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International crew changes amid global pandemic outbreaks: Key issues and system innovations

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\section*{ABSTRACT}

The outbreak of COVID-19 pandemic all over the world has seriously affected seafarers’ work and life. In this paper, we focus on the countermeasures of major countries and organizations on the seafarer shift matter during the pandemic period. And the target of this paper is to become useful in promoting the shift change of seafarers more smoothly. Policies are identified on the basis of a systematic review of importance in combination with a detailed analysis of the primary global and national policy initiatives. Findings suggest that the root cause of the international crew change crisis lies in the issues and deficiencies in the crew change system, economic security, seafarers’ welfare, and seafarers’ social security among other aspects. On this basis, this paper gives feasible suggestions in the respects of system innovation, economic security and welfare, social security system innovation and technical innovation.

\section{1. Introduction}

Since the global outbreaks of the COVID-19 pandemic in 2020, the global shipping industry has been experiencing unprecedented difficulties, with the shipping supply chain, international trade, and shipping rates severely affected. Despite the fact that multiple regions in the world started to gradually see economic recovery from the pandemic in 2021 and that the demand for bulk commodities and goods rebounded rapidly around the world, the high shipping costs and the continuous shortage of manpower mean the global maritime supply chain remains in a tight corner. However, the volume of global seaborne trade, an important pillar industry of international economy, rebounded to 12 billion tons in 2021, returning to the pre-pandemic level\cite{1,2}.

But this growth has added to seafarers’ woes as they need to cope with the various pandemic prevention measures in different countries and regions while handling the rising workload. This has made shift changes more difficult. Coupled with the fact that ship owners or ship enterprises remain relatively passive in protecting the rights and interests of seafarers due to cost concerns\cite{3}, the nature of work results in the fact that crew members are usually in areas under the jurisdiction of other countries when they finish their shifts. As their home countries’ intervention in these areas is weak, seafarers’ rights and interests face more uncertainties. Moreover, repatriation remains a key concern for them. During the peak of the pandemic in 2020, as many as 400,000 crew members were stranded at sea across the world, and some of them even remained stuck at sea for more than 10 months\cite{4}.

Seafarers play a critical role in the sustainable development of the maritime supply chain. More than 80% of the world’s trade in goods relies on seafarers for transportation. However, due to the different overall pandemic prevention requirements of various countries and regions, the problems of inconsistent seafarer protection systems, legislative standards, and control procedures in different regions emerged one after another. The shift change of seafarers becomes more challenging with the inadequate legal systems, economic measures, and social security for protection\cite{5}. When the unified international convention cannot meet the anti-pandemic requirements of all countries, how to propose effective solutions and countermeasures by studying key issues about seafarer shifts is a common concern of

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governments, industry organizations, and scholars. Therefore, we will focus on the responses of major countries (organizations) in the world on the seafarer shift matter, explore the current key issues and major challenges, and propose a direction and feasible strategies for innovating the existing systems to maintain the long-term stability of the maritime supply chains. The major contributions of the present paper are as follows. First, this paper deeply analyzed the main difficulties faced by seafarers during the shift change. Second, in order to find out the key issues behind the crisis, this paper makes comparison and analysis to the crew change policies issued by various countries and organizations. Third, in view of the key issues, this paper puts forward feasible suggestions for formulating future policies and fills the research gap on seafarer shift matter.

The rest of this article is organized as follows. Section 2 introduces the relevant measures issued by major countries and organizations in the world to address seafarer shift changes during the pandemic. Section 3 goes further on key issues based on specific policies and measures and lists relevant cases. In Section 4, we propose solutions to relevant problems and system innovations. Section 5, the final one, summarizes the full text.

2. Countermeasures of countries (organizations) around the world

2.1. Selection of research objects

The International Maritime Organization (IMO) Council is the executive organ of the IMO, and its members are elected by the IMO Assembly for a two-year term. All members of the Council are divided into three categories: A, B, and C. Specifically, Category A members are the countries with the greatest interests in international shipping, Category B are the nations with the largest international seaborne trade volumes, and Category C are the countries that have special interests in international shipping or navigation and can represent the interests of major geographic regions of the world.

