

Construction and application of the risk classification index system for epidemic prevention and control in the shipping-port industry

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Abstract. To ensure the prevention and control work of COVID-19 in the shipping-port industry, we carried out research on the risk classification index system of shipping-port and the criteria for the epidemic risk level of key positions. This study focused on the key positions and links of epidemic prevention and control in the shipping-port passenger transport and passenger ships. After continuous optimization, we have established a risk classification index system for staff in the shipping-port industry. Moreover, we assessed the risk levels of different posts in the passenger terminal and passenger ships. This research provided technical guidance for the differentiated epidemic prevention and control and management of the shipping-port industry. At the same time, it has been widely adopted by government authorities and highly recognized by the industry.

Keywords: Shipping-port passenger transport; COVID-19; Risk prevention and control; Risk classification index.

1. Introduction

Since the outbreak of the COVID-19 pandemic, it has had a series of destructive impacts on the transportation industry [1], such as the forced isolation of crew members, the stagnation of passenger lines, the panic of passengers [2]. In particular, the outbreak of coronavirus cases on cruise ships such as "Diamond Princess"[3] and "World Dream" has attracted great attention from society. Shipping-port passenger transport has become one of the crucial areas for epidemic prevention and control in the transportation industry. The main reason is the larger passenger flow and passengers tend to gather in narrow spaces [4,5]. According to the statistics, the passenger throughput of ports across the country reached 87 million, of which 82 million were handled by coastal ports and 50 million by inland ports in 2019. In order to minimize the spread of COVID-19, some researchers have constructed a risk classification index system for epidemic prevention and control in the port and shipping industry [6,7], and carried out classification management of the epidemic for different links in the port and shipping field. This has laid the foundation for the formulation and implementation of relevant policies.

2. Construction of risk classification index system for epidemic prevention and control

There are many types of operations and positions in the shipping-port industry. The risks of the epidemic vary in different places and positions, so the requirements for epidemic prevention and control are dissimilar. To achieve differentiated management and control, we have used the principle of the Graham method (abbreviation is LEC) to establish a risk classification index system for epidemic prevention and control in the shipping-port industry. Specifically, factors such as work style, contact time, contact rate of outsiders, and goods were environmental exposure indicators [8]. The number of human infections or economic losses was the outcome indicator. After several rounds of expert scoring and enterprise verification, we constructed a risk value calculation model based on the LEC method. By assigning risk indicators and determining the risk level judgment standard corresponding to the risk value.

2.1 Establishment of a risk classification index system in the shipping-port industry

This risk classification index system for the operator obeys the LEC method. To evaluate and classify the risks existing in different positions in the shipping-port industry, we further established index parameters and scores according to the operation features and work content. Among the LEC method, L represents the likelihood of an epidemic, E represents the exposure to dangerous environments, and C represents the consequences of an epidemic or personnel infection. The product D of the values represents the danger. The corresponding equation is shown in (1). The larger the value of D, the higher the risk of the operational activities of the post.

$$D=L \times E \times C. \tag{1}$$

2.1.1 Likelihood (L) of epidemic occurrence criteria

The likelihood of epidemic refers to the possibility that the shipping-port workers are infected with COVID-19 and cause the epidemic, which can divide into seven grades (Table I). From the highest score of "10 points: completely predictable. Infected people have been found", to the lowest "0.1 points: impossible in fact".

The main judging factors include:

The risk level of the area where it is located.

Whether there are ships from a high-risk area, and their frequency.

Whether there are foreign-related cruise ships.

Whether there is cold-chain cargo operation and operation frequency.

Individual protection and control measures are taken on-site.

Whether protective measures are implemented (such as no protective equipment, no personal protective equipment).

The formulation and implementation of operating procedures.

There are control measures on-site, but the control measures are not effective and inappropriate.

Staff's hygiene awareness.

By analyzing the responsibilities of various positions, working methods, and individual protective measures taken, we have given the likelihood of the outbreak of the epidemic caused by the infection of employees. It is worth noting that the following points need to be comprehensively considered when assessing the likelihood of an epidemic in a certain position.

The risk level of the region.

The job content.

The possibility of exposure to the virus or suspected personnel.

TABLE I. Secondary factors and frequency in sixty-seven tank accident cases

Score	The likelihood of epidemic or contact with suspected persons
10	Completely predictable. Infected people have been found.
6	Probable. Located in high-risk areas. There are often have shipped from high-risk areas or countries berthed. Constantly have foreign-related cruise ships docked. There are frequently engaged in cold-chain cargo operations. Direct contact with those who are loading and unloading, or ticket checking. Monitoring and individual protection and control measures have not been taken on-site. Such events often occur.
3	Possibly, but not often. Located in high or medium-risk areas. There are occasionally ships from high-risk areas or countries berthed. Foreign-related cruise ships are rarely docked. There are cold-chain cargo operations. Inspectors have indirect Contact with other people through the use of hand-held inspection equipment.

