, the crew will be able to see a centralized display. The pilot as well does not board the vessel but is fed data from the ship, including cameras and radar sensors that utilize the 4G network; 5G would be an added value. The benefits of the project are reduced transit risk, enhanced productivity, and increased operational data. The cons may be crew culture and worries including job losses (Holm, 2019).

However, technology incompatibility is a problem in the maritime industry; different regions of the world have developed their own digital solutions that might be incompatible with the technologies utilized in other regions. This could be a barrier to maintaining the safe and sustainable global movement of vessels and ultimately reducing the efficiency of the transport chain. Container ships waste an average of 6 % of their operation time at anchorage areas because of ports' delays which result in extra costs and risk of accidents (Rostopshin, 2019).

As a response to this issue, there are basic steps that need to be carried out to achieve the global harmonization of technological solutions:

- Define and publish the basic and unified solutions;
- Guide how contemporary technology can be utilized to apply solutions;
- Create an obligation to follow solutions;
- Publish how solutions have been implemented in any given geographical area.

This process should then be examined for e-navigation applicability with the proper security and share of natural resources (Eriksson, 2019).

In this regard, the national authorities can play a more active role in the implementation of e-Navigation technologies (Ismagilov, 2019). For example, E-navigation has been introduced in Russia through a range of state programs which have included the introduction of a new Vessel Traffic Service and an automated hydrographic trawling system. This carries a better solution to port congestions, which optimizes a ship's speed to coincide with the time schedules of the ports' terminals, enabling a substantial reduction in fuel consumption and better emission control. For example, a 10% decrease in the global fleet's speed would reduce 19% of CO2 emissions. The use of an IT solution based on real-time synchronization enables the optimization of a ship's speed with navigational routes for precise arrival timings (Rostopshin, 2019).

2.1. Future Scenarios and Impacts

Enhanced ship autonomy opens up opportunities for improved, safer, and more cost-effective operations with much less engagement of the human element, the primary cause of accidents. Many business impacts may be expected e.g. automated sailing without the intervention of humans, which could lead to fewer crew members and reduced ship operation costs (Negenborn, et al., 2018; Smart Port, 2019) since several occupations on ships will shift to shore side. In order to locate their berths, vessels will communicate their precise location and status to a lock or bridge entrance of ports (Smart Port, 2019). Furthermore, docking, lock, and bridge decisions should be taken automatically, taking into consideration the implications of all surrounding vessels' intentions when headed towards the same destination.

A Port Control Center (PCC) should be effective in monitoring, navigating, and controlling autonomous ships to investigate ports' impacts. The PCC's design could potentially pose a significant influence all over investment and operational expenses and present a serious challenge to stakeholders (Smart Port, 2019). Responsibilities and job description for a harbour master should be defined properly including levels of interventions and their timing. Repair docks should be also developed to host automated ships; investment in such services would need highly intensive and dynamic capital.

2.2. Smart Concepts and Cyber Security

'Working from home and online operations may solve some COVID-19 consequences but cyber security should be considered at all levels of companies.' Based on the cyber-attack on Maersk in 2017, inter alia, research has shown that 69% of Danish shipping companies have been attacked in 2018 (Steffensen, 2019). The IMO is a bit behind in maritime cyber security; only on 1st, Jan. 2021 cyber security embeds in the safety management systems of shipping companies.

In an automation era where many organizations' missions and fundamental tasks rely on IT, the capability to manage this technology and ensure information security, availability, and reliability is crucial (Secretary of Defense Office, 2017).

Many challenges are to be solved at the level of 'port' authorities and the relevant stakeholders on a global scale in terms of standardization of legal schemes and sharing data and information security under a sustainable cooperation scheme. To solve that, it is essential to identify challenges and find solutions to the applicability of digitalized maritime sectors in the most beneficial way by linking smart ports and autonomous shipping (Hong, 2019) under the best security practice. Electronic Navigation (E-Navigation) is lacking a mechanism to ensure the security of communication.