By referring to the list of Council members for the 2022–2023 biennium and considering the research value in terms of seafarer shift change and maritime industry status, we decided to select China in Category A and Singapore in Category C as research examples for the following reasons. As the world’s top international shipping center, Singapore’s developed transportation system and perfect seafarers’ guarantee system make Singapore an important transfer station for seafarers around the world. As one of the most influential shipping countries in the world, China has the largest port scale in the world, and its huge maritime trade volume requires a large number of seafarers to complete. At the same time, as the country where COVID-19 first broke out, China’s strict port epidemic prevention measures have considerable research value. On the other hand, as the most influential international organizations on the seafarer shift matter (though the EU should be taken as the European economic and political community), IMO and ICS first assessed the development and changes of the global pandemic situation and then provided a general solution framework for managing crew changes during the pandemic. IMO and International Association of Independent Tanker Owners (INTERTANKO) jointly released the Crew Change Management Plan on April 1, 2020, suggesting that all member states implement a procedure where all seafarers who change shifts must undergo temperature screening and travel exposure history screening in the dedicated arrival area before boarding or after disembarking, and that all the items the seafarers come into contact, including vehicles and personal protective equipment, should be disinfected in time [7]. In addition, ICS put forward the “12-Step Guide to the IMO’S Recommended Framework” (Fig. 2) for the first time which has a strong guiding significance as well as a wide range of application, and then the framework was circulated to governments via IMO [4]. And it is worth mentioning that on the basis of the framework, national governments can adapt it according to prevailing national circumstances which provides great convenience for governments to formulate the shift procedure. ICS officially released the Coronavirus (COVID-19): Seafarer Shore Leave Principles, which is applicable to most countries and regions in the world, in September 2021. The document stipulates that in terms of crew change and leave conditions, ship enterprises must evaluate the crew change and disembarking risks and ensure that all the seafarers changing shift are vaccinated and have relevant documents in place, including visas and health certificates [8].

To ensure the continuity and safety of maritime shipping, the EU has taken actions after the pandemic to facilitate and coordinate member states’ crew changes at their ports. The EU released on April 14, 2020, the Guidelines on protection of health, repatriation and travel arrangements for seafarers, passengers and other persons on board ships [9]. Firstly, the document emphasizes that EU member states must allow seafarers to travel to the ports where they perform their duties without any restrictions. Secondly, in cases where the seafarer’s repatriation is not feasible, Seafarer’s Employment Agreement (SEA) extension should be prevented and relevant responsible parties should provide the early repatriation with as much convenience as possible. Besides, the document also calls for member states to designate several ports which should be geographically dispersed in Europe for rapid crew changes so that necessary transport conditions could be provided for seafarers of a shift change.

As a major shipping country, China’s seaborne import and export volume in 2020 reached 3.46 billion tons, accounting for 30% of the global seaborne trade volume. It is also the country with the largest number of crew members in the world, namely 1.65 million registered ones, including 780,000 seafarers. The Ministry of Transport, the Ministry of Foreign Affairs and other ministries of China jointly issued the Notice on taking precise measures to prevent and control the epidemic on international ships and crew [10] on April 22, 2020. According to the prevailing national circumstance of China, the document lays emphasis on setting forward instructions for shift changes of international ship seafarers and Chinese crew members separately. Though all crew members of shift changes on international ships must comply with strict closed-off management and health condition monitoring, the difference is that crew members’ onshore activities should not be arranged except
normal changes of Chinese crew members after the ship arrives at the port. Meanwhile, the prevention and control measures for Chinese crew changes have been improved, Chinese crew members can enjoy convenience of the local people’s government of the port after they complete the shift change and other necessary procedures.

The Maritime and Port Authority of Singapore (MPA) has successfully issued several versions of circular documents since the beginning of 2020 to ensure that the current policies ensure smooth crew changes. The MPA released the latest PORT MARINE CIRCULAR [11] on March 2, 2022, which updated the seafarers’ embarkation and disembarkation process. The crew members set to embark must be provided with the Stay-Home Notice (SHN) of the origin country/region with the period of time before their departure to Singapore. While the crew members set to disembark must comply with closed-off management in advance and be in good condition before disembarkation. Seafarers who have been vaccinated and have recovered are exempt from all testing and home quarantine requirements.

(2) Health management
The Crew Change Management Plan stipulates that, for seafarers’ personal pandemic prevention, the ship enterprises should fully consider the ship-shore relationship and the vaccination status of seafarers and distribute the ICS Guidelines for Coronavirus Disease 2019 (COVID-19) to seafarers, while encouraging seafarers to be vaccinated as soon as possible. Ship enterprises should refer to existing industry guidance on seafarer vaccinations and urge seafarers to fully receive the Janssen vaccine at least 14 or 28 days in advance for maximum protection [7].