Score	The likelihood of epidemic or contact with suspected persons
	The occurrence of hazards is not easy to be found. There is no detection system or protective measures on-site, such as no personal protective equipment and no monitoring. There is no strict compliance with the operating procedures. There are control measures on-site, but control measures are not effective and inappropriate. The danger occurs when expected.
1	Unlikely, totally unexpected. Located in a medium or low-risk area. No ships from high or medium-risk areas or countries docked here. No foreign cruise ships are involved. There are occasional cold chain cargo operations. Operators all use tools to contact goods. the occurrence of hazards is easy to detect. There is a non-contact monitoring system on site. Similar incidents have occurred in the past or under abnormal conditions.
0.5	Impossible but conceivable. Located in low-risk areas, All domestic cargo ships are docked. Do not involve cold-chain cargo operations. Hazards can be detected in time and monitored regularly.
0.2	Impossible. Located in low-risk areas All domestic trade ships dock. Do not involve cold chain cargo operations. There are sufficient and effective prevention, control, monitoring, and protection measures. The safety and hygiene awareness of employees is quite high. The operating procedures are strictly implemented.
0.1	Impossible in fact.

2.1.2Criteria for exposure (E) to hazardous environments

Exposure to dangerous environments refers to the likelihood that shipping-port operators are exposed to the environment of patients with COVID-19 or suspected cases during their daily operations (Table II). We analyzed the exposure from three aspects. (E1) the number of contacts with passengers and people coming to the port, including passengers and other personnel aboard port, (E2) the contact with cargo, and (E3) the contact with other items. Where the E1 index is suitable for judging passenger transport enterprises or cruise service personnel. E2 index is suitable for judging cargo terminals or freight transshipment, disassembly, and assembly. The E3 indicator is suitable for general employees or internal management personnel of port and shipping enterprises. If there are two or more situations, the judgment shall be made following the more serious circumstances.

2.1.3Criteria for the consequences (C) of an epidemic or personnel infection.

The consequences of an epidemic or personnel infection refer to the severity after a shipping-port enterprise, ship staff discovered an epidemic or personnel infection. Herein, assessments obey the following three aspects: laws, regulations, and other requirements, personnel infection, and direct economic losses. At the same time, we divided the scores from 1 to 100 into six grades (Table III). Laws and regulations and other requirements chiefly considered the severity of the violation of relevant requirements for epidemic prevention and control by shipping-port enterprises or ships. The criteria for personnel infection were customized from the impact of the epidemic caused by the COVID-19 staff. The direct economic loss is referenced from the requirements of direct economic loss caused by safety production accidents and gives the judgment

limit of the severity of the consequences. For serious consequences of two or more situations, the judgment shall be made in accordance with the more serious circumstances.

TABLE II. Criteria for exposure (E) to hazardous environments

Score	E1	E2	E3
10	>200 (people/day)	Contacted with cargo carrying pathogenic microorganisms (with confirmed precedents or related reports), such as cold-chain containers	Frequent exposure to contaminants (such as suspected cases vomit, excrement)
6	100~200 (people/day)	May come into contact with cargo carrying pathogenic microorganisms (with confirmed precedent or related reports), such as refrigerated containers and cargo	Potential exposure to contaminants (such as suspected cases vomit, excrement)
3	50~100 (people/day)	Frequent contact with cargo carrying pathogenic microorganisms (such as cargo from high or medium risk areas)	Frequent contact with highly circulated items such as banknotes, bills and receipts
2	25~50 (people/day)	May have been exposed to cargo carrying pathogenic microorganisms (such as from high or medium risk areas)	Occasionally contact with items highly circulated items such as banknotes, bills and receipts
1	5~25 (people/day)	Occasional exposure to common handling and stockpiling cargo	Less contact with objects outside the work area
0.5	<5 (people/day)	No contact	No contact

TABLE III. Criteria for the consequences of an epidemic or personnel infection

Score	Laws and regulations	Personnel infection	Economic losses
100	Serious violation of laws, regulations and standards	Causes social infection, which may cause more than 50 people to be infected	≥ 5000 million yuan
40	Violation of laws, regulations and standards	Regional infection, which may lead to 11-50 people	1000~5000 million yuan
15	Potential violations of regulations and standards	Small-scale infection, may cause 4-10 people to spread	100~1000 million yuan
7	Violating the epidemic prevention and control policies, systems and regulations of the superior or the industry	Small-scale infection, may cause 1-3 people to spread	10~100 million yuan
2	Violating the relevant operating procedures and regulations of the enterprise on epidemic prevention and control	Possible infection risk, but no personnel infection	1~10 million yuan
1	No violations	No risk and no personnel infection	<1 million yuan