Cyber Security in e-navigation needs identification and authentication mechanisms; the Maritime Connectivity Platform and blockchains can contribute to cyber security in e-Navigation (Hahn, 2019). IACS and BIMCO, inter alia, have made recommendations on building cyber resilience and have been issuing guidelines for maritime cyber security. The most important pillars of effective cyber-resilient ships are:

1. Equipment software should be designed with cyber risks in mind;
2. Ships should be built in a cyber-resilient way.

To do so, **BIMCO** advises that:

1. *"The risks involved in cyber security are real and must be tackled at every stage;*
2. *To safeguard ships against potential cyber-attacks, cyber security should be in-built into the safety management system;*
3. *A cyber resilient ship is one where the software, hardware and operational practice are all designed to deter an attack;*
4. *Having a robust cyber security clause will protect the interest of ship-owners in the business arena." (Srinivasan, 2019).*

2.3. Mega-ships and Port Operators' Challenges

In a very dynamic market, the economy of size has changed dramatically i.e. adding a new concept to maritime economics. Mega ships would lead to larger peaks in ports and a need for bigger yards and larger demand for hinterland transport (International Transport Forum, 2015). 'Nearly 50% of the existing shipbuilding requests are concerning ships with a capacity of more than 12,000 Twenty Equivalent Units (TEUs'). Many ports in the USA have planned to invest billions of dollars to accommodate mega-ships, even though there isn't any assurance that mega-ships would include these ports in their potential destinations (Hacegaba, 2014).

With the estimated escalation in world trade i.e. expected to grow by 3.2% before 2022 (UNCTAD, 2018) port operators should be ready for activities impacted by innovations. Nowadays, some mega-ships can hold over 20,000 TEUs. Ports and Terminals must invest money in new cranes, extended dredging capabilities, strengthened jetty walls, and longer berths to be prepared for the upcoming era of mega-ships (Saxon & Stone, 2017; Smart Port, 2019).

Both developments in liner shipping and ports face technological races and challenges. A 24,000 TEU container ship would be difficult to host and manage from processes of cargo planning to stowage. The technological application may standstill in some developing countries to host and handle such mega-ships i.e. to be promoted in the industry race towards escalated technology compatibility.

Moreover, capacity building and fiscal and administrative factors should be considered in development to remain competitive. Consortiums should be invited to invest in developing countries (Baik, 2017). Furthermore, Baik, (2017) argued that cargo handling rates need to increase by 3 – 17%, depending on the increase in vessel size, to keep operational costs at the same levels. This could be difficult for some developing countries and SCZone without aid from industry tycoons.

Safety is another scope to be considered in ports and coastal seas; the larger the ship, the more costly it is insured, for the consequences of accidents on capital and environmental risks. In order to survive, shipping companies merged, and others made acquisitions or at least cooperated under some sort of alliance (Baik, 2017) to survive. Ports may also do the same: consolidation, alliances, merging or acquisition; technology should offer some solutions for bonding ports, which would be useful in cost reduction, slots and berths reservation and reducing waiting times. Under these solutions, members of a port alliance would share ship routing and schedules including terminals vacancies, operate under singular unified networks and share information on ports of call.

SCzone shapes a good opportunity for a regional port consortium. With their combined volume, Global Terminal Operators (GTOs) would have more favourable conditions for shipping liners, particularly mega-ships, and improved attraction for new companies. Mega ships and shipping alliances' growth means less ocean carrier product differentiation and more competition among ports. For better business attraction, GTOs will retain service differentiation by way of factors such as service levels, infrastructure, location, and inland connectivity. Moreover, the size of alliances allows SCZone to negotiate better cargo handling tariffs if proper networks are applied. SCzone offers a great opportunity to use 24/7 hinterland transport i.e. a great competitive advantage, assuming that customs and legislations are to cope with these smart port demands.

3. CASE STUDY: SCZONE

The SCZone is recognized as a trade hub and a world-class free zone of 461 km^2, about two-thirds the size of Singapore, where more than 10% of the world trade is passing through each year; The zone comprises:

- Two linked and integrated regions include two ports each; "Ain-Sokhna" with "Ain-Sokhna Port" & "East Port Said" with "East Port Said Port".
- Two development areas; Al-Qantara West, and East Ismailia.
- Four ports: West Port Said Port, Al-Adabiya Port, Al-Tor Port, and Al-Arish Port (SCZone, 2016).

The SCZone has been developed in 2016 to attract operators from all kinds of maritime, industrial, and commercial businesses all over the world to invest in Egypt under new economic incentives. SCZone gives a big opportunity to generate a competitive advantage against mega-ship owners, shipping liners, and other rival ports. Increase in efficiency and a reduction in turnover times, GTOs can effectively merge several terminals and operate as if they were one. The (6) ports of SCZone may cooperate with a GTO under one consortium.