The EU stressed in the Guidelines on protection of health, repatriation and travel arrangements for seafarers, passengers and other persons on board ships that ports should provide seafarers with accessible and adequate medical services and accessible welfare services during seafarers’ embarkation, disembarkation, and quarantine periods [9].

The Maritime Safety Administration of the People’s Republic of China (MSA) issued the COVID-19 Prevention and Control Guidelines for Ship Crews (V7.0) [12] on August 4, 2021. The document stipulates that seafarers should be fully equipped with personal protective equipment throughout the crew change process, and undergo temperature screening and other measures. Meanwhile, the crew who intend to leave the ship after a shift should undergo a body temperature check at least twice a day and foreign-going ships that intend to enter a domestic port should report the health information of crew members on board to the maritime administration 48 h before the expected arrival at the port. Moreover, Crew members on board on a new shift should stay in quarantine after boarding the ship for the first 14 days and avoid non-essential contact with other crew members or passengers.

Fig. 1. Timeline of related regulations issued by major countries (organizations).

Fig. 2. ICS “12-Step Guide to the IMO’s Recommended Framework”. 

[Image of diagrams showing protocols for joining and leaving a ship, with timelines and steps for embarkation, disembarkation, and repatriation]
Table 1
SRP beneficiaries and amounts.\(^1\)

|                  | MPA  | SMOU* | SOS** | Total |
|------------------|------|-------|-------|-------|
| Qualified officer| $500 | $300  | –     | $800  |
| Adult student    | $200 | $300  | –     | $500  |
| Crew registered  | $500 | –     | $300  | $800  |

Note: The total funding period does not exceed 6 months.

\(^1\) https://www.mpa.gov.sg/web/portal/home/port-of-singapore/circulars-and-notices/detail/5f51a607-80b1-4e53-aa34-e0345cfe4288.

\(^2\) Denotes a qualified member of the Singapore Maritime Officers’ Union (SMOU).

The PORT MARINE CIRCULAR\(^1\) released by the MPA on March 2, 2022, stipulates that crew members must be tested negative for COVID-19 at a government-approved or ISO 15189-approved laboratory within 48 h before departure for Singapore. The document also emphasizes that crew members who have been fully vaccinated and have recently recovered (that is, within 90 days of last infection) are exempt from all testing and home quarantine requirements if an appropriate proof document can be provided. Besides, crew members must be certified fit to travel by a local Singapore hospital within 24 h prior to disembarkation.

Table 2
Key countermeasures to address crew changes from 2020–21.