2.2 Criteria for judging the risk level of the COVID-19 epidemic of port and shipping

After calculating the indicators of epidemic risk classification, expert evaluation and scoring, and demonstrations, we divided the risk classification criteria for the COVID-19 epidemic of shipping-port into four levels according to the order of the hazard consequences. As shown in Table IV, there are four warning colors. The red, orange, yellow, and blue correspond to significant risk,

greater risk, general risk, and low risk, respectively. The risk value corresponding to each risk level conformed to the characteristics and actual situation of the post. For positions where personnel may perform multiple tasks, the highest risk level in its various evaluation results is regarded as the risk level of the position. At the same time, we also analyzed the actions or control measures that shipping-port enterprises should take under different risk levels. Excitingly, the posts risk level was significantly reduced after adopting the management and technical requirements proposed in this study.

2.3 Posts risk assessment

In this research, the risk of the posts was considered from two aspects. The first one is inherent risk. It refers to the possibility and severity of an accident for a specific object in the course of daily operations due to internal factors and the impact of the objective environment without considering the existing epidemic prevention and control measures. The purpose of identifying inherent risks is to ensure that risks are given sufficient attention and can be effectively managed.

The second one is a real risk, which refers to the risk that remains after all epidemic control measures have been applied. It is used to characterize the actual danger level of the hazard source and can reflect the effectiveness of existing control measures. It should be noted that as long as that specific object does not change substantially, the inherent risk remains unchanged. However, the actual risk will change with the timeliness of risk management and control measures. Generally speaking, after the epidemic control measures are taken, the risks of staff will be under control, and the actual risks will be lower than the inherent risks. Regrettably, this controlled state will change due to the timeliness of control measures. Hence, the actual risk value cannot stabilize at the same level.

2.4 Realistic risk classification management and control

Risk classification management and control follow the following two principles. First of all, the higher the risk, the higher the level of control. Secondly, the upper level is responsible for managing and controlling the risks, and the lower level also needs to manage and control them. Before implementing management and control, it is necessary to determine the management and control level based on factors such as risk level, required resources, capabilities, and difficulty of measures. Specific measures can then be implemented step by step. It is worth mentioning that staff who come into contact with refrigerated goods that may carry the virus and those who have frequent contact with the outsider should focus on control. The risk classification management and control requirements for different positions are shown in Table V.

Shipping-port enterprise need to be fully responsible for the company or ship's epidemic risk management and control. The company manager or the captain is the first responsible person for the epidemic risk management and control. It is necessary to clarify the responsible departments and persons of epidemic risk to achieve risk management for all employees.

TABLE IV. Danger (D) level criteria and control measures

Risk level	Risk value	Actions	Execution period
Significant risk IV	≥ 320	Do not continue operations until measures are taken to reduce the hazard, and evaluation of improvement measures.	Immediately
Greater risk III	160~320	Take emergency measures to reduce risk, establish epidemic control procedures, and conduct regular inspections, measurements and assessments.	Immediately or rectification within a time limit
General risk II	70~160	Establish operating procedures and work instructions for epidemic prevention and	Within one week

Risk level	Risk value	Actions	Execution period
		control, and strengthen training and communication for staff.	
Low risk I	20~70	Establish epidemic prevention and control operating procedures and work instructions, and regularly check the implementation.	Governance when conditions and funds are available

TABLE V. Risk classification management and control requirements guidelines

Risk level	Tolerance	Control requirements	Control level
Low risk	Permissible	Existing epidemic control measures are effective, maintaining the current risk level and status	Individual, team
General risk	Moderate risk	Identify moderately dangerous content and factors that may cause infection. Comprehensively consider the possibility of infection and take safety measures to control.	Team, company
Greater risk	High risk	It is necessary to establish an epidemic management and control file, clarify the highly dangerous content and the factors that may trigger the epidemic. Besides, strengthened epidemic prevention and control measures are needed. If the risk involves ongoing operations, emergency measures should be taken.	Company, local government epidemic prevention and control department
Significant risk	Unacceptable	Stop operation immediately. Clarify the unacceptable dangerous content and the factors that may trigger the epidemic. Immediately implement mandatory control and emergency measures until the risk is reduced to an acceptable range. If the risk involves the ongoing operation, the operation must be stopped immediately and reported to the local epidemic prevention and control department for disposal.	Company, local government epidemic prevention and control department

2.5 Improvement reassessment

It is worth noting that when the following situations occur, the above methods and steps should be used again to re-evaluate the epidemic risk classification and supplement the risk list. First, when existing risk management and control measures were ineffective. Second, the control measures were not in place during the epidemic notification. Third, there are new requirements, new standards, new technologies, and changes in the operating environment and work content. Fourth, the process technology, equipment, and facilities have changed.