SCZone ports are actively competing with other neighbouring countries' ports e.g. Piraeus in Greece under Chinese control and Jabbal Ali in UAE.

Fortunately, some SCZone ports have avoided a consistent decline in domestic container market share vis-à-vis container transit (Pallis, et al., 2017; Notteboom, 2016). The market share of at least East Port-Said demonstrates long-term progressive growth in the east Mediterranean (SCZone, 2016; SCA, 2017). Shipping liners indicate a preference to use a variety of ports rather than putting all volume at a single mega-port; SCZone introduces (6) ports against one in Greece, and another in UAE i.e. another competitive advantage.

Giving rise to the unique location, Africa and Middle East market access, feasible use of Egyptian labour, business-friendly process requests, better infrastructure and logistics hopes, and privileges offered to companies operating within the SCZone such as:

- A 100% company foreign ownership,
- A 100% foreign control of importing and exporting operations,
- All imports are free from sales tax and customs fees,
- Customs fees on exports to Egypt are only on the imported components but not the final product,
- Services of fast-track visa issuance (SCZone, 2016).

Suez Canal introduces a huge competitive advantage by being capable to host the largest container ship ever built (SCA, 2017; Essallamy, et al., 2019). However, investing in such a promising region still need some legislative, taxation, automation and networking adjustments for better attraction. Moreover, as SCZone depends mainly on investors to develop the infrastructure, investors are still in fear to put huge capital on land. Perhaps it would be better for SCZone to develop the basic infrastructure of business development to attract operators. Gap analyses may be a good approach for investor needs and the offered services particularly for the next generation of mega-ships, in order to end up with a win-win situation.

SCZone would leave a carrier fewer options to find a cheap port and less time to find direct calls, and it would remove some individual ports from the competition. Furthermore, it gives a shipping line less bargaining power against SCZone. If failed to react properly, it would be removed from the shipping schedule. Therefore, it should work on the development of abilities and its terminal capabilities including automation of services to survive. Figure (2) shows the SCZone integrated ports' locations, cargo service specialities, and the estimated transit time to linked Airports.

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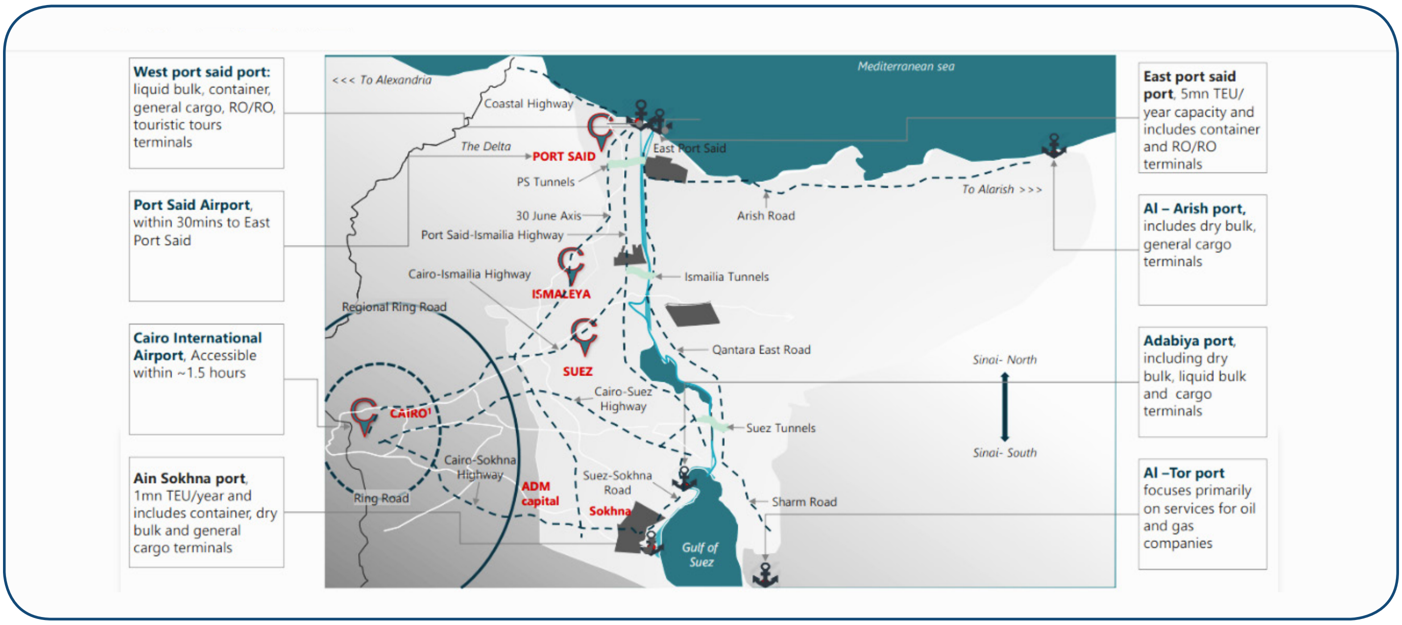