| Conditions | IMO/ICS | EU | China | Singapore |
|------------|---------|----|-------|-----------|
| Coronavirus (COVID-19): Seafarer Shore Leave Principles | | | | |
| Before a shift change, ship enterprises must evaluate the shift change risks for vaccinated seafarers. | Guidelines on protection of health, repatriation and travel arrangements for seafarers, passengers, and other persons on board ships | Notice on taking precise measures to prevent and control the pandemic on international ships and crew | PORT MARINE CIRCULAR |
| (1) Member states should guarantee the right of seafarers to change shifts at ports within their territory and ensure that seafarers are not subject to any travel restrictions; (2) Ship enterprises are prohibited from extending the sea for seafarers who are on service for a prolonged period of time. | (1) Seafarers from AVTL countries who have been fully vaccinated are exempt from quarantine requirements. | (1) Chinese seafarers who need a shift change can do so after arriving at the port of shift change if they have passed the customs quarantine; (2) Non-Chinese seafarers must undergo strict closed-off management and are not allowed to go ashore to change shifts in non-emergency situations. | (1) Crew members must undergo nucleic acid testing at their place of departure within 2 days before arriving in Singapore, and the testing result must be negative; (2) Crew members must perform home quarantine before changing shifts and must be certified fit to travel after disembarkation. |
| Rights | | | | |
| Coronavirus (COVID-19): Seafarer Shore Leave Principles | Guidelines on protection of health, repatriation and travel arrangements for seafarers, passengers, and other persons on board ships | | Extension of assistance to Singaporean seafarers under the seafarers relief package |
| (1) Allow seafarers to use shore welfare facilities; (2) Allow overdue crew members on board to contact their families and friends. | | For crew members who have served continuously on board for 12 months, the shipping company should immediately arrange crew changes. If a shift change is impossible due to the relevant anti-pandemic measures at the port, the shipping company should immediately arrange a rest for crew members on board. | Singaporean active seafarers can apply for financial assistance of up to US$800 per month. On top of the US$150,000 annual appropriation, additional US$50,000 is provided on a one-time basis to assist seafarers serving in Singapore. |
| Anti-pandemic | Crew Change Management Plan | Guidelines on protection of health, repatriation and travel arrangements for seafarers, passengers, and other persons on board ships | Notice on taking precise measures to prevent and control the pandemic on international ships and crew | PORT MARINE CIRCULAR |
| Seafarers must undergo temperature screening and travel exposure history screening in the dedicated arrival area before and after shift changes, and any objects exposed should be disinfected. | Ports should provide seafarers with accessible and adequate medical services and accessible welfare services during seafarers’ embarkation, disembarkation, and quarantine periods. | (1) Enforce strict closed-off management for crew members of shift changes and strengthen crew health monitoring; (2) After the ship arrives at the port, do not arrange crew members’ onboard activities except shift changes of Chinese crew members and under other special circumstances. | (1) Seafarers from AVTL countries who are fully vaccinated are exempt from quarantine requirements. |
| Coronavirus (COVID-19): Seafarer Shore Leave Principles | | | |
| Urge seafarers to fully receive the Janssen vaccine at least 14 or 28 days in advance. | | | |
The Seafarers International Relief Fund (SIRF) set an emergency aid fund in May 2021 aimed at raising US$1 million (US$1.1 million has been raised as of February 2022), which will be used to assist the seafarers and their families in India and other countries ravaged by the COVID-19 pandemic. The fund is overseen by Seafarer’s Charity and will also process international remittances from relevant charities, respond to the needs of seafarers affected by the outbreaks around the world. To ensure efficiency and transparency, the organization has established sound monitoring and evaluation management mechanisms and procedures [14].

To facilitate the study on the existing systems of various countries and organizations around the world during the pandemic, we have summarized the key countermeasures by the above-mentioned IMO, EU, China, and Singapore for addressing the crew change issue during the period 2020–21 in Table 2. By analyzing countermeasures of major countries and organizations on the seafarer shift matter, we found that most policies lay emphasis on further standardizing shift procedure and seafarer’s health management while few policies explicitly provide financial assistance to seafarers. As previously mentioned, most documents issued by international organizations such as IMO and ICS are generalized framework documents. These documents such as Coronavi-rus (COVID-19): Seafarer Shore Leave Principles and Crew Change Man-age ment Plan are characterized by wide applicability and modifiability so that national governments can adapt details according to various national conditions. Unlike IMO or ICS, policies issued by the EU such as Guidelines on protection of health, repatriation and travel arrangements for seafarers, passengers, and other persons on board ships primarily attempt to normalize the shift change procedure for European seafarers. The EU has been prompting member states to confront the crew change crisis together, for example by proposing measures such as designating several ports in Europe for rapid crew changes. However, due to the various extent of the pandemic and different national conditions across member states, it can be expected that the current countermeasures will hardly achieve the desired effect. For the countermeasures at the national level, the major shipping countries such as China and Singapore focus mainly on seafarers’ health management. For instance, the Chinese government stipulates that every seafarer must be placed under medical observation for 14 days and comply with strict closed-off management before crew change, while the Singapore government stipulates that seafarers must be provided with relevant documents such as Stay-Home Notice (SHN) of the origin country/region with the period of time before crew change. To some extent, it is the strict measures on seafarers’ health management that make these countries respond more effectively to the seafarer shift matter.

3. Key issues for seafarers to change shifts during the pandemic

Although various countries and organizations have released many policies on crew change during the pandemic, with the emergence of variants such as Delta and Omicron, hundreds of thousands of seafarers are still unable to change their shifts normally, and this number is so huge that it has seriously affected the stability of the maritime shipping supply chain. It is obvious that most of the current policies and measures are not perfect and cannot fully resolve the crew change crisis as pandemic becomes a normalized situation. Therefore, it is of great practical significance to explore and study the key issues. By analyzing relevant policies and cases, we believe that the key issues leading to the crew change crisis in the pandemic largely lie in the existing systems, economic security and welfare, social security, etc.

(1) Shift change systems

Before the COVID-19 outbreaks, although the international convention on crew change repatriation clearly stated that the maximum length of service on board before crew change repatriation should be less than 12 months, the convention did not limit the maximum period of crew employment agreements. The right to waive paid annual leave or not to exercise the right of repatriation is subject to the interpretation of the law of member states. This has indirectly led to the obstacles for international seafarers to change shifts.