3. Risk classification of epidemic prevention and control in the shipping-port industry

3.1 The risk classification of the COVID-19 for the shipping-port passenger terminal

Shipping-port passenger terminal posts include loading and unloading workers, boarding bridge drivers, luggage truck drivers, security personnel, safety inspectors, central control room personnel, station service personnel, station auxiliary personnel, cleaner, shuttle bus drivers, managers, and

other personnel. The job content of each position is different. After the risk identification and analysis of the possibility, frequency, and severity of exposure to COVID-19, we have given the inherent risk level of different positions. More details as shown in Table VI.

Through identification and analysis, the risk level of epidemic prevention and control for positions such as loading and unloading workers, boarding bridge drivers, luggage truck drivers, central control room personnel, and station auxiliary personnel is classified as low risk (level I). The risk level of the managers in the station is a general risk (level II). Shuttle bus drivers and other personal are classified as relatively high risks (level III). Security guards, Safety inspectors, station service personnel, and cleaner is classified as significant risk (level IV).

3.2 Risk identification and classification of COVID-19 for passenger ships

We listed the post setting and work contents of passenger ships. More details can see in table VII. In general, these positions can be divided into four departments: deck department, engine department, steward department, and passenger transportation department. The main positions include captain, second officer, carpenter, chief officer, boatswain and sailor, chief cook and kitchen worker, chief engineer, second engineer, NO.1 motorman, copper craftsmen, motorman, ship doctors, steward, and pilot. After the risk identification and analysis of the possibility, frequency, and severity of exposure to COVID-19, we gave the inherent risk levels of different positions based on the job content of the passenger ship.

To sum up, due to the relatively closed situation of passenger ships and the frequent communication of staff, the overall risk is relatively large. In the above positions, the risk levels of captain, second officer, third office, carpenter, chief engineer, chief engineer, second engineer, third engineer, chief engineer, coppersmith, mechanic, and pilot are classified as general (level II). The chief officer, boatswain and sailor, chief cook and kitchen worker, doctors, and the steward are a significant risk (level IV).

Name	Risk identification and analysis	Inherent risk assessment					
		L	E	C	Value	Level	Classification
Loading and unloading workers	Loading and unloading workers often contact various types of luggage during the operation of luggage and material. There is a certain risk of infection. However, the consequences of personnel infection are not very serious. It can control within the local area of the company.	3	3	7	63	I	Low risk
Boarding bridge drivers	The boarding bridge driver will not directly touch luggage or passengers during the operation of the boarding bridge or hydraulic lift bridge. The risk of infection is low. The infection can control within the local area of the company.	1	2	7	14	I	Low risk
Luggage truck drivers	Luggage truck drivers drive tractors and forklifts to transport luggage and supplies. They will often come into contact with various types of luggage. There is a certain risk of infection. However, the consequences of the driver's infection with the virus are not very serious and can control within the company's local area.	3	3	7	63	I	Low risk
Security guards	Security guards will frequently contact passengers in the process of maintaining order at the passenger terminal and passenger terminal. They are at a higher risk of being infected; Once infected, it will spread to many passengers and staff, and the consequences will be more serious.	3	6	40	720	IV	Significant risk