Fig. 2. SCZone ports
Source: (SCZone, 2016)

3.1. Sustainability and Smart Concepts

Environmental sustainability has recently turned into a major concern of the global maritime shipping strategy where multiple environmentally-related legislation and rules are influencing the dynamic nature of the shipping market (UNCTAD, 2019). In this manner, the SCZone ports should provide valuable services to its customers while maintaining a minimum of adverse effects on society and the environment. Considering the use of green fuel can be significantly essential for achieving this objective. For example, methane (or CH_4) is a fossil fuel that will most likely be a bridge technology towards the more intense use of green energy (EU Horizon 2000 Program, 2018) i.e. expected to show significant growth in the long run.

Sislian et al, (2016) described three primary perspectives that comprise the concept of port sustainability as follows:

1. *An economic perspective that considers the investments-returns, effectiveness of using the port area, and the infrastructure provision for improved companies' efficiency.*
2. *A social perspective that considers the contribution to increasing employment opportunities in multiple companies and operations related to the port operations and indirect employment created by the interaction and relationship between the port and the city, in addition to the contribution to the development of knowledge/education, and ultimately the livability of the geographical regions around the port.*
3. *An environmental perspective that considers the performance and management of multiple environmental aspects including pollution prevention, noise control, low emissions, minimized effects of dredging activities, and adequate disposal of wastes.*
(Sislian, et al., 2016; UNCTAD, 2009).

Digitalization would make shipping easier and more efficient: paperless bills of lading, e-certificates, and similar smart contracts improved trade flexibility and robust intelligent systems both onboard and onshore. Many of these technologies are currently being trialled in many countries. Therefore, governments, such as in the UK, work with industry and academia to develop a 'port innovation hub'. This hub could be a physical location provided in a port to generate opportunities for networking across sectors, creating industry partnership opportunities thus helping to develop expertise in maritime autonomy research and development (Department for Transport UK, 2019).

Another example can be given in communication scope i.e. necessary for the cargo owner, shipper and consignee including the carrier and the necessary port interface to deal accordingly. Intelligent Ship Reporting Gateway systems such as "I-Ship", which is a cutting-edge software application, have been created to assist ship representatives in fulfilling their reporting duties to some ports in Europe and international maritime and custom authorities (Maritime Europe Strategy Action, 2013). In other words, ports of SCZone are required to pursue innovative technologies and seek to catch up with the industrial revolution in parallel with developed countries and shipping companies.

4. CONCLUSION

In conclusion, seafarers and port operators should adapt to survive through innovative techniques of education and promotions of skills to cope with the automation and 4IR revolution and to reduce infection probability. The maritime industry is now evolving in two aspects; becoming a furtherly digitalized industry and preparing itself to host autonomous vessels technology. The first aspect is in deep need of cyber security for the protection of ship/port transactions e.g. cargo handling and delivery, while the second requires significant development in all ship-port operations to deal with mega and autonomous ships.

In this regard, AI and automation give rise to better investment and development opportunities. Accordingly, GTOs consortiums and SCZone authorities should work on gap analyses to cope with investors' needs such as the next generation of mega-ships.

Applying cyber security requirements in safety management systems are good chance for the industry to adapt to recent challenges and better data protection, however, it may be better to link with ports.

The world after the pandemic is less resistant to change to new methods of working; digitalization is now the highest priority. More expected support from the government and digitalization of processes in the supply chain, particularly administrative ones.

The new normal seeks new requirements including health, social and transport considerations and how these can be incorporated.
Moreover, SCZone hinterland connections facilities should adapt to the growth of mega container ships that will cause the port congestion problem, which is against the reliability of service. Adaptations would take ages and need huge capital investment for the port and hinterland. Investing in capacity building and legislative adaptation is essential before investing in infrastructure to cope with the latest technologies. Technical cooperation programs under international bodies can play an important role in these adaptation developments.

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