The current international regulations on crew change and their implementation standards vary. The root causes can be summarized into two points. First, most of the documents issued by international organizations during the pandemic are generalized framework documents, such as IMO’s COVID-19: Seafarers’ Shore Leave Regulations. In view of this, countries and regions need to study and promulgate their own laws and regulations on crew changes. Second, the COVID-19 pandemic varies from country to country in terms of size, duration, and severity, leading to the different prevention and control efforts in different countries. According to International Transport Workers Federation (ITF) [15], a Chinese seafarer on a Capesize bulk carrier died in August 2021 during the shift change in the waters off New South Wales, Australia. The reason is that the local law stipulates that seafarers can only change their shifts at sea, rather than on the shore. Its so-called ‘biomedical security measures’ make it impossible to safely change crew members at port.

Countries around the world haven’t agreed on crew change pro-cedures. Although nations such as the United Kingdom and Singapore require crew members to be in good health and not exposed to any known or suspected COVID-19 cases within 14 days before the shift, and that they can use a health certificate issued by the local testing agency to change the shift, some countries and regions with stricter pandemic prevention procedures, such as China, require that seafarers not only should prepare relevant supporting documents in advance, but also undergo mandatory quarantine of varying durations. The inconsistent shift change procedures between countries and regions will result in ship enterprises’ failure to timely coordinate the lead time for crew changes. In particular, due to the localized management measures currently implemented in most nations, seafarers usually can only start to prepare for the shift change based on local pandemic prevention regulations after they berth at the destination port. This undoubtedly greatly increases the difficulty of crew changes.

(2) Economic security and welfare

The pandemic has disrupted global trade, and more and more shipping companies are struggling with mounting debt. If the shipowner’s debt cannot be repaid, the only result will be abandonment, sale, or transfer of the ship, which indirectly increases crew abandonment at sea. According to relevant statistics [16], since the outbreak of the pandemic, the crew abandonment incidents have increased significantly. Taking 2020 as an example, there were 85 crew abandonment incidents, involving more than 1300 seafarers. As many ports reject abandoned ships, the crew members are forced to stay at sea without getting ashore. In addition, in some countries the government requires the crew to remain on the ship as guarantors until the shipowner pays the berth and other fees to the port authority when the ship is allowed to be berthed and the crew can be disembarked. Apart from the difficulty of getting paid, crew members of abandoned ships also face the dilemma of running out of supplies. In most cases, they can only obtain supplies from other ships. They may have opportunities to obtain assistance from local charities at the port, but the long wait and the lack of a real solution may push some crew members to the brink of suicide.

On the other hand, the physical and mental health of seafarers will directly affect the quality of their services. Due to the pandemic, a large number of seafarers have to stay at sea for extended time. Even if the ship is berthed at the port, the opportunities for seafarers to communi-cate with the outside world are very limited, which often makes seafarers physically and mentally exhausted [17]. Therefore, seafarers’ timely access to various benefits through shift changes also needs urgent resolution. However, the welfare services provided to seafarers vary from country to country. Though a few nations can meet the needs of seafarers in transport, communications, leisure, and health services, most seafarers on shifts experience mismatches between demand and services.

(3) Social security
Since the outbreak of the pandemic, the IMO has issued circulars calling on its member states to designate seafarers as "key workers" to facilitate crew changes and stabilize the global maritime supply chain. According to the latest statistics [18], as of February 10, 2022, 64 IMO member states and regions and 2 associate member regions have identified seafarers as "key workers". Nevertheless, the majority of countries (111) have not identified seafarers as "key workers", including China, Australia, and other countries and regions with a large crew base. Due to various reasons such as government’s pandemic prevention requirements and regional pandemic situations, crew members cannot enter these countries as "key workers", hindering crew change repatriation and greatly affecting the safe operations of maritime trade.