Safety inspectors	Security inspectors need to conduct security checks on passengers' luggage and carry-on items. They are constantly in contact with various types of luggage and passengers. Once infected, it will spread to many passengers and staff, and the consequences will be more serious.	6	10	100	6000	IV	Significant risk
Central control room personnel	This type of staff is mainly in the central control room to communicate with the ship on the shore and to command and dispatch-related production management. They do not have direct contact with outside luggage and passengers. Once infected, it can control within the company's local area.	1	2	7	14	I	Low risk
Station service personnel	The station service personnel need to be responsible for ticket sales, inquiries, guidance, ticket checking, and other service tasks. They have long-term contact with passengers, and they are all close contacts. Once infected, it will spread to many passengers and staff, and the consequences will be more serious.	6	6	100	3600	IV	Significant risk
Station auxiliary personnel	The responsibilities of auxiliary personnel are to repair, maintain and routinely inspect machinery and equipment. They will not directly contact luggage and passengers. Once infected, it can control within the company's local area.	1	1	7	7	I	Low risk
Cleaner	The cleaning staff needs to clean the ground in the passenger station and the terminal building. They have been in contact with passengers for a long time, and they also need to deal with passengers' vomit and clean the bathroom. Once infected, it will spread to many passengers and staff, and the consequences will be more serious.	6	6	40	1440	IV	Significant risk
Shuttle bus drivers	The driver is mainly responsible for driving the passenger ship, not in contact with passengers or luggage, but there is a certain risk of infection. Once infected, it will spread to some passengers and staff.	3	6	15	270	III	Greater risk
Managers	Managers are responsible for the production management of the passenger terminal and may come into contact with passengers. Once infected, they will spread to some passengers and staff.	3	3	15	135	II	General risk
Others personal	Other personal involved in the passenger terminal will also have contact with inbound and outbound passengers and luggage. There is a certain risk of infection. But the farther apart, the less likely to be infected. Once infected, it will spread to some passengers and staff.	3	6	15	270	III	Greater risk

TABLE VI. Shipping-port passenger terminal post risk identification

TABLE VII. Passenger ship posts risk identification

Name	Risk identification and analysis	Inherent risk assessment					
		L	E	C	Value	Level	Classification
Captain, second officer,	During the operation of the cabin or splint, these staff will contact passengers or shore personnel, but the frequency is low. Once infected, it can control within	3	3	15	135	II	General risk

Name	Risk identification and analysis	Inherent risk assessment					
		L	E	C	Value	Level	Classification
third office, carpenter	the local scope of the ship.						
Chief officer, boatswain and sailor	In the process of cargo stowage, loading and unloading, handover and transportation management, as well as the maintenance of the deck department, employees will come into contact with passengers and luggage. Therefore, there is a greater risk of infection. Once infection occurs, it may affect the entire ship.	6	3	40	720	IV	Significant risk
Chief cook and kitchen worker	In purchasing, stockpiling, storing grain, non-staple food, and meal ingredients, some frozen foods are exposed, workers who have been in contact with infected food can spread the virus to the dining staff. Once infection occurs, it may affect the entire ship.	6	3	40	720	IV	Significant risk
Chief engineer, second engineer, third engineer, fourth engineer, NO.1 motorman, copper craftsmen, motorman	During the maintenance, repair, and troubleshooting of mechanical, power, and electrical equipment throughout the ship, these staffs have fewer opportunities to contact passengers and luggage. Once infection occurs, it can control within the local scope of the ship.	3	3	15	135	II	General risk
Ship doctors	In the process of medical treatment for crew members or passengers, there is a high possibility of being exposed to suspected cases. Workers are at high risk of infection. Once infection occurs, it may affect the entire ship.	6	3	40	720	IV	Significant risk
Steward	In providing services for crew members and passengers, they need to communicate with passengers at close range for a long time. Once infected, it will spread to many passengers and staff, and the consequences will be more serious.	6	6	40	1440	IV	Significant risk
Pilot	The pilot needs to board the ship and will be in contact with the ship's staff. Since contact times are usually short, the infection can control in a small area if it occurs.	3	3	15	135	II	General risk

4. Conclusions

In this study, we established a COVID-19 epidemic risk classification index system and the epidemic risk level criteria of key positions. This system was constructed through the risks analysis of important places, locations, and operational characteristics in the shipping-port industry. Above all, we divided the risk of the COVID-19 epidemic in the shipping-port industry into four levels: significant risk, greater risk, general risk, and low risk through the evaluation of epidemic risk grading indicators and expert evaluation. The scoring standards under each risk level and the control measures that shipping-port enterprises should take were discussed in detail. What's more, we have determined the epidemic risk level by classifying the risks of each post in the passenger terminal and passenger ships. This research played an important role in guiding the shipping-port enterprises to implement the requirements of differentiated prevention and control strategies. At the same time, it can prevent the spread of the epidemic in key areas such as passenger terminals, cruise terminals, and ships.

5. Application

This research supported the issuance of documents from the Central Committee and the Ministry of Transport, which provided decision-making references and technical guidance for guiding the port and shipping sector to carry out epidemic prevention and control. In particular, it supported the Ministry of Transport's 'Guidance on the Prevention and Control of COVID-19 for Ports and Its Front Lines Staff'. The English version of the Guidelines was adopted by the International Maritime Organization (IMO) and issued as a guideline to all Member States, Intergovernmental and Non-governmental organizations. This guideline shows Chinese wisdom and Chinese solutions.

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