In terms of medical security, especially the vaccination of seafarers, even though many international organizations have called attention to the issue of seafarer vaccination, the global seafarer vaccination progress is slow [19], [20], [21], [22]. In 2021, various countries saw their economy recover to some extent, although the pandemic may further impact the already strained global supply chain. With the increase in the number of COVID-19 infected seafarers, some ports continue to restrict the entry and exit of seafarers from developing countries which are the main sources of international crew and are still waiting for vaccines from the international community. The shortage of seafarers is obvious. For example, according to the Centre for Health Protection of the Department of Health in Hong Kong [23], 15 of the 23 crew members on a cargo ship (MV Thor Monadic) arriving in Hong Kong from Indonesia tested positive for COVID-19 in August 2021. The China Maritime Service Network (CNSS) said the Singapore-flagged bulk carrier "North Sunda" called at the French Port of Le Havre with all 16 Filipino crew members testing positive, of which 5 had serious symptoms.

Fig. 3. Crew change solutions and system innovations.

Fig. 4. Suggested embarking process for seafarers.
4. Problem solutions and system innovations

From the COVID-19 pandemic outbreaks in early 2020 to its normalization, seafarers engaged in international shipping have faced practical difficulties such as extended service after service period ends, difficulty in changing shifts, and problem in repatriation [24]. According to our previous research, we have summarized the key issues of the crew change crisis in the pandemic. For instance, the lack of rights for seafarers to change the shift even if the maximum period of crew employment agreements is exceeded, the lack of seafarers’ welfare and economic security, the lack of medical and other social security for seafarers, etc. By analyzing these key issues, we further summarized them into 4 aspects which are crew change system, economic security and welfare, seafarers’ social security and technology (Fig. 3).

4.1. Shift change system innovation

Currently, the regulations and systems for crew change face such common problems as inconsistent regulations, inconsistent implementation standards, and inconsistent shift change procedures. We hereby put forward the following suggestions.

1) In view of inconsistent international legal systems, it is recommended that IMO set up a special working group during the pandemic period, which will be specially responsible for researching and formulating a detailed international crew change policy system, so as to maximize the protection of seafarers’ rights and interests on the premise of meeting the anti-pandemic regulations of major countries, while supervising the full implementation of each member state. Second, an international unified crew change agreement should be established based on the latest existing standard Coronavirus (COVID-19): Seafarer Shore Leave Principles [8], and the shipping industry and governments should use the highest operable standards to minimize the risk of COVID-19 spread, allow crew changes to be carried out in a safe manner, and ensure that the measures taken are generally accepted.

2) To address the non-uniform implementation standards of the shift change system in various countries, the focus is to establish a global cooperation guarantee system. The most important task is to urgently strengthen mutual cooperation between nations. In view of the high...
mobility of ships on international voyages [25], it is temporarily difficult for global organizations to establish a unified implementation standard. Therefore, it is suggested that countries should first conduct effective supervision on their own ship enterprises, such as strictly reviewing the terms of the seafarer labor agreement on shift repatriation and prohibiting the inclusion of "No Crew Change" and other terms, to prevent any extended service by seafarers after their service period has ended. In addition to strengthening domestic supervision, IMO member states need to further enhance cooperation and open green channels and feedback routes for crew changes when conditions permit. In addition, it is recommended that the ship enterprise and the charterer share information publicly and cooperate with each other to minimize the additional cost arising from crew change. The ship enterprise should provide the charterer with information on the crew change plan.

3) Regarding the non-uniform crew change procedures, we have reorganized and summarized the specific procedures for crew changes of major shipping organizations and countries at this stage, and taken into account the pandemic prevention requirements of major nations or regions. The following suggested processes for seafarers to embark and disembark are given below (Fig. 4, Fig. 5).

By learning from the existing crew change process in Singapore and the successful experience of the Chinese government in fighting the pandemic, we suggest that the specific procedures be unified according to the different statuses of seafarers during the shift change [26–28].

4.2. Economic security and welfare

The economic security of crew changes can be addressed from three aspects: the cost of repatriation of seafarers, the security of seafarers’ daily necessities, and the payment of seafarers’ wages. First, one of the main reasons for crew abandonment is that shipowners are unwilling to pay for crew changes [29]. In this regard, we suggest that under the premise that the current regulations on crew changes in different countries are inconsistent, ship enterprises in various countries must strictly implement the "financial guarantee" clause in MARITIME LABOUR CONVENTION, 2006 (2018 Amendment), that is, the ship enterprise must establish a financial guarantee after signing the labor agreement to ensure the normal shift of seafarers and prevent unpaid crew change fees [30]. Second, for the problem that the living conditions of seafarers cannot be guaranteed under the pandemic, the MARITIME LABOUR CONVENTION, 2006 (2018 Amendment) provides two options for seafarers to protect their rights: the labor provider country and the flag state. In view of the fact that it’s impractical for the flag state to provide living security for seafarers, we suggest that no matter where the seafarers are, the country to which the seafarers belong should provide them with normal living security, and when necessary, the labor provider country should provide help to the seafarers through embassies and consulates abroad. Finally, though the issue of seafarers being owed wages was already common pre-pandemic [31], as the pandemic continues to affect the shipping industry, a large number of seafarers may have to face wage arrears for a long time. We believe this issue can also be solved by requiring the ship enterprise to provide financial guarantees in advance. In addition, after receiving complaints from the crew, the destination port of the ship should refuse the ship to berth and punish it until the crew wages are paid. However, for crew and ship abandonment, we currently can only suggest the IMO and its member states to establish protection laws for abandoned crew members as soon as possible to maximize economic security for the crew members.

Our research on crew welfare shows that regular shore leave is extremely important to seafarers’ physical and mental health, and can meet seafarers’ needs to enjoy various welfare services, which in turn has a significant impact on seafarers’ lives and property at sea. Various welfare services are necessary to alleviate seafarer fatigue and reduce the risk of fatigue-related accidents [17], [32]. In view of this, we would like to make the following suggestions. First, countries should establish welfare centers with institutional norms and complete infrastructure at the port locations. These centers must be supported by the governments, trade unions, and other relevant partners. To ensure sufficient funding to support the centers’ daily operations, it is recommended to collect port welfare facility fees from shipping parties to meet various needs of the crew. Second, while complying with and implementing the relevant regulations of MLC2006, voluntary organizations including religious ones should be encouraged to strengthen their cooperation with the global community and join international programs on crew welfare to improve the port’s own welfare system, such as the International Port Welfare Program (IPWP), which aims to encourage and support the establishment of a welfare council for seafarers worldwide [33] (Fig. 6).

4.3. Social security system innovation

First, it is urgent and necessary to identify seafarers as ‘key workers’. With the global pandemic situation becoming volatile, the normal production of some countries is still at a standstill, and some major manufacturing countries are ushering in the peak of export of goods, rendering the status of seafarers more and more important. Second, seafarers face greater risks than other occupations. Although the pandemic situation in many countries has been effectively controlled, seafarers at the front-line are exposed to imported goods and risks due to
the nature of their work. In this regard, we make the following suggestions: (1) Countries should strictly abide by the circulars issued by international organizations such as IMO [34], [35], [36], International Labour Organization (ILO) [37], [38], and ICS [39]. On the basis of recognizing seafarers as "key workers", the official seafarer’s identity document, departure record book, STCW certificate, employment agreement, etc. should be used as evidence for the change of key personnel; (2) IMO member states should grant seafarers any necessary immunity for the latter to enter or leave the country without travel, health, or movement restrictions to facilitate their use of ships, aircraft and other means of transport; (3) Seafarers, as "key workers", have the right to use the medical facilities of the port state. When the port of call cannot provide the required medical care, the port state must offer all possible services to the seafarers in need of emergency medical care, and the port state should be responsible for properly handling the shortage of basic medical resources to seafarers due to their unexpectedly prolonged time on board.

Second, in order to effectively address seafarers’ vaccination and further facilitate seafarers’ shift-change leave, we put forward the following suggestions on the basis of existing relevant documents [40], [41], [42], [43]. (1) Currently, more than half of the world’s 1.6 million crew members are from developing countries such as India, the Philippines, or Indonesia, and the vaccination rate in these countries is far behind that in developed nations. Therefore, we call on qualified countries to vaccinate all crew members entering the port regardless of nationality. The foreign crew members who regularly travel to the country’s ports more often should be especially vaccinated as soon as possible to reduce the risk of virus spread at the terminal and the community; (2) It is recommended to adopt the captain application system, and the customs or the anti-pandemic department in the area where the ship is called should organize the vaccination services on board to reduce the contact between seafarers and others on shore and facilitate observation after vaccination; (3) It is recommended that countries choose the adenovirus-based recombinant vaccine as the preferred vaccine for seafarers, because this type of vaccine requires only 1 dose to achieve basic immunity, making it very suitable for seafarers with short docking time and high mobility; (4) Based on the current situation, most ship enterprises can accept appropriate vaccination fees. Considering the fact that most international ships calling at the port are foreign ones, it is reasonable to charge for vaccines, and the measure can also mobilize the enthusiasm of the customs or pandemic prevention departments of various ports. Therefore, it is recommended that port countries charge ship enterprises according to the dose (Fig. 6).

4.4. Technical innovation

The key to solving the crew change problem lies in pandemic prevention and control. In view of the multi-point and wide-range characteristics of international seafarers’ pandemic prevention and control, cutting-edge technologies such as big data integration, Internet of Things, artificial intelligence (AI), and deep learning can play a positive role in the COVID-19 pandemic prevention and control. We propose to build a complete technical response process by linking information technology with the different statuses of seafarer pandemic prevention and control (Fig. 7). This framework can help port authorities have a clearer picture of how information technologies are applied to seafarer pandemic prevention and control and how they play a role in different stages of the pandemic.

After summarizing the practical experience of various countries in fighting the COVID-19 pandemic, we believe that the big data technology plays a critical role in close contact tracing, pandemic prevention, epidemiological investigation, etc. [44–49]. For example, international organizations such as IMO can publish health QR codes for seafarers or close contact detection programs that can record seafarers’ health status and activity trajectories more accurately, monitor seafarers’ activities, and locate close contacts. Cloud computing can be used for big data analysis, vaccine development, and drug development. The AI technology can enable the use of drones to measure body temperature in real time. The computer-aided diagnosis system based on deep learning can assist doctors in diagnosis and improve diagnosis accuracy in the port area. In the event of confirmed cases on the ship, the 5 G telemedicine system can provide remote video consultation and diagnosis for personnel on board.

5. Conclusions

As the COVID-19 pandemic continues to plague the world, crew change has become one of the major key issues affecting the normal operations of the international maritime supply chain. According to statistics, as of July 2021, a total of about 250,000 seafarers have been trapped on merchant ships and cannot change shifts, and the contract periods of these seafarers have expired. It is also worth mentioning that there are nearly 1 million seafarers working on about 60,000 large cargo ships around the world on any day [50]. This is one of the biggest challenges facing the shipping industry at this stage. Due to COVID-19 restrictions, a large number of seafarers have had to extend their service on board after working at sea for months, or cannot be replaced or repatriated after long-term service. This situation is not sustainable, either for the safety and well-being of seafarers or for the safe operations of maritime trade. As the global pandemic has entered a stage of normalized development, most international seafarers have to face the dilemma of shift change.

By summarizing and interpreting the crew change policies announced by various organizations around the world (such as IMO and ICS) and countries (such as China, the United Kingdom, and Singapore) during the pandemic, we found that the root cause of the international crew change crisis under the global pandemic lies in the issues and deficiencies in the crew change system, economic security, seafarers’ welfare, and seafarers’ social security among other aspects. In view of these problems, we have put forward feasible suggestions.

First, to better resolve the problem in the crew change system, we suggest the IMO set up a special working group during the pandemic to establish an internationally uniform crew change agreement. Meanwhile, we hope to establish a global cooperation guarantee system and give implementation suggestions for seafarers’ embarkation and disembarkation procedures. Second, in terms of economic security for seafarers, we suggest that ship enterprises in various countries must strictly implement the “financial guarantee” clause in the 2014 amendment to the 2006 Maritime Labour Convention. In terms of basic living guarantees for seafarers, the country to which the seafarers belong must provide them with normal living support and, when necessary, the labor provider country should provide assistance to the seafarers through embassies and consulates abroad. In addition, various nations must recognize the need to identify seafarers as “key workers”, should lift seafarers from any travel, health, or mobility restrictions for entering or leaving the country, and must grant seafarers the right to medical assistance. Eligible countries should vaccinate all crew members entering the port with the adenovirus vector recombinant vaccine regardless of nationality, and conduct unified management of the vaccinated personnel. Finally, it has been proved that cutting-edge information technologies can play a very important role in the response to the COVID-19 pandemic. If big data computing, 5 G technology, AI technology, deep learning, and other technologies are applied to the process of crew changes, the result can be doubled with half effort to provide maximum convenience for the repatriation of international seafarers.

Regarding the future research in the domain of the international crew changes, it is worth pointing out that except the major organizations and shipping countries mentioned in this paper, countermeasures of other developing countries also have important research values because of the large number of seafarers from these countries. Moreover, we only analyze the policies issued during the writing of this paper.
because of the limited timeliness of relevant policies, while the latest policies need to be analyzed in future research. Finally, due to the limited data contained in this paper, field trips are needed in the future research to obtain primary data.

**Data Availability**

No data was used for the research described in the article.